1
Introduction

Pervasiveness can be recognized in game playing every time the boundaries of playing expand from the virtual (or fictional) world to the real world. Sensor technologies, mobile devices, networking capabilities, and the internet make pervasive games possible.

In the present work, we consider "pervasive mobile games" as context-aware games that necessarily use mobile devices. Also we consider that smartphones are the main driver to fulfill the promises of pervasive game playing.

This chapter provides an overview for this research work, including the work methodology, the objectives, the main contributions and its organization.

As far as we are aware, this is the first general work on pervasive mobile game design. Further work is foreseen towards other stages of the game design where more formal methods of Software Engineering can be used to improve the quality of the game without sacrificing creativity and innovation.

1.1
Overview

We consider the process of building a game as having three general parts: game design[1], software design, and software implementation.

The term "design" in game development has many interpretations. Firstly there are tasks related to the work of designers and artists, which is more frequently associated to "game design". Secondly, we may have the software development process in mind. In each of these cases there are various stages of design. Nevertheless, the term game design also involves aspects of software design. This is specially true in the conceptual design stage of a game, because game development is an interdisciplinary task.

However, in general the development process of current mobile games revolves around resolving implementation issues for specific smartphones plat-

1 Chapter 2 discusses issues related to games and game design in general.

forms. This includes the options of developing everything from scratch, working with APIs, and/or using game engines, which makes developing mobile games a hard task. Many developers have been using mobile game engines as Unity (2011) and Corona (2011) (both for iPhone and Android-based devices), because they are practical, fast, and cheap. However, game engines are frameworks restricted to some platforms and some specific types of games. Creative, innovative, and state-of-the-art mobile games do not usually comply with requirements of existing game engines. Also, developers cannot adopt the same approaches used in personal computer platforms, due to distinct characteristics of mobile devices, which include: *(i)* more restricted computing power; *(ii)* nonexistence of cooling systems (what holds up the use of more powerful microprocessors and batteries); *(iii)* smaller physical screen size; *(iv)* huge diversity amongst mobile phone platforms; and *(v)* restricted input modalities (Capin *et al.* 2008; Akenine-Möller and Ström 2008). Another issue is that mobile devices are battery-powered – this means that developer must use mobile device resources[2] carefully so as not to drain the battery quickly.

We also remark that mobile devices (specially smartphones) are not just handheld devices – their characteristic of being intrinsically connected everywhere[3] makes those devices unique, as this opens up opportunities not possible in PC and game console platforms.

Independently of using game engines or not, mobile game designers have very few resources available when it comes to guidelines for mobile game design, including the game software part. Also there are few references on Software Engineering techniques, tools, and formalisms for mobile game design. Part of these problems is due to the fact that game design is not a well-defined area. Furthermore, most of the design guidelines for mobile games come from artists or designers, who often claim that programmers or software engineers are not game designers, and thus not able to suggest guidelines. Unfortunately, the majority of artists and programmers do not understand that game development is an interdisciplinary

2 For example, this includes vibration motors, device sensors (as GPS and accelerometers), processor-greedy algorithms, 3D graphics (which promotes intensive communication between CPU and GPU) and keeping the device screen lit all the time.

3 Theoretically. In practice this depends on mobile operator coverage.

activity embracing design theories, design methodologies, and techniques from several areas. Nowadays, the entertainment industry is claiming for a new brand of "*hybrid game developer"*, who is an individual capable of transiting through the great diversity of the above-mentioned areas, with especial performance in both arts and programming. Chris Crawford (2003) wrote something related to the origins of this idea back in 2003: *"True, a game designer must understand programming just as a game programmer must know something of game design"*.

To help in filling these gaps, this research work proposes a methodology[4] that concerns aspects related to *software design* – the second part of the game development process[5], but applied to pervasive games. This methodology focus on the conceptual design stage – this means we are not concerned with software implementation details.

1.1.1 Pervasive games and game design

The literature tends to consider the debut of this game modality in the year 2001, after the huge success of *The Beast*[6], although other "pervasive games" also appeared in 2001 (as *Pervasive Clue* and *Pirates!*), and even a bit earlier (as the *Nokia Game* series, from 1999 to 2003) (Montola *et al.* 2009).

However, the game design scenario for pervasive games becomes critical when we consider that: 1) pervasiveness in video-games is not a well-defined concept; and 2) the design experience with this game modality is very low in both industry and academy. This situation turns out to be extremely critical when we move towards mobile games. In this later, the literature on design methodology is rare and on pervasive mobile games is even scarcer. Again, the literature concentrates on general design guidelines and is far from Software Engineering issues, as we can notice in (Nokia Developer 2011b). As examples, researchers have proposed patterns for mobile game design (Davidsson *et al.* 2004) and playability

4 Chapter 4 presents an overview of the proposed methodology.

5 As we outlined at the beginning of this section: a process composed of game design, software design, and software implementation.

6 *The Beast* (also known as the *A.I. Game)* has been created as a marketing campaign to promote the Steven Spielberg's movie *A.I.* Please refer to Section 3.1 for more information on the mentioned games and pervasive game origins.

heuristics for mobile game design (Korhonen and Koivisto 2007), but those results are far from a design methodology – furthermore, pervasive mobile games are only presented as a pattern, without further detailed analysis. The work by Montola and co-authors (2009) represents the first and still the only general reference on the design of pervasive games. However, this latter reference focuses on cultural aspects and general guidelines, aimed to designers who are not software engineers.

Another issue that pervasive games can help to solve is the complaints on the lack of innovation in the gaming industry. Over the last few years, it has been possible to notice a tendency for big game development companies to concentrate on rehashing games that had been successful in the past. The end result is that the game market has been flooded with sequels and franchises, which has been deemed as the "game industry sequelitis" (Jones 2010). Several sources have reproduced this complaint, such as researchers (Egenfeldt-Nielsen 2007; Chehimi *et al.* 2008), people from the game industry (Murdley 2006), and the general press (Hudson 2011). This issue needs attention as the strategy of rehashing of game titles has already started to fail, as reported in (Graft 2010).

1.1.2 The role of smartphones

Using smartphones for realizing pervasive games was one of the main drivers for this research work. Smartphones are ideal candidates for pervasive gaming. For example, here are some reasons to support this claim:

- Smartphones are always-connected devices.
- Smartphones are convergent, multimedia devices.
- Smartphones are means for integrating local context to games and applications.
- Smartphones are becoming mobile computers, with increasing processing power and storage capacities.
- Smartphones are social devices, meant for communication.
- Smartphones have efficient application distribution channels

- Smartphones are ubiquitous.

We define a "smartphone" as a mobile phone with characteristics as follows: 1) an operating system that allows for installing third-party applications[7], 2) advanced networking capabilities, 3) advanced multimedia capabilities, 4) embedded sensors, 5) "high" processing power and "high" memory capacities[8].

The "advanced networking capabilities" means the device offers several options for connecting to networks, in global and local scopes[9]. In fact, by definition smartphones are always-connected, as they are tied to a mobile operator net-work operator network. This opens up the possibility of using mobile computing anywhere there is coverage of the mobile operator. This is important for pervasive games as they often require wireless networking[10].

The "advanced multimedia capabilities" make it possible for a device to produce and consume several media types. For example, this includes audio, video, images, games, and office documents. Thanks to cellular network connectivity, users are able to augment this feature by producing and consuming media on the go. This is especially interesting for games and entertainment applications.

The "embedded sensors"[11] in smartphones enables a game to sense and use local context, making it context-aware. One of the often cited references for *context*, (Dey 2001), defines it as:

> "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves"

This means that the game is able to change its behavior according to the current environment conditions, using this information as source for game content to provide customized experiences. This is a central characteristic of pervasive games[10].

7 Applications that are not pre-installed on the device from the factory.
8 With "high processing power and memory" we mean "the best possible available at the moment for mobile devices" as is the case of the so-called "high end devices".
9 An example of global network is the internet. A local network would be one that covers a restricted area, or a network were devices are co-located.
10 Chapter 3 discusses this subject.
11 Examples of sensors found in current smartphones: inertial sensors (*e.g.* accelerometers, gyroscopes), high resolution cameras (5 MP+), multi-touch screens, light sensors, proximity sensors, magnetometers, and GPS.

Current smartphones have evolved into tiny computers that have dual-core CPUs reaching the gigahertz mark, dedicated 3D graphics hardware, and working memory (RAM) touching the gigabyte line. Secondary storage has already surpassed dozens of gigabytes of capacity, mainly due to memory cards becoming very cheap. These characteristics open up possibilities for more sophisticated applications using higher-quality multimedia content, which is the case of games in general.

Smartphones are highly personal devices and people carry them all the time, everywhere, using them to communicate with other people. When exploring the contents of a smartphone, probably it is possible to discover a lot about its owner, as those devices may store text messages, multimedia messages, emails, photos, and other types of personal media. Pervasive games often have a strong social factor, a characteristic that matches the social nature of smartphones[10].

Another important characteristic of smartphones regards application distribution. Currently, there are several *application stores*[12], which are centralized places that gather a multitude of mobile applications for users to download. Usually, users access application stores through a special application that is built-in to the devices. Considering the networking capabilities of smartphones, the reach of application distribution is very broad, making application stores a convenient method for accessing applications. Interestingly enough, the games category is the most popular among paid applications in various application stores, such as Apple's App Store, Android Market, and Nokia Store (Distimo 2010; Nokia Developer 2010).

Finally, although smartphones do not represent the majority of mobile phones, it is important to notice that mobile phones in general are ubiquitous. For example, in Brazil (where the present work was developed) there were more than 200 million mobile phone subscriptions in late 2010, according to the ANATEL, the Brazilian National Telecommunications Agency (Anatel 2011). This is more than the population of Brazil (~190.73 million people), according to the 2010 population census (IBGE 2011). In the future, with the evolution of mobile phones in

12 Application stores are available for current major smartphone platforms, where users are able to download free and paid applications. For examples, please refer to (Distimo 2011).

general, smartphones will become more ubiquitous, making them ideal candidates for advanced mobile applications as pervasive games.

1.2 Objectives and contributions

After developing several mobile games and noticing the potentials of pervasive games, we understood that the area of pervasive mobile games greatly needs general guidance. In this regard, this research work set out the following objectives:

- Discover common features in pervasive games;
- Investigate how technology enabled or influenced the realization of pervasive games, and player experience;
- Develop some pervasive game prototypes.

Considering that simplicity and creativity are of utmost importance for this game modality, we focused on the first steps of game development: the conceptual design stage. The decision of concentrating efforts on this stage has another strong and even more important underlying reason: the nature of pervasive mobile games demands the focus on conceptual design and requires simple and light formalisms, otherwise creativity may be jeopardized.

This observation leads us to formulate and use a simple methodology comprising two main parts:

1. A domain knowledge mapping;
2. A domain specific language (DSL) specification for designing activities in pervasive mobile games.

The first part organizes the knowledge about a domain of pervasive games into domain boundaries, pervasive game features, checklists, and other concepts. The domain boundaries define a subset of all pervasive games that interest us – we have named this subset as “pervasive mobile games”.

The second part defines a DSL specification based on concepts, consistency rules and diagrams to support the specification of activities in a pervasive mobile

game. In this work, an activity represent a set of actions involving players, (mobile) devices, sensors and actuators[13] to reach some goal in the game.

A DSL (Mernik *et al.* 2005) is a language designed for a particular application domain, comprising specific types and constructs that encode the domain knowledge. This DSL specification has two levels, which are: ontological and operational[14].

We believe that this proposal is adequate for the conceptual design stage, which is the one we are aiming at. This methodology applies to the design of pervasive mobile games[15]. However, it certainly could be applied or extended to other types of pervasive games, but this is left as an exercise to the reader.

As an example, throughout this research work we present a concrete pervasive mobile game specification using elements defined in our methodology. This specification uses elements of an *enhanced game design document template* – a standard game design document that adds elements of our methodology (which pertain aspects of Software Engineering). Appendix D provides an empty template for this document.

1.2.1 Main contributions

The main contributions of this research work are:

1. A novel list of prominent features of pervasive games, identified from game projects and the literature, and checklists for each feature. This feature list (and corresponding checklists) can be used to spark novel game ideas, and to help in discovering functional and non-functional requirements for pervasive mobile games. Chapter 5 and Appendix B discuss this contribution;
2. A domain specific language to help in specifying activities in pervasive mobile games that use mobile devices, sensors and actuators as the main interface elements (see Chapters 6 and 7);

13 Chapter 6 defines in detail the concepts of activity, actions, devices, sensors, and actuators.
14 This could be classified also as “static” and “dynamic” views.
15 Chapter 4 discusses the criteria for defining “pervasive mobile games”.

1.2.2
Secondary contributions

Our journey into pervasive games began in 2007 and culminated with the production of this research work. However, during this period other secondary contributions have been produced as results of this whole process. Here is a list of these secondary contributions:

1. The first non-visual game for mobile phones, *The Audio Flashlight*[16], developed as an exploration of non-visual mobile phone interfaces, using Semiotic Engineering principles (de Souza 2005) to design the user interface. Two publications (Valente *et al.* 2008; Valente *et al.* 2009) provide details on this specific topic of research. This contribution relates to topics in Chapter 5;
2. The first multi-player non-visual game for mobile phones, *The Audio Flashlight 2*, detailed in (Valente and Feijó 2011)
3. A survey on the current state of the art of pervasive games, helping to sort out the confusion on this field by discussing the main concerns of common approaches for defining pervasive games (see Chapter 3);
4. A game design document template for pervasive mobile games. Appendix D;
5. Seven innovative pervasive mobile game prototypes (Appendix C): *Location-based Quiz Game*, *Pervasive Word Search*, *The Audio Flashlight* series (5 games).

1.3
Work methodology

The origins for this research work began back in 2007 when we became involved with application development for mobile phones. The idea was to start exploring games for mobile devices, eventually leading to pervasive games.

In 2007, Nokia unveiled the N95, a smartphone equipped with a number of sensors (including GPS). In mid-2007, Nokia released an API that enabled using

16 This research work has been awarded with "best paper award" at the SBC Symposium on Human Factors 2008.

the accelerometer sensor in applications for the N95. We used this opportunity to start exploring gesture-based control for mobile phone games, which gave birth to the first game on mobile phones[17] using the accelerometer for in-game control – Accelerinvaders (Valente 2007). This experience was the basis for later mobile games and pervasive mobile games such as *The Audio Flashlight* series, which have been used in this research work.

Games that are based on location are also part of pervasive games. In this sense, we explored a number of issues related to this subject when developing the *Location-based Quiz* prototype. In this project, we also started exploring issues related to networking for smartphones.

We also explored other sensors found in smartphones as cameras, Bluetooth, WiFi, GPS, and light sensors. Exploring cameras in smartphones resulted in an early (unpublished) prototype named *Real-world Color Picker* (in 2008), which was a tool to help color-blind people in identifying colors in the physical world using the device camera. The findings of this experience were applied in the prototype *Pervasive Word Search*. We made experiments with WiFi and Bluetooth sensors in *Pervasive Word Search* and *The Audio Flashlight* series. In case of *The Audio Flashlight* series, we explored multi-player gaming with co-located players. *Pervasive Word Search* also uses light sensors and GPS.

During all those experiments, we have used a number of application runtimes, all for Nokia Symbian platforms: Java ME, Python, C++, and Qt (Nokia 2011; Blanchette and Summerfield 2008). In the end, we chose Qt as it proved to be easier to use and more productive.

All the knowledge gathered during those development experiments influenced this research work in a number of ways. These experiences were one of the sources for the first part of the proposed methodology – the domain knowledge mapping for pervasive mobile games. This part also included extensive research on existing pervasive games. These experiences also influenced the second part of our methodology (the DSL for activities in pervasive mobile games), helping to shape which elements should be considered important in game activities.

17 To the best of our knowledge.

1.4 Organization of this work

This research work presents a specification for a concrete pervasive mobile game (*Pervasive Word Search*) throughout the main text as an example of applying the elements of our methodology.

This work is organized as follows. Chapters 2 and 3 discuss the fundamental concepts. Chapter 2 provides an overview on concepts related to games and game design in general, also presenting the general game design for *Pervasive Word Search*. Chapter 3 provides a survey on the state of the art for pervasive games, drawn from different perspectives.

Chapter 4 provides an overview of the proposed methodology, defining boundaries that guide our study of pervasive games (defining the notion of *pervasive mobile games*) and summarizing the ideas behind the domain knowledge mapping and the domain specific language.

Chapter 5 details the discussion on the domain knowledge mapping, also presenting how the pervasive game features are present for *Pervasive Word Search*.

Chapter 6 presents the ontological level for the DSL, defining the vocabulary to support the specification of activities. Chapter 7 presents the operational level for the DSL, through templates and activity diagrams.

Chapter 8 discusses how the DSL is applied to specify a concrete game – *Pervasive Word Search*, which represents the final part of our case study.

Chapter 9 presents the conclusions of this research work.

This work also has some appendices. Appendix A provides a description of all pervasive games analyzed in this research work. We have opted to include this appendix to avoid duplicating descriptions of game projects when discussing some topics in this work (especially the ones in Chapter 5). This appendix works as a central reference point for the analyzed games, avoiding cluttering the main text with this information and helping the reader to get to know reference game projects. Appendix B deepens the discussion of Chapter 5. Appendix C provides a description of the prototypes developed during this research work, and describes how the pervasive game features (Chapter 5) are present in the other prototypes.

Appendix D presents a template for an *Enhanced Game Design Document* based on our methodology, which we have used to develop our prototypes. The case study for *Pervasive Word Search* uses elements of this enhanced game design document.