Development of educational videogames in m-Learning contexts

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Abstract

The educational gaming field is rapidly growing both in acceptance and variety. Within this variety, the technological evolution of wireless/handheld (W/H) computing devices is opening new possibilities in the so called mobile learning (m-learning). M-learning opens new learning opportunities, but due to the special characteristics of these devices (such as their reduced computing power or the size of the display), some design considerations must be taken into account when creating the games. This project explores both the potential advantages obtained through the m-learning educational videogames and the technological challenges that must be faced in the process. In order to illustrate the challenges, we analyze the process of adapting an existing game-based learning platform (<e-Adventure>) for its use in a mobile environment and discuss how the adapted platform makes it easier to develop m-learning educational videogames.

1. Introduction

In the last few years, the academic and private sectors are focusing on the new possibilities offered by the new portable devices. Some companies consider that these devices, which include PDAs (Personal Digital Assistants), SmartPhones, TabletPCs, iPods or even low costs laptops will play a key role in the future of the of information distribution. .

Mobile devices technological evolution has brought in new models with higher computing power and Internet connections. These devices now include new features that blur the barriers between cell-phones and PDAs, and extend their capabilities borrowing from other device families with new features such as GPS (Global Positioning System) receptors, digital cameras, Bluetooth/Wi-Fi connections or audio and video players.

The new possibilities offered by these devices come hand in hand with a broadening market. Buying a last generation cell-phone or PDA is no longer an unaffordable luxury. Even the laptops, which were reserved to the business environment, have become a real alternative to desktops [1]. The cost of the connection services have also been reduced thanks to the development of new technologies like WAP (Wireless Application Protocol), GPRS (General Packet Radio Service), and the WI-FI networks.

From an educational perspective, this allows the students to go one step closer the original e-learning motto, *learning anytime and anywhere*, because we are not limited by the availability of a connected desktop computer. One of the advantages given by this characteristic is supporting Just-In-Time Learning (JIT-Learning) scenarios. The user can now access the knowledge at the specific moment that it is required, in contrast with the classical way in which the concepts are acquired with the expectancy of eventually being used. Highly specialised tasks can benefit from this approach (a typical example often heard is installing a specific part in an airplane and learning the procedure right when it comes to the installation).

Another view is the distribution of educational contents in third world countries. The use of mobile devices is useful to access these contents in places where no internet connection (or maybe even electricity) is available. Some studies have been done about the use of videogames over cell phones to teach languages and safety knowledge in India [2], and the One Laptop Per Child initiative[1] is certainly a step in this direction.

On the other hand, the rapidly increasing importance of game-based learning [3] can benefit from the advantages of mobility. M-learning systems can be an ideal platform for the distribution of educational videogames and simulations, obtaining more versatile educational systems, and improving the

[1] http://laptop.org/

opportunities for long life learning. However, the mobile field is still young and evolving very fast. This means that integrating games in m-learning scenarios is a significant technological challenge that needs to be studied.

In an attempt to bring together the best of both worlds in a mobile game-based learning approach, we have adapted an existing educational game platform (the <e-Adventure> platform [4]) for its application in mobile environments. In the process, several technical challenges emerged as reported in this paper.

This paper is thus organized as follows: In section 2 we provide a brief overview of the potential advantages of bringing both worlds together and some considerations about the design challenges that this may bring. Section 3 presents a survey of the varied technologies that may support mobile game-based learning. In section 4, as a case study, we present our experience porting the <e-Adventure> educational game platform to a mobile environment, with a reflection about the challenges that emerged and lessons learned. Finally, in section 5 we summarize our conclusions and outline future lines of work.

2. Educational videogames and mobile devices

Using mobile devices as platforms for the execution of educational videogames offers new possibilities for providing better learning experiences. However, these advantages have a price. The special characteristics of these devices affect in different ways the possibilities offered and some design considerations must be taken into account in order to get the most out of these applications.

2.1 The best of both worlds

Using computer and videogames as an educational medium is not a new concept. However, a discussion of the educational benefits of game-based learning is beyond the scope of this paper, with the topic having been thoroughly discussed in the literature [3, 5-8]. Roughly speaking, the usual reasons argued are that videogames are entertaining, immersive and that they stimulate cooperation and competition. All of these aspects of educational gaming can actually benefit from the advantages of mobility:

- Videogames are entertaining: This is the main characteristic of a videogame, and the most used argument in favor of game-based-learning. The belief that some idle moments like the time spent in the public transportation or waiting in lines can be taken as an opportunity for learning. In this context, game-based learning is especially relevant because the original vision of learners using mobile devices to study contents is not nearly as extended as the use of portable gaming platforms Game-based m-learning can really attract students to learn *anytime* and *anywhere*.
- Videogames are immersive: In regular videogames the user gets immersed into the game world through the use of different techniques like the inclusion of a character, which represents him in the game, called avatar or through a first person view of the action. With the use of mobile devices a new method immersion is obtained. Thanks to the different systems which ship with these devices, the users can become an active part of the game. These systems, such as GPS receptors or Bluetooth connections, make the game aware of the location and movements of the users, making them feel really inside the game. This effect is achieved because their actions in the real world have an effect in the virtual world. The use of more senses, the embodiment factor, improves the educational activity [9].
- Videogames stimulate cooperation and competition: The game stimulates the cooperation and competition skills of the users while they play at home, in front of their computers. But the user is experiencing some relationships in the virtual world while getting isolated in the real one. By using mobile devices, the user can move during the activity, interact with other people, related or not to the game. This allows a more embodied interaction and facilitates the effectiveness of collaborative learning because the learners can play together and think cooperatively a common strategy.

In summary, game-based mobile learning not only allows the user to access to the videogame anytime and anywhere. It enhances the attractiveness and effectiveness of m-learning scenarios and offers additional value for the educational advantages of game-based learning.

2.2 Design considerations

Traditionally, mobile devices have been considered as small computers and, in some cases, the contents accessed through these devices have not received any special design consideration. But the advantages offered by mobile devices might be drastically reduced due to the special characteristics of these devices, if some design considerations are not taken in account.

One simple example of these problems comes out when executing a text based application. Long texts may be hard to follow in a small screen, making the user loose interest in the activity. Another example is the interaction method. Trying to emulate the interaction of a mouse using a stylus may become really uncomfortable.

The m-learning systems must be considered as a new research field and the mobile applications must be designed in a specific way. These considerations about content and interaction must be also taken in account while developing m-learning educative videogames. In other words, we must consider the kind of information supplied by the system (videos, text, pictures) and how the user will interact with these contents.

First, the mobile application developer has to take into account which concepts the application display and the way that the whole experience works. This design activity must not be done in the same way that a PC application. The contents displayed easily in a laptop may not be adequate to be displayed in a PDA. The same approach must be taken for the interaction method. Besides this, the mobile devices offer new ways of communication and concepts like the possibility of movement, so it's necessary new tools and techniques for designing these systems. Parsons et al. [10] propose a conceptual framework which is useful as a script for the analysis and requisites capture phase. They define four perspectives in the design of an application for a mobile platform: generic mobile environment issues, learning contexts, learning experiences and learning objectives. The complete framework is presented in Figure 1.

In the first perspective (generic mobile environment issues) the designer must take into account characteristics common to all this kind of applications. These characteristics are: the mobility, the different users and their role, communication support, media types allowed by the devices, design of the interface, etc. The second perspective centered on the specific application, defining the context where the educational experience takes place, such as the different actors involved, the target social group, the activities which conforms the experience, the resources and facilities supplied and so on.

The third and fourth perspectives get deeper in the concepts related to the design of the specific educational experience, its structure and expected goals. Parsons et al [10] divide the educational experiences in two types: the narrative experience, where the data is provided without any other interaction; and videogames. After this, he chooses the structural elements that Prensky [11] found in videogames: organization of the contents and rules, feedback methods to the user (scores), objectives and goals proposed to the user, representation of the story, conflict and challenges to the user and the social interaction while the experience.

With the use of this framework the designer is supplied with the main points which must be addressed while defining the educative system. Possibilities like the mobility, spatio-temporal awareness or facilities like GPS receptors and Bluetooth connection are not usually considered in the design of desktop applications. Neither are limitations like the media types supported by the devices.

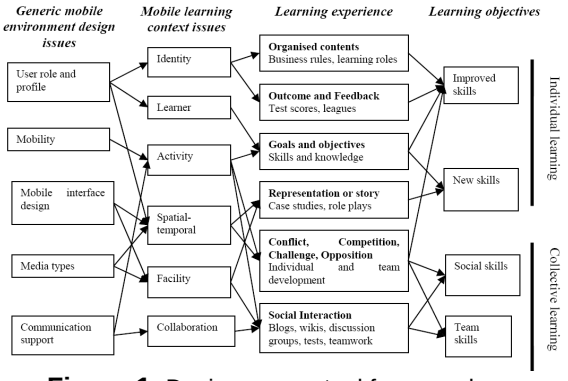

Figure 1. Design conceptual framework.

The second issue which must be designed carefully is the interface. The main limitation of these devices is the size of their screens. Usually these screens are 3.5" size and their resolution 320x240 pixels. Albers and Kim [12] study the problems created by small size of the screens. Some of the identified problems are: reading is harder than in a regular screen or paper, the graphical representations are limited by the size of the images, being sometimes too small to be understood. The interaction with the small contents without a mouse makes the activity quite difficult.

Churchill and Hedberg [13] propose a set of good practices in order to obtain high-quality mobile applications. These techniques are also valid for developing videogames and can be summarized with this list:

- The text must be short and formatted in a way that some meta-info about the importance of the content is also supplied. In this way the user can identify the most relevant information.
- The images must be resized without losing their meaning. Images for decorative reasons should be removed.
- Scroll-bars are annoying to work with and must be avoided when possible.
- The educative objects must be designed for being displayed in full screen mode. The navigation

menus and title bars use some space which should be used by the application (e.g. Internet Explorer for Windows Mobile 5™).
- All data must be displayed at the same time in a single screen. Some alternative methods like audio or video are proposed. Design practices prove than a single screen can accommodate a lot of information elements.
- Design for landscape presentation. Typically the screen of a mobile device is presented in portrait layout. This other presentation method is similar to the one used in television screens or computers.

These good practices do not guarantee to obtain a good mobile application but will avoid a number of common errors and will make the application easier to interact with. .

3. Technological issues

M-learning application success is tightly related with the type and number of devices which can execute it and this is very dependent of the implementation technology. Therefore designer should first choose the best technology for a specific application because the development cost and complexity is very different.

These technologies can be group in two general categories: the applications which are executed, at least partially, in the device and those applications which are executed in a remote server.

In the first group comprises the applications developed for specific platforms, Flash Lite based applications and Java ME (Java Micro Edition) based applications. The second category groups: SMS based applications and Web based applications. In this last case, the m-learning application works as a simple front-end of the system.

3.1 Applications for specific platforms

Due to the technological advances, PDAs and cell-phones are closer to the structure of a computer. Typically they come with 32 bits processors and several megabytes of memory. These devices use complete operating systems. Some of the most important platforms are: Symbian, Windows Mobile, Qtopia, BlackBerry and iPhone. At the end of this year, the new platform Android, the new open source platform developed by the Open Handset Alliance (headed by Google), will join them.

Usually these platforms also supply a software development kit (SDK) for application development (Symbian S60 is probably one of the platforms with more variety of development environments). These applications will take full advantage of the platform, with faster execution and better performance because the program is written specifically to be executed over the operative system. The problem of this approach, however, is that the applications written for a specific platform must be rewritten to be executed in another. This implies a bigger cost in order to supply the same contents to a wide range of devices.

3.2 Flash Lite based Applications

Flash Lite is the mobile version of the well-known application Adobe Flash. It is a language with fewer possibilities than the applications written in C or C++ for specific platforms or Java ME. Now it does not provide controls for the GPS receptors or Bluetooth connection what reduces the possibilities offered by the mobile devices. On the other hand the applications developed with Flash Lite are easier to write and provides great visual effects without too much effort. In the last version of this application typical features of more complex languages are provided. Some of these features are the internet connection for downloading new context or an object oriented language. The applications developed for this platform aren't executed natively over the operative system but over the Flash engine. This characteristic makes the application more independent of the device and being supported in any Flash Lite device. Kam [2] shows how flash videogames can be useful for spreading educative contents in less favored regions.

3.3 Java ME based Applications

Java ME or J2ME is currently the most important platform for developing applications for mobile devices. It provides a flexible and robust environment where applications for embedded systems o mobile systems can execute. This platform gives support for a number of devices from TV sets, passing by PDA, cell-phones, smart-phones, etc. J2ME promises the same advantages given by Java 2 Platform, Standard Edition (J2SE): "Write it once, run anywhere". Actually, J2ME platform is a subset of J2SE what implies that a java developer could learn how to program in J2ME pretty easily. Java object orientation properties make the things easier when a complex system must be created.

Java ME provides two different configurations depending on the characteristics of the device where it will be installed. CLDC (Connected Limited Device Configuration) is the configuration for devices with

less memory and processing power. CDC (Connected Device Configuration) is the configuration for more powerful devices and includes a whole virtual machine which can run standard Java byte code and utilize J2SE libraries. Each of these configurations can be complete with profiles and optional libraries which provide control over additional features.

3.4 SMS based Applications

The Short Message Service protocol (SMS) has achieved a great acceptance during the last years, especially among teenagers. The low cost of this service has made this technology a daily way of communications. This main limitation for developing games is that SMS is a simple text based technology with a limitation in length messages. On the other hand it is simple but powerful enough for creating quizzes or as a communication method among the users of a ubiquitous game. SMS simplicity is also its main advantage. The SMS protocol is shared by all kind of devices with phone features so the application can be set in a central server and accessed by all the users no matter which device or platform is using. This characteristic reduces considerably the cost of the application.

3.5 Web based Applications

Years ago the price of the internet connection via the Global System for Mobile communications (GSM), was too expensive for the average user to use these services. With the Wireless Access Protocols (WAP) the user got the possibility to access Web contents with lower costs. Nowadays the majority of the mobile devices come with features for accessing Web content. With the development of the General Packet Radio Service (GPRS) and the Universal Mobile Telecommunications System (UMTS) the cost of these services becomes inexpensive and affordable by any kind of user (in many cases on a flat rate).

In this kind of applications the problem is the features offered by the devices. Some cell-phones support images, other do not, some devices support video and millions of colors, others only support text based information. The server where the application is running must find out with type of contents is supported in each specific device, and supply only this type of contents, changing the contents not supported by other alternative with the same information. In order to provide this knowledge to the server, some methods of description have been developed: CC/PP, UAProf or WURFL. With these technologies, the server can choose the contents to be displayed to every specific device, but the contents in our application must be organized in a way that conflictive learning content could be exchanged by another.

4. Adaptation of <e-Adventure>

<e-Adventure> is a platform designed to allow instructors to develop their own instructional games without any programming knowledge [4]. }. Thanks to this platform, an expert in any knowledge field can develop his own conversational videogame, with only some little knowledge about computing science. This expert will only need an artist who will help him/her with the game art assets.

The platform focuses on the creation of educational *adventure* games, a well-established videogame genre identified by different authors as one of the most effective genres for learning [14-16].

<e-Adventure> provides a visual editor that simplifies the creation of this type of educational games (see Figure 2). The user can define his/her custom videogame with just some clicks with the mouse. In this way the cost of producing an educational videogame is also reduced because professionals such as videogame designers or programmers are not necessary. The efforts invested in the creation of these applications can focus on the contents instead of programming concerns.

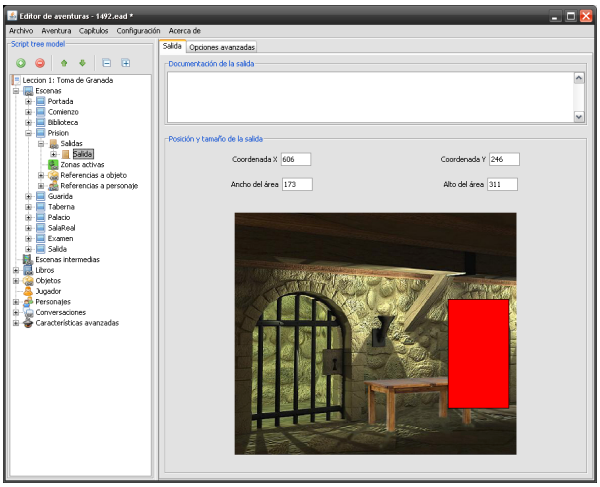

Figure 2. The <e-Adventure> visual editor.

4.1 Objectives of the project

The use of educational videogames in m-learning offers new ways for designing quality educational activities. The knowledge acquisition is enhanced by new methods of immersion and the actual possibility

of accessing to the contents anywhere. But the development of educational videogames which take advantage of mobility is quite complex. The special characteristics and needs coming with mobile devices are added to the intrinsic difficulty of designing a high quality educational videogame.

We think that the adaptation of tool like <e-Adventure> can provide benefits in two ways: this tool will help to create mobile conversational videogames in an easy way because some of the identified design problems are already considered. As a second benefit, some of the main difficulties found while adapting traditional applications to a mobile platform will be exposed.

4.2 Compatibility problems and technical limitations

For the development of the adapted platform we chose Java 2 Micro Edition with its CDC configuration. This configuration provides a complete virtual machine similar to that included in J2SE. Given that <e-Adventure> was developed using Java 2 Special Edition, we expected a reasonably simple transition process.

Within the CDC configuration there are three different profiles which give extra libraries. These profiles are the Foundation Profile, which is the basic profile, the Personal Basic Profile which offers some GUI libraries and some compatibility with AWT, and the Personal Profile which supplies complete support for AWT.

In order to simulate a Java-enabled mobile device, we used Sun's CDC Toolkit Simulator. This simulator does not ship with the Personal Profile but supports a custom profile based on the Personal Basic Profile and an additional library that completes its AWT support.

During the porting process, however, we found that the current Java implementations for mobile devices were not a match for their desktop counterparts. This is clearly a challenge for the general implantation of game-based m-learning experiences. These are some of the issues that we had to tackle:

- **Version gap**. Given that both Java 1.4 and Java 1.5 are already in their *End Of Service Life* periods[2], the configuration CDC of J2ME is based on the version 1.4 of the J2SE platform. The <e-Adventure> platform was developed using version 1.6 of J2SE and, therefore, some of its code structures and libraries are not supported by the current mobile devices. This limitation implied changing the improved instructions and structures for obtaining a Java 1.4 compliant version of the code.
- **XML-parsing**. <e-Adventure> uses XML files to annotate the storyboards that define all the features in the game, such as characters, dialogs, interaction with the objects, etc [17]. The original platform treated these files using SAX. However, neither the default libraries, included with the profiles, nor the optional libraries provide an implementation for this API. This aspect remarks another open issue: some libraries included by default in the J2SE platforms are missing from their mobile versions.
- **Compatibility of the interface libraries.** The Personal Profile and the Personal Basic Profile should give a plain support for AWT. This compatibility is based on version 1.3 of AWT so some features and classes are not supported. One of the most concerning examples are the buffer politics. <e-Adventure> uses double buffering in order to avoid the blinking effect caused by repainting elements on the screen, a typical issue in game development. A custom double buffer had to be implemented, which fixed the blinking problem, but slowed down the execution of the application.
- **Media libraries.** <e-Adventure> provides support for several types of audio files like MP3 or MIDI and the display of video clips. As of now, the implementation of the APIs required are still being considered for development, with pre-defined APIs but lacking an official implementation[3].

After having completed this transition, and as we will discuss later in the conclusions, the choice of a Java-based environment facilitates the creation of game-based mobile learning solutions, but it is still a difficult task.

4.3 <m-Adventure>

In spite of the technical challenges, the first version of our mobile educational game platform, <m-Adventure> is now complete. Given the characteristics of these devices, the mobile version of the engine does not support all the features offered by the original <e-Adventure> platform, especially those related to managing media files, for example, video files.

The editor remains as a desktop application, because it would be very cumbersome for the

[2] http://java.sun.com/products/archive/eol.policy.html

[3] http://jcp.org/en/jsr/detail?id=135

instructor to create the materials with the constraints of a mobile device. Once the instructor has finished the creation of the game, he or she can choose whether to export the complete game for execution on the fully-featured <e-Adventure> engine or export a reduced version adapted to the requirements of the mobile implementation of the engine (see Figure 3).

The reduced version of the game, in this iteration, reduces the size of all images proportionally (to fit the smaller screen of a mobile device), performs some technical adjustments (such as reflecting images or resampling sound files) and substitutes the videos for still images when possible.

This workflow, which uses the editor as the starting point and allows the same game to be executed on both platforms, could be extended in the future to include support for more types of devices.

Figure 3. An <m-Adventure> game running on the Sun CDC Toolkit Simulator

4.3 Technical considerations

After the experience of this project, we can deduce that Java 2 Micro Edition is a flexible and robust platform, with an easy learning curve for J2SE programmers. However, the development of applications for mobile devices must take into account some significant differences between the standard and mobile platforms. Even when J2ME is the main platform for developing applications for mobile devices, the CDC configuration of the J2ME platform would need more support in terms of providing implementations for the existing APIs.

The main problem is that, currently, the development of optional libraries is focused on the CLDC configuration which is more extended among the low-end devices such as cell-phones. However, the current increase in the use of the CDC configuration makes us think that in the near future new libraries will be developed in order to support this kind of files.

Some of the initial worries about the limitations of the devices and the possibility of porting this platform to a mobile environment focused on the computing power of these devices. Fortunately, one of the advantages of adventure games is that they have low technical requirements, not needing high speed interactions or complex graphics. The current implementation of the engine can be executed in the current generation of PDAs that implement the Personal Profile of the J2ME CDC configuration. It must be noted that other game types, with higher levels of interactivity and graphical complexity, may be constrained by the current computing power of these devices. However, adventure games are one of the most appropriate game genres for educational contexts [14, 16].

5. Conclusions

Educational videogames in m-learning offers new possibilities for creating high quality educative experiences. However, the actual application of this model has to overcome a number of significant challenges. In order to analyze these issues, we have extended the <e-Adventure> educational game platform, porting the engine for its execution in mobile environments and reported the challenges that we had to face.

Even though most of the work has been focused on solving technical challenges, the resulting platform should facilitate the development of educational adventure games for mobile devices. The creation of the games is based on the already stable <e-Adventure> editor, which takes care of the authoring complexities as described in [4]. Then, the adapted <m-Adventure> engine allows the learners to use these educational adventure games at any moment.

This opens new scenarios for game-based learning without an excessive additional cost. The games can be played during the students' idle time (in the bus, waiting in a line…), but they will also have the possibility of accessing the contents right when needed

(Just-In-Time Learning). For example, if the videogame recreated the use of a type of building machine, the user could use the games to solve some doubts standing right in front of it.

Prospective works for this platform include adding features which will use some of the features that ship with next-generation mobile devices. The GPS position of the user might be used to provide different contents depending on the location (context aware games). In the case that the user is moving through a museum, the videogame could change the scene accordingly.

Other future research lines are related to the possibility of adapting the application depending on the preferences and characteristics of the user and the device. As previously stated, having a single editor with multiple adaptation profiles may be a flexible approach to support incrementally an increasing variety of device families. Additionally, the academic community is increasingly concerned with the adaptations needed for users with functional diversity. These adaptations are difficult to implement afterwards and this approach could help to include some of these features from the very beginning.

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