Master in Informatics Engineering

Dissertation

Final report

Interactive Soundscapes in Mobile Contexts

Luís Miguel Carreira Marques
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Supervised by:
Prof. Licínio Gomes Roque

January 29th, 2016

FCTUC DEPARTAMENTO
DE ENGENHARIA INFORMÁTICA
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE DE COIMBRA

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Summary

The following document presents all the work and study performed by Luís Miguel Carreira Marques on his Informatics Engineering Master's dissertation, at the Faculty of Sciences and Technology of the University of Coimbra.

This dissertation builds up on several subjects related to Sound Design, and how sound can be actively explored through a soundscape composition. Therefore, the direction of this project is to incorporate and develop a structured and meaningful soundscape composition in a mobile context (smartphones/tablets), to be tested in an urban environment by the user in an interactive scenario. The desired interaction is provided by the user, with the player's movement input of the mobile application being the user's real movement, while he is walking through urban scenarios and being engaged by the soundscape composition that is played, leading him to a real live sound experience. This acts as an audio exploration in an Augmented Reality context.

Through this document is presented each step of the project, from its elaboration stages to the state of the art and architecture, and the detailed evolution of the prototype implementation as well as the tests performed to validate the defined research goals.

Keywords

"Audio Augmented Reality", "Acoustic Ecology", "Game Design", "Interactive Soundscapes", "Mobile Gaming", "Soundscape", "Soundscape Composition", "Sound Design".

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Acknowledgements

For my supervisor, Professor Licínio Roque, a word of my appreciation and thanks for all the support and comprehension along this project. His mindset and insight about Sound Design in Games was so helpful and inspiring.

I would like to also thank to my colleagues in LabC62 at the Department of Informatics Engineering for their full availability to help and guide me in the proper way. To Durval Pires, for being the predecessor of this dissertation and for his knowledge and enthusiasm when sharing his ideas with me; and to Rui Craveirinha, for his helpful support and positive mindset every time it was needed.

To my friends and family, thanks for the continuous support and for the patience given in several moments.

A unique and meaningful thanks to my girlfriend Cláudia, for the extensive support always given, the patience, motivation, affection, and strength to move forward.

For the seven participants that helped me in the concretization of this project, thank you all very much.

Also, a gesture of appreciation to Centro de Documentação 25 de Abril, for all the effort, dedication and willingness to help providing audio recordings and valuable information.

Chapter 1 - Introduction

Today, the videogame industry has exceeded players' wildest expectations. It has grown and developed and delivered amazing games so fast that now it has a fair share of the entertainment market business, larger than the movie industry's [Video Game Sales Wiki]. As recently seen by the Grand Theft Auto V phenomenon, where their sales went through the roof in just one day [Pilchner 2013], and with the expansion and usage of mobile devices, it is fair to say that gaming is at the distance of a "touch". Leaving behind the big blockbusters titles, the mobile gaming world has too become a vast market for developers, since from the simpler games to the more complex ones, everything is now around us. It is just a matter of choice and mindset. From major software companies, to small independent developers, everyone everywhere, is developing games whether in a web context, consoles context, mobile devices, with all the tools needed being relatively easy to access to, then, start developing games.

On one hand, despite the great titles that enter the market, the gamer only has access to the final product, not knowing technical details about them. Of course that visually they are getting more stunning each day, and that seems what pleases the public. On the other hand, and for the public that is aware of it, sound design in games sometimes feels that it did not get the deserved attention by developers. Indie developers and others with more resources start to develop their games, expecting to deliver the best product there is, but forget to factor in how sound impacts player experience. As Schafer once said: "*Hearing is a way of touching at a distance*" [Schafer 1994] and for him, touch was the most personal of senses – (as opposed to the more common vision). This emphasizes the role that sound has in our lives and, consequently, in videogames.

New forms of technology emerge from time to time, Augmented Reality for example, and it mainly focuses on visual contents too. Displaying virtual layers over the real world. This kind of visual and appearances society that we are inserted in, is a reflection of this, so it is needed that sound experiences emerge and get more attention from the audience. If we play most of the games without sound, we will experience some emptiness and disconnection from the game because sound, besides being a complement of the visuals, it is too an integrant part of the game and most of our experience or feelings comes from the sound experience.

1.1 - Contextualization

In this section, is intended to give continuation to the themes described above, being sound the main "actor" in this dissertation. It is an area that has been explored for many years, but more recently and at FCTUC, it has been the subject of substantial work and research. By this, Game Sound Design has been studied in the last years and some results have been obtained, specifically a Pattern Language for Sound Design in Games [Alves 2011] and an innovative Sound Engine for game audio [Pires 2013]. As mentioned above, sound design either in cinema or games, is a hard task because it is mainly executed at the end of the development, in other words, it is "pasted" on the movie or game. However, in

digital games it can be even harder because the sound composition needs to be applicable to the interactive context on which the player actions occur. Many actions or decisions made by the player should influence the sound composition that is performing, and for that, the developers need to control manually the sound sources, in order for them to converge with what is happening in the game.

This concepts about sound design, are related to the soundscape design and its vision of how an ecological soundscape design in context could embrace and upgrade a sound experience. Therefore, it urges the necessity to explore the dynamic soundscapes in interactive scenarios, which means, through augmented reality based on audio.

1.2 – Objectives

This dissertation's main goal is the creation and implementation of a soundscape composition related and applicable to an urban environment, which is then played through mobile devices while the user walks in the surrounding areas, as if it is an interactive game experience.

Besides the development of the prototype and its functionality, a crucial goal of this dissertation was the creation of a mobile sound-based experience as a tool for testing a proof of concept. This proof of concept, as an objective, involved the particular nature of the human being, his organic and mental dimensions, the way he senses life and the world, and with the developed product we wanted to evaluate how the user experienced, felt and sensed his emotions through an experiment provided only by audio together with only one mode of interaction - walking.

To accomplish this experience the defined goals were: the development of a prototype of a mobile application within a context of augmented reality focused on audio; the elaboration and design of a soundscape composition to be applied in the prototype; the analysis and evaluation of the users direct and indirect feedback and behavior; and the validation of the developed proof of concept.

With this standalone prototype and the results for the validation of the proof of concept conceived for this dissertation, we intended to demonstrate and present new forms of exploring sound design in mobile devices and in contexts of augmented reality.

1.3 – Document Structure

The structure of this document was designed according to the Design Research approach followed in this dissertation. In the State of the Art chapter are combined the relevant themes and subjects that were addressed in the paradigm of this project's perspective (Acoustic Ecology and Design, Soundscape Composition, Augmented Reality, Pervasive Games, Sound Design, and others). Next, the Methodology chapter indicates the proposed research goals and the approach justification, as well as the schedule of the development. For the achievement of the research goals, the Design and Architecture Model chapter was compiled, followed by the Development Activities were the prototype development is described. The Evaluation presents the process that led to the validation of

the research goals, and finally, some future remarks, and the accomplished answers and knowledge obtained, are presented in the Future Work and Conclusion chapters.

Chapter 2 – State of the Art

On this chapter, the state of the art presents the information and background of all the thematic, technics and technology on which this dissertation is made. The current project cover's two main fields of study – Soundscapes/Acoustic Ecology and Augmented Reality/Pervasive Games – and import some previous works performed on those fields of study.

Along this chapter all those themes and study areas will be presented for context purposes, providing the viewer with the information gathered from research activity and by the results and contribution given by three previous works for the study areas involved in this dissertation.

2.1 – Acoustic Ecology

2.1.1 – The Acoustic Ecology field of study

In order to understand and be aware of the main theme that led to the conception of this work, a reference to two important names in the study of Acoustic Ecology and Soundscapes, is required. They are, Raymond Murray Schafer and Barry Truax.

The first one, Schafer, is known as "the father of Acoustic Ecology" for his study work and researches made during de 1960s. He is a composer, writer, music educator and environmentalist, and while he was teaching at Simon Fraser University he founded the World Soundscape Project (WSP), a large project that was intended to study the relationships between people and their acoustic environment. In his mind, the soundscape of the world was changing, the acoustic environments were already changing due to some events – eras of mechanical and industrial influence – and for him that was taking influence in the level of people's awareness of sound of the surrounding acoustic environment. He took note of the ascendance that the visual impact was having in society (describing it as "eye culture"), and at the same time, how the world's acoustic, the new emerging sounds, were causing a degradation of the sonic environment, identifying it as noise pollution [Wrightson 2000].

"*Our senses are clogged with too much*" [Schafer 2005], a more recent and insightful declaration of Schafer, makes every sense according to what has been is life studies and objectives. His vision of the relationship between man and the sounds of his environment, made him study and try to understand what were the consequences of the changes in that sonic environment, so he projected himself to the study of noise pollution.

According to Schafer, "*Noise pollution results when man does not listen carefully. Noises are the sounds we have learned to ignore. Noise pollution today is being resisted by noise abatement. This is a negative approach. We must seek a way to make environmental acoustics a positive study program. Which sounds do we want to preserve, encourage, multiply? When we know this, the boring or destructive sounds will be conspicuous enough and we will know why we must eliminate them. Only a total*

appreciation of the acoustic environment can give us the resources for improving the orchestration of the world soundscape." [Schafer 1994]

This way, aware of the degradation caused by man to the sonic environments, and the damaging effects of technological sounds on humans, Schafer wrote two booklets: The New Soundscape and The Book of Noise. His effort was well intentioned, but the booklets focused too much on anti-noise legislation and on the need of elimination or reduction of theoretically destructive sounds in the urban soundscape. Through the years ahead and with the work and study developed to the WSP, he wrote The Tuning of the World, which is considered his main publication about acoustic ecology, covering all his researches, philosophies and theories about the subject. [The Canadian Encyclopedia].

Therefore, what is Acoustic Ecology? The theory is based on environment sounds being perceived as a whole, being part of a balanced ecological entity, and understood as that. From Schafer words, Acoustic Ecology is "*the study of the effects of the acoustic environment, or soundscape, on the physical responses or behavioral characteristics of the creatures living within it, with the aim to draw attention to imbalances which may have unhealthy or inimical effects.*" [Schafer 1994].

In other words, more than fighting noise pollution or excluding sound, acoustic ecology pursues the delicate balance between organisms and their sonic environment, because, for Schafer "*if we become too dominant and too unobservant about the other sounds in the environment, then we're ruining the richness of our whole lives*" [Razdan 2005].

2.1.2 – Soundscape Definition

Schafer, along with his work and research published at the WSP, had some objectives and goals to achieve. The work at WSP was mostly the record, analysis, and document of different acoustic environments – functional and dysfunctional – at several different places in the world, having collected a wide diversity of soundscapes that he and his co-workers analyzed in order to rise the public awareness of the importance of the soundscape. Thus, he composed his theory of the Acoustic Ecology and launched the concept of soundscape. [Truax 2000]

The definition of soundscape differs from author to author, but by the concept of Schafer a soundscape is a combination or group of sounds, that compose and form a certain sonic environment. It can be any acoustic field of study, because a "*soundscape consists of events heard not objects seen*". [Schafer 2004]

Fundamentally, the subject of Acoustic Ecology is the study of soundscapes.

Being a sound and acoustic studious, Schafer declared that to know and interpret a soundscape it must be analyzed by three basic elements that make a soundscape, as "*those sounds are important either because of their individuality, their numerousness or their domination*". These three types of elements are: Keynote Sounds, Signals and Soundmarks [Schafer 1994]. The distinction between them is:

- **Keynote Sounds** – keynote comes from musical terms, identifying the tonality of a particular composition. In a soundscape scope, it is the central tone of a

composition, it functions as a reference point from which everything else modulates. They may not be consciously perceived, but they have influence on the behavior and perception of who is hearing them, allowing other tonalities and sounds to be distinguished in the soundscape [Schafer 1994].

- **Signals** – this element corresponds to any sound that is listened to consciously, and to which the attention is directly drawn. Usually they are linked to warning or alert sounds like sirens, horns or bells, so they are intended to be heard [Schafer 1994].
- **Soundmarks** – derives from landmark. This is, it refers to a specific, unique, community sound that has qualities which make it easily noticed by the people in that community. If that soundmark is identified, it has to be protected because it could help to make the acoustic life of a certain community unique [Schafer 1994].

Through the continuous WSP members work and studies around the soundscape concept, new approaches for this field of study began to appear. By this means, other soundscape "students" and theoreticians, centered their challenge in discovering what others areas and themes could be related to soundscapes in order to elaborate more specific frameworks and disciplines so that the public could have knowledge of all the soundscape principles and sonic, acoustic ecology.

Having by reference the three elements that Schafer used to elaborate a soundscape (Keynote Sounds, Signals, Soundmarks), other authors, having these concepts by reference, expanded them accordingly to their studies and work on this subject. If the term "soundscape" can be defined of several ways and is being used by some disciplines to describe the relation between a landscape and the sounds that composes it, a direct relation between acoustic ecology and landscape ecology was made, giving birth to a transdisciplinary field: **Soundscape Ecology** [Pijanowski et al 2011; Truax et al 2011; Pijanowski et al 2011]. So, what principles where taken in consideration and contributed to the concept of Soundscape Ecology? These principles that guided the soundscape ecology come from the contribution of different concurrent disciplines, explicitly landscape ecology, bioacoustics, psychoacoustics and acoustic ecology. [Farina et al 2014].

According to Pijanowsky, 2011, the Soundscape Ecology is the result of the interaction and concurrence of the disciplines stated before, and as it is shown in Figure 1.

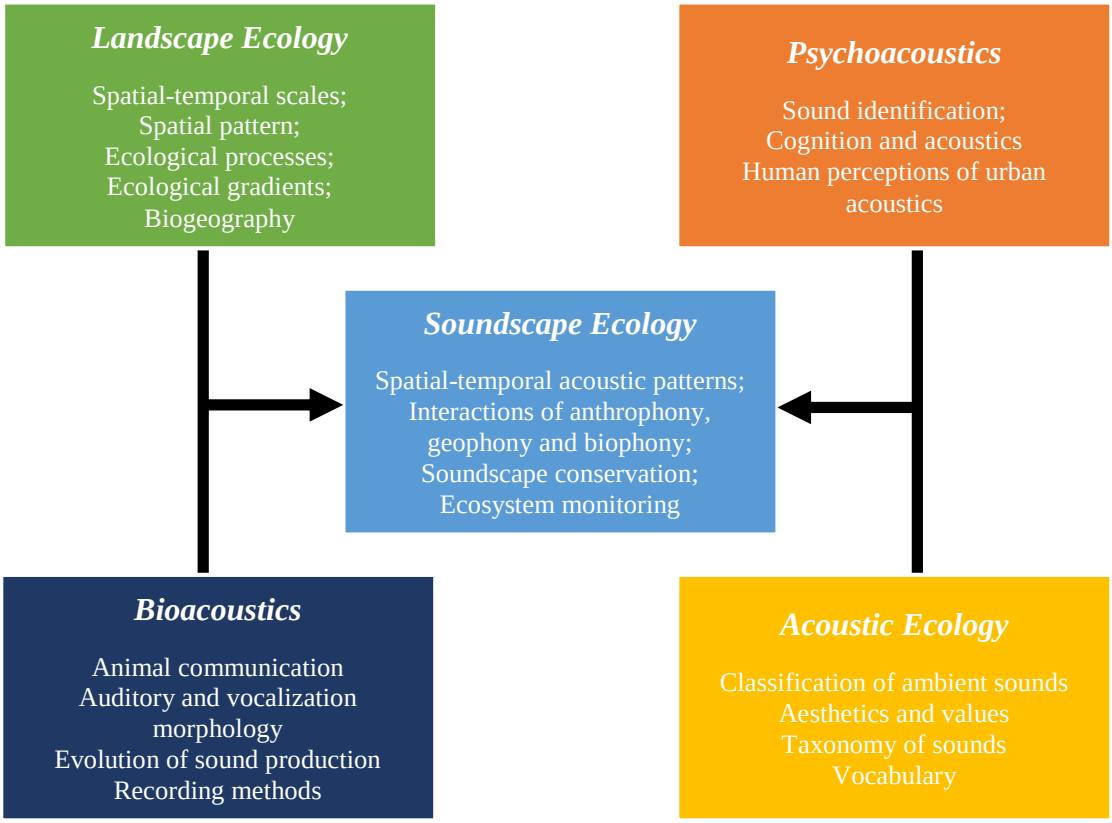

Figure 1- Disciplines and contributions to Soundscape Ecology [modified from Pijanoswky et al 2011].

As Farina mentioned "*soundscape is the result of sounds produced by abiotic or biotic agents and that are first perceived and successively interpreted by organisms: this means that a cognitive component must be added or at least considered in the soundscape process*." [Farina 2014]. He even displays a number of terms used as synonyms of soundscape, on which is understandable the relation between sound and the environment:

- The acoustic environment
- The sonic environment
- The sound environment
- The environment of sound
- The aural space
- The natural acoustic environmental sounds
- The ambient conditions
- Quiet areas (areas where environmental noise quality is good)
- City soundscape
- The total ambient acoustic environment

- The total soundscape
- The acoustic soundscape

Building up on this, soundscape ecology was the result of landscape ecologists who had the necessity to investigate the patterns and processes created by sounds at all levels of biological and ecological complexity [Farina 2014]. Therefore, to indicate the quality of a soundscape environment, the source of sounds being collected and identified were distinguished in geophony, biophony and anthrophony components [Farina 2014]:

- **Biophony** – all the sounds produced by non-human living organisms located over a specified time. For example, birds, frogs, insects, mammals, crustaceans, fishes, in different locations and time do not have the same behavior or reaction.
- **Geophony** – geophonies are all the sounds produced and with origin in geophysical environment, non-biological natural agents, which includes wind, sea, volcanoes, rain, thunderstorms. They are affected by the geomorphic, climatic and weather conditions of the region, acting as a background sound where others sounds can mix or mask.
- **Anthropophony** – represents all sounds that are caused by humans, and from human-made objects, such as cars, trains, airplanes, and industrial and domestic devices.

These sources of soundscapes are actually more "audible" for the common person, since they are sounds more easily perceived, and the listener ca not individualized them from the sonic environment. Thus, there is a relationship between the three sources in the soundscape:

- The geophonies are the sonic sources that influence directly, the biophonies, and secondarily, the anthrophonies, being this last the one that can have a stronger impact on biophonies. (Figure 2)

This interaction between them, allows the determination of peculiar patterns in the soundscape environment. For instance, the sound of a train depresses the sound of many living species in the area, or a strong windy day muffles the song of birds [Farina 2014].

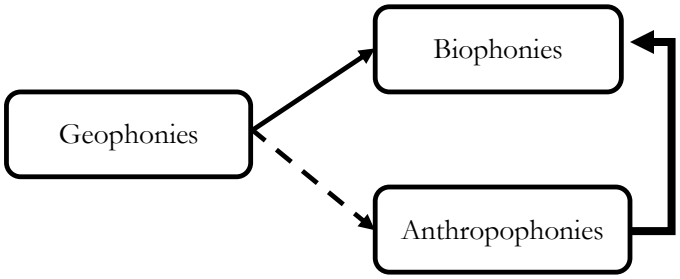

Figure 2- Soundscape Ecology sources [Farina 2014].

In order to understand the purpose of Soundscape Ecology and this system, some goals were pronounced:

- Achieve a more comprehensive state of the natural dynamics of ecosystems;
- Preservation of sounds as a natural and cultural resource;
- Analyze long-term sound dynamics, respecting alterations of climate and others caused by humans;
- Estimate the possibility of using acoustic diversity as a proxy for biodiversity. (Sueur et al, 2008).

2.1.3 – Acoustic Communication

On this sub-chapter, is going to be presented an approach of acoustic communication that was studied by Barry Truax, a member of the WSP, as mentioned before, and a previous student of Schafer's work. From Schafer words "*Touch is the most personal of the senses. Hearing is a way of touching at a distance*" and "*Man likes to make sounds to remind himself that he is not alone*" [Schafer 2008].

These quotations made by Truax colleague, have meaning in the way he bended over the study of soundscapes because he wanted to understand how sound affected people and their forms of communication. The public take sound for granted, as something that's intrinsic to their lives so how can they be aware of the relationship that's established between them and the surrounding environment? Not having this awareness in them, could mean that they are not listening sensitively to the acoustic environment, and therefore making no connections and memories from the soundscapes that play a pervasive role in their lives in those specific acoustic communities. Thus, according to Truax, Acoustic Communication *"is the most general way to describe all of the phenomena involving sound from a human perspective*" [Truax 2001]. From this approach he emphasizes the importance of the notion of context, because he noticed that despite the meaning that sound acquires from what produces it, the circumstances under which it is heard are crucial for the listener's acoustic perception.

To describe the soundscape's capacity to deliver information, Truax elaborated a relationship model (Figure 3) where he designate sound as a mediator between the listener and the environment [Wrightson 2000]. Through this system he tries to understand the connection and behavior of sound, the listener and the environment, because this is a system without isolated entities or connections, everything interacts with everything else. Therefore, this is a dynamic stream of communication because the listener also functions as a sound maker and sound is responsible for the established and developed connections between the listener and the environment.

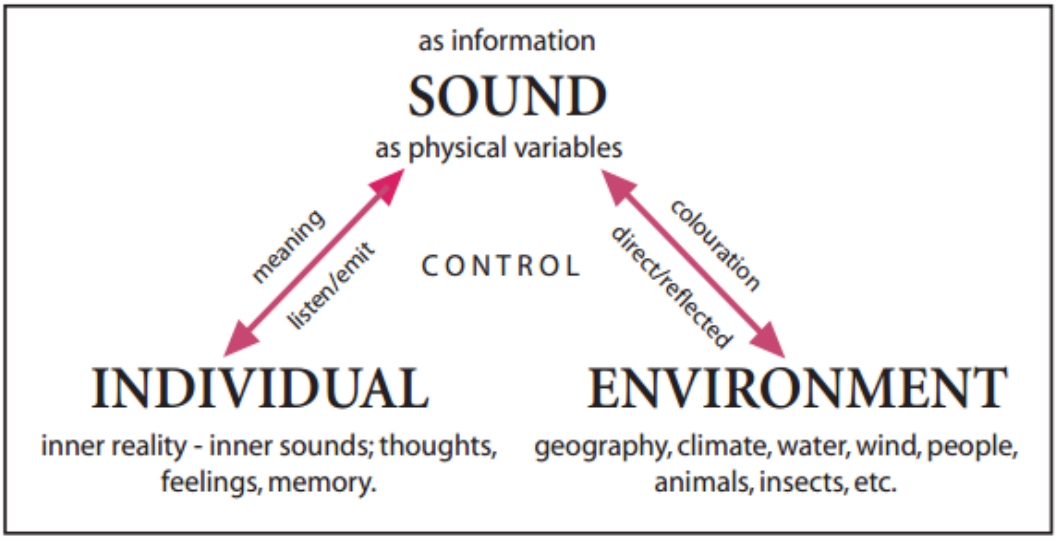

Figure 3- The mediating relationship of an individual to the environment through sound [modified from Truax 2001; Wrightson 2000]

In order to understand sound and its behavior, Truax studied the framework of the model that most disciplines dealing with sound rely on – the energy transfer model. The applied model, focus on the acoustics behavior that occurs during a series of energy transfers from the source to the receiver, which in this context is the obvious production of a certain sound [Truax 2001]. Regardless of the results this model could achieve, it only processes acoustic energy in the forms of sound waves and vibration (the notion of hearing), and for his communicational framework Truax was more focused on the information that is exchanged and communicated by a sound (the notion of listening). In his words, listening is "*the processing of sonic information that is usable and potentially meaningful to the brain*", and it plays as a key element of a communicational model because it is the main interface between the listener and the environment. [Truax 2001].

Since listening has a major role in acoustic communication, it can be self-developed by the listener and it is his primary source for the interpretation of acoustic information. However, different listeners in different situations, may not be able to perceive the information accordingly, so here are mentioned three types of listening that must apply to those scenarios: **Listening-in-search**, **Listening-in-readiness**, and **Background listening** [Truax 2001]. The first one involves a consciously listener searching the environment for clues; the second one refers to situations where our focus is in something else but the listener's attention is activated and he is ready to receive and evaluate the new information; and the last one reports situations where someone might ignore a sound but has notion and awareness that it occurred. Although these might be the most common listening types, every situation, in time and space, is object of different behaviors [Truax 2001].

As mentioned in the beginning of this sub-chapter, hearing allows man to "touch at distance", to receive acoustic information and decode it considering its context, its environment. That is a sign that like when smell is activated, the individual could have a journey to a memory from the past, experiencing it in the present. Sound has the same

power – "*sound seems romantic because it has the power both to evoke the past context and to idealize it*" [Truax 2001] – because along with its original context, sound is stored in memory as patterns, allowing our system to receive new sounds and compare them to other stored patterns.

Until the current moment, sound has been looked over as a concept, a definition, and an element that participates and has a relationship with daily life. Based on this premise, Truax acknowledged that sound became specialized in areas, so he presented three of those areas as systems of acoustic communication: Speech, Music and Soundscape (Figure 4).

Figure 4 - System of Acoustic Communication Continuum [Truax 2001].

In this continuum system, moving from left to right, on one hand there is an increase in the size of the acoustic repertoire, on the other hand, there is a decrease in the specificity of meaning from speech to music - because it depends more on the relationship between the elements and between them and the whole - and a decrease on the density of information.

2.1.4 – Acoustic Design

Acoustic Design is an interdiscipline that is guided from a model that has a criteria and that could be the reflection of a system on which the aesthetic quality of an acoustic environment may function successfully. To enable this process, it is necessary to conceive the acoustic environment as a massive musical composition, involving the existing soundscapes of all sources and manage them (both environment and listener aspects) in order for it to be improved. [Schafer 1994, Truax 2001]

For that purpose, three principles should be fulfilled:

- **Variety**: different types of sound with their variations present and clearly heard, properly "rich" in acoustic information.
- **Complexity**: it is present within the sounds and in the way the information is communicated. This leads to listeners who are able to decode and interpret small details in the soundscape, because of their knowledge of the environment.
- **Balance**: an acoustic environment is balanced when the variety and complexity of that system is in a functional equilibrium. If spatial, temporal, social and cultural constraints of the environment go unbalanced, the system might face obstacles to reorganize itself and to keep the organizational and structural level.

Binding this as a positive look of how a sonic environment could be improved, acoustic design is a perspective of soundscapes which depend on their physical properties as a basis for its natural ecological balance. By achieving those principles or, by Schafer, "*eliminating noise, introducing new sounds, preserve soundmarks, and the creative selection of sounds to create attractive and stimulating acoustic environments*", the concepts of acoustic design converge and it could be succeeded. [Schafer 1994]

2.1.5 – Soundscape composition

Through the years that Barry Truax and his partners worked and developed material at the Simon Fraser University, their concepts about soundscapes and acoustic design evolved, being at certain stage, confronted with the concept of electroacoustic music [Truax 2008]. A soundscape composition is also a form of electroacoustic music, since the soundscapes are recorded in a specific spatial and temporal environment context, without the interference of mixing and manipulating sound technics. This way, a soundscape composition is "*characterized by the presence of recognizable environmental sounds and contexts, with the purpose of invoking the listener's associations, memories and imagination related to the soundscape*" [Truax 2002].

With the introduction of electroacoustic sounds and the ability to develop a "soundscape composition" without going to the outer world, to a context, Truax knew that different kind of experiences where coming related to soundscapes. Therefore, he established differences between an electroacoustic composition and a soundscape composition. For him, electroacoustic composition that uses prerecorded environmental sound as source material, through all the manipulation that it suffers it ends up losing its original identity, the sound loses its environmental context and the listener could not recognize the source no more. On the other hand, in a soundscape composition is exactly the environmental context that is preserved, enhanced, and the listener's past experiences, associations, memories, is integrated in the compositional strategy by the composer because he also tries to enhance the listeners awareness of environmental sound. If a soundscape composition changes the listener awareness and attitude toward the soundscape, and his relationship with it, the soundscape composition is successful and has social, political and artistic value. [Truax 2001, Truax 2008, Truax 2012]

Although the imprecisions and dilemmas around the concept of soundscape composition, Barry Truax has compiled a list of four criteria points for a soundscape composition:

- The listener ability to recognize the source material and maintaining it, even if it goes through later transformation;
- The knowledge the listener has of the environmental and psychological context of the soundscape, is invoked and encouraged to achieve the meanings scattered through the music;
- The shape of the composition could be influenced, at any level, by the composer's knowledge of the environmental and psychological context of the soundscape, being the composition imbibed on some or all of those aspects of reality;

- "*The work enhances our understanding of the world, and its influence carries over into everyday perceptual habits*" [Truax 2000, Drever 2002].

Finally, and from Hildegard Westerkamp, another member of the WSP, along his studies and sonic recordings, analysis, he presented a concept for soundscape composition: "*in soundscape composition the artist seeks to discover sonic/musical essence contained within the recordings and thus within the place and time where it was recorded. The artist works with the understanding that aesthetic values will emerge from the recorded soundscape or from some of its elements*" [Westerkamp 2002].

2.2 – Pervasive Games

2.2.1 – Context and definition

Since the beginning of the 2000 millennium, the concept and design of games have been facing some changes and upgrades, emerging from technology improvements and from a wide range of genres, independently of their digital or non-digital nature. They are designed and used for: personal entertainment; to foment social interaction; creation of teaching-learning tools; and to function as an experimental platform of new technologies or even publicity purposes. [Sedano 2007]

In this new era of information and permanent communication, the technology advancement allowed the public to perform a variety of tasks through their mobile devices, already merging their real life with the virtual one. What if this crossover between real world and virtual environment surpasses the daily life and steps up to game design? That is how Pervasive Games are. By definition, a Pervasive Game is a game that do not rely on natural input (keyboard, mice, controllers), that is always present, available to the player, and according to Koivisto "*pervasive gaming often means that the games are location-based, they mix real-life events or objects with the gameplay or can be seamlessly played during the day amongst other activites*". [Koivisto 2007]

Pervasive games introduced a new game genre that is being explored in a way to create and provide new kinds of gaming experiences to the players. This games can use context information to improve and enhance the gameplay, and are capable of blending daily life and normal social situations of the players into the game. [Paavilainen 2009]

Although this exciting view of what pervasive games are, mixing real and virtual world is a complex situation, so it is expected that they push and blur some boundaries between game fiction and reality. This expansion of the boundaries of the game space creates an ambiguity between game world and non-game world that could alter the player's perception of place during or after the game. [Davies 2007]

From a user perspective, this games are typically played in city areas, using mobile phones, websites, GPS tracking, and they could use other media types such as posters, maps and notes.

When we play a game, we are confined by a specific set of rules, objectives and codes of conduct that differ from the ones we normally follow in our everyday lives. This way,

we enter into a different world, or technically, a Magic Circle [Montola 2005]. According to Zimmerman "*the Magic Circle presents games as closed systems: when players join a game they simultaneously enter a sort of contract with this game, agreeing to understand and accept the game world, its rules and its boundaries*" [Montola 2009]. When we expand our play area from a private location to a public area like cities, parks, "the" world, that is when a pervasive game challenge and pushes the Magic Circle. [Davies 2007]

Montola [2009] declared that "*a pervasive game is a game that has one or more salient features that expand the contractual magic circle of play spatially, temporally, or socially*". By breaking and challenging the traditional boundaries of a game, this genre of gaming is expanding in order to produce efficiently new kinds of game experience, providing to the players a greater immersive notion of enrolment in spatial, temporal and social dimensions. "*This design challenge within Pervasive Games represents a broader shift in interest from representing spatial reality in gaming, to being a part of shaping it*" [Davies 2007].

2.2.2 – Pervasive Games expansion areas

As mentioned above, pervasive games expand their spatial, temporal and social elements in order to support their ability to mix the real world with the virtual environment. That is what defines and provides the "playground" for these type of games.

2.2.2.1 – Spatial Expansion

The spatial expansion that is allowed in pervasive games, could largely transform its play areas into something that is not predictable for the player. A typical single-player mobile game is not spatially expanded in nature, it is isolated from their surroundings, and in a pervasive game the player's spatial context is affected, either being embraced by environments and contexts, or by physical places and others players.

The possibilities and chances that this spatial extensions deliver are huge and vast. It can be an opportunity for games being played socially in many and odd locations simultaneously, pushing the game to places where they aren't normally considerate and creating an idea that they could exist and be played everywhere.

If a game takes the user to unpredictable, uncertain and undedicated areas, it can inevitably lead to surprises because the play area is new and unknown. Taking into account that besides the physical architecture pervasive games can manage objects, vehicles and other assets of the physical world into the game, it is expected for the environment to change and that could also be dangerous. This way, some problems might happen such as instigating unwanted public disturbance, traffic hazardous situations, and expanding the game to places that might not be the most appropriated for playing like hospitals, airports, and army facilities.

Even though minor disorder could happen in pervasive games, their concepts and development is being widely studied, inclusively many of them are being experimented with augmented reality, providing an interface that could be a perfect way to add game content to the physical world. [Montola 2009; Montola 2005]

2.2.2.2 – Temporal Expansion

For a better understanding of temporal expansion in games, Holopainen and Björk considering game as a system, described the concepts of game instance, game session and play session as: "*a game instance defines the complete collection of all components, actions, and events that take place during the playing of single game. A game session is the whole activity of one player participating in such a game. A play session is the uninterrupted stretch of time when one player is actively playing a game*" [Holopainen, Björk 2005].

This concepts are all wrapped in the temporal component of a pervasive game. It expands explicitly in play sessions because if the duration of the game instance was part of one play session, it would have to include sleeping, working and talking with nonparticipants. That way, a game session is interlaced and mixed with everyday, ordinary life, being the exact times of play uncertain, ambiguous and hard to determine [Montola 2009]. The players give their consent to play in advance, so they are aware of some scenarios, such as:

- The game stays dormant for an undetermined period of time, but alerts the player for action at any time;
- The players are unaware if the game has finished;
- The players are not sure when and if the game started;
- Uncertainty about actions that might constitute a game action or not;

The main problems that could come from temporal expansion are similar to the above mentioned. Therefore, the game can require attention at not recommended times and, on the contraire, demand too much attention; if failing to attend the game when needed is too penalizing (even in costs) for the player, he might be turned off; and there are always the privacy elements that come from playing constantly. [Montola 2005]

Even though the above issues that come from temporal expansion, the opportunities it offers are undeniable. Its ability to mix and interlace games with everyday life is remarkable, delivering to the player the intriguing uncertainty of when his daily routine could turn into game, augmenting the effects of an enchanted reality.

Finally, any mobile game could be selected to surpass some boring moments of life (as it is seen everyday in different contexts), but temporal expansion in pervasive games provides the player with expectation of the next step, reaching, this way, the moments of not-playing. [Montola 2005]

2.2.2.3 – Social Expansion

Regarding the social expansion of pervasive games, it can contribute to a more exciting experience and at the same time, it can be controversial because of the elements around it. This social component stands by the participants and the nonparticipants in the game, and it gets tricky to define the player itself. Since the pervasive game is played in unexpected

places and moments, unexpected people (outsiders) tend to get involved and make a difference in the gameplay.

This way, the outsiders play a role in the game and their actions or participation could vary. Their participation can be in many shapes and sizes, from the outsider that is only a spectator with no intervention in the game, to the outsider that is used as a game element by the organizers. Along it as well, an outsider could just constitute and audience to the game but he may be seduced by the game and then influence and participate in it as well.

On the other side, there are risks of this social expansion that create some challenges for the players or to the game itself. It could happen that truly unwilling and out of the mindset persons join the game, causing some frictions with others in the game space or by sabotaging and compromising the game flow. The creation of new social relationships are not as easy and engaging as it seems, so as Montola said: "*problems similar to ones encountered in dating services might emerge*." [Montola 2005]

2.2.3 – Pervasive Games Genres

Pervasive Games can act as a subcategory of games and as an expansion of what games are. In this sub-chapter it is presented and identified the different genres that are considered to be types of pervasive games.

2.2.3.1 – Treasure Hunts

This genre is one of the oldest types of game there is, and one with the most well-established and well-known variants. It has traveled through time and in some way, was a start point for the development of many other kind of games.

Treasure hunts are a game genre that can be a competition between individuals or teams, or just missions where one person takes the challenge and tries to accomplish it. This challenges can be physical, mental or social, and the objectives of treasure hunts are the discovering and finding of certain objects or other particular tokens in a wide and no boundaries game-space. The targets of these treasure hunts can be the detection of a buried object, the finding of a particular location, a photography took by the player in order to catch some event or task, the discovery of a specific object… the variety of defined targets is big and that is one of the reasons it is one of the oldest genres of games. The prize or reward for accomplished missions is not particularly valuable, the discovery/accomplishment is the reward itself. [Montola 2009]

Nowadays, one of the most well-known type of treasure hunt is Geocaching.

2.2.3.2 – Assassination Games

The Assassination Games are, for itself, self-explanatory [Montola 2009]. The genre appeared in the 1960s decade in United States universities, where students started to play games inspired by the movie "La decima vitima" (1965) and followed the next set of rules of the hunt:

- Every player had to play as a hunter and as a victim;

- The hunter had all the information about the victim: name, address, habits;
- The victim does not know who is his hunter, so the victim should neutralize him;
- The winner will receive a prize and the recognition of his skills.

The set of rules might change on more contemporary times, but the basics are still the same and effective for the game. In the mobile context, BotFighters [BotFighters 2002] assassination game is one example of a pervasive game in the sphere of the new technologies.

2.2.3.3 – Pervasive Larps

According to Montola, "*pervasive larp is a style of pervasive gaming that utilizes live-action role-playing techniques*" [Montola 2009]. To accomplish and participate in a pervasive larp game, the player must be aware of the need of physical acting driven by character-based make-believe, in other words, the player needs to pretend and act as being someone else by role-playing in an environment that was prepared and propped to present a specific setting.

The history of larp is not clear, but is believed that it progressed from people initiative to put on a fantasy costume and head up to the forest and the streets, and start to role-play with each other. It is established how Vampire: the Masquerade [White wolf publishing 1991] influenced the pervasive larp community by taking their game to the streets.

Normally, pervasive larps utilize urban areas as a backdrop, and one of the most important factors that contributed in this expansion to public urban areas, was the propagation of mobile phones, allowing less costs and easy game mastering.

Pervasive larps are usually created by the community for the community, and although widespread, they do not get much recognition from the media. Being the fantasy genre dominant within more traditional live action role-playing games, pervasive larps are often inspired by crime, weirdness, cyberpunk, secret agent, or other current themes. Maybe the themes involved and the embarrassment that one could experience with all the acting and role-playing, are some factors that turn the pervasive larp genre avoided. [Montola 2009]

2.2.3.4 – Alternate Reality Games

Currently, Alternate Reality Games are one of the best known genres of pervasive games. They use the three expansions (spatial, temporal and social) to create an illusion to the player of games not being games, even if they assume that they really are games.

The International Game Developers Association describes this type of games as: "*Alternate Reality Games take the substance of everyday life and weave it into narratives that layer additional meaning, depth, and interaction upon the real world. The contents of these narratives constantly intersect with actuality, but play fast and loose with fact, sometimes departing entirely from the actual or grossly warping it – yet remain inescapably interwoven*" [Montola 2009].

Alternate Reality Games act as a subcategory of pervasive games because they feature collaboration instead of competition, Internet-based gameplay, large self-organized player

communities and secretive production styles. They feature evolved puzzle-based gameplay, giving the players hard tasks to complete, and after they recognize the puzzle/problem, the task is so hard that a single player cannot achieve it and in that way, a large number of players is brought via Internet to help solving the mystery.

2.3 – Augmented Reality Audio and Space

With the technological evolution performed in nowadays mobile devices, from smartphone to tablets, a new era of possibilities arises from this gadgets. The innumerous sensors now incorporated in the devices (cameras, accelerometers, gyroscopes, compasses, barometers, GPS, among others…) allow the most common user to perform or to be a target for the exploration of this features. Therefore, the concept and idea of augmented reality has become more vulgar and familiar in the past recent years. It is no longer strange or weird if we see someone facing his smartphone camera to a certain real place and insert or visualize a virtual object that was placed there. That said, it is important not to mistake Augmented Reality with Virtual Reality. Augmented Reality is a research area where a virtual world is overlayed on top of the real world [Rozier 2000] and the sensations provided by the real environment are not replaced but augmented with virtual objects [Albrecht 2011]. This system can have three characteristics: combination of real and virtual, interaction in real time, and registries in 3D. On other side there is the Virtual Reality which, according to Albrecht is "*where a completely virtual environment, e.g., visual or auditory, is created, replacing the real environment*" [Albrecht 2011]. The differences between these two concepts are evident, since the immersive environment of virtual reality contrasts with the augmented reality attempt to use the flexibility of the digital world in order to enhance the environment that surround us. As Rozier said "*users of an augmented reality system are able to maintain the context of their surrounding environment, while still obtaining the benefit of additional sensory input and information*" [Rozier 2000].

There are three mainly fields where augmented reality can take form: visual-based, audio and haptics [Churchill et al. 2013]. The most commonly explored form is the visual-based, but in this dissertation our focus is about the audio form in augmented reality. This form of augmented reality exploration could be tricky, but in a functional way, the natural soundscape environment is augmented with virtual sound sources, which means that if wanted, the virtual sounds can be practically indistinguishable from similar real-world sounds, blending perfectly with the natural sound environment. However, the virtual sounds can too stand out from the natural environment on purpose, facilitating the task of the listener to distinguish between virtual and real sounds. What also influences the perception of the audio in an augmented reality space, is the direction or location of the sound, or even the position and orientation of the user's head [Albrecht 2011]. If we cross this information with some acoustic ecology concepts, it is undeniable that for the perception of a healthy soundscape some variables have to be taken in consideration. What Albrecht also affirms is that for a mobile augmented reality audio application, not all the reproduction systems are valid, which means that loudspeakers and conventional headphones, aren't quite ideal for experiencing the natural soundscape. The first because it limits the area where the loudspeakers are located, since the goal is to have mobility; the

second one because the headphones occlude the ear canal opening, attenuating or blocking the sounds from the environment. However, being the listening of the natural soundscape essential to the experience, one solution for this issue is the use of microphones at each ear that captures the environment sounds and then mixes them with the audio of the virtual sounds, passing it to the ears through the headphones. [Albrecht 2011]

2.3.1 – Audio Augmented Reality Applications

Although the audio augmented reality is one of the less explored features in augmented reality, there are some cases of how it is applied effectively. One of the most common scenarios is its applicability to deliver museums audio-guides.

The following case, is a similar case which occurrence is in the city hall of Aachen in Germany. This city hall was a place where along the 16th century several activities took place such as coronation feasts to other types of festivities. However, gathered documentation allowed the application developers to know who attended that feast, the seating arrangement, the role of the guests along the ceremony, and subjects discussed at the time, such as the Black Death. From this information, the developers created a virtual audio scene with spots that according to the visitor's position and movement, could hear what was in the virtual audio space. In some place they could hear some conversations and as the distance increased they would hear less and less of what was in that audio space radius. It was what could be designed as "navigation-by-ear". The visitors aren't part of the conversations but instead, they turned to be observers of the "ceremony". [Heller 2009; Heller 2011].

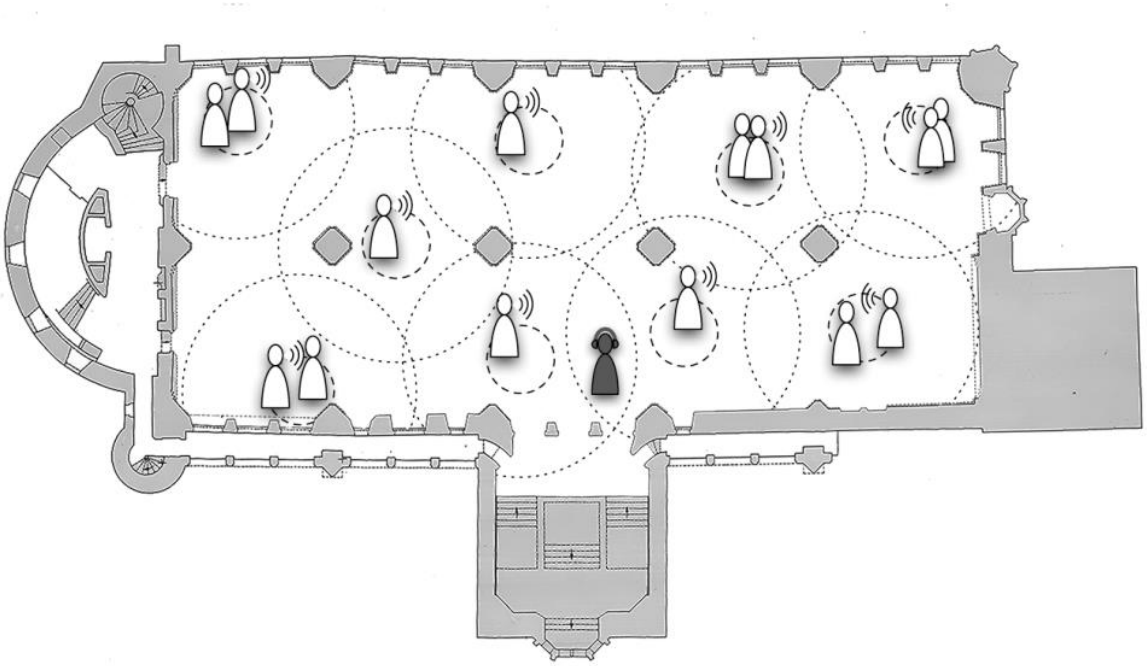

Figure 5 – Floor plan of the Coronation Hall with the audio space and its source areas [Heller 2009]

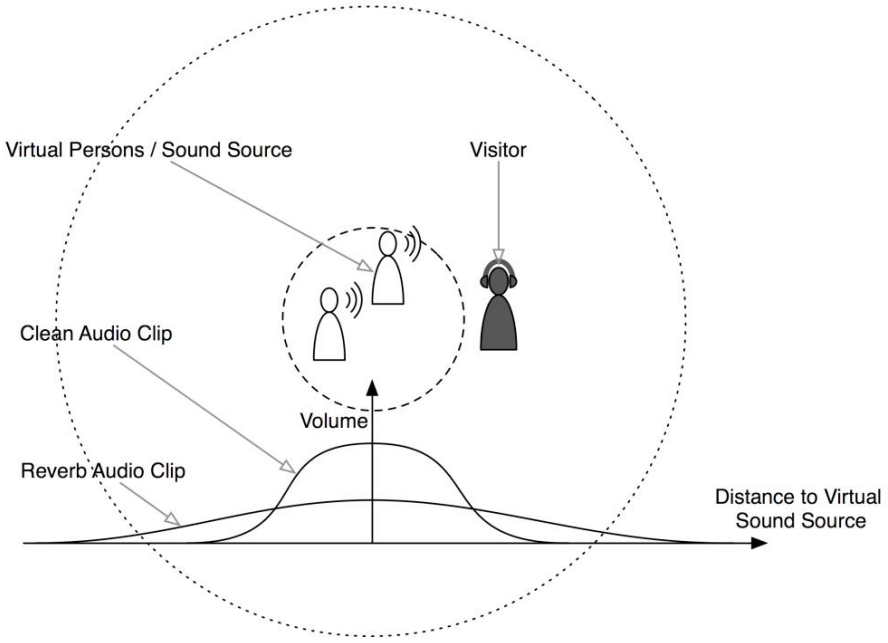

Figure 6 – The design of a source area. In the outer circle the voices of the two talking characters become clearer towards the center. [Heller 2009]

Another experiment was carried away by Jacoby et al 2013. They built an Android application for an audio-only augmented reality system for social interaction. Their interactive context was a silent rave party (indoor), where the application measured the related position of the device from freely moveable Bluetooth beacons. With this initiative, they tried to explore the potential of music consumption through mobile devices. What they wanted to achieve was that effect on social behavior and location-based services. For that purpose, they installed six Bluetooth beacons on physical objects (colored balloons), that could be freely moved by the participants and thereby changing the structure of the music in the virtual space. Each time a nearby beacon is identified by the application, it plays an audio loop that is played by the sound zone players. All the sound zones are modules that can be rhythmically and harmonically synchronized with each other in several combinations. Two groups of participants were assigned, one comprising the interactive blocks and the other the control blocks. What resulted from this experience was that the interactive components of the system promoted more participant movement in space, therefore, more social interaction. [Jacoby et al 2013]

Besides these examples of how audio augmented reality systems were conceived, there are other fields where this form of AR has been applied and expanded. These applications rely on a combination of location based features (GPS tracking) with the concept of audio tours or audio guides.

A field where these applications have being developed and that contribute to an improvement in the quality of life of a specific public, is the visually impaired community. For that purpose, and as an example, two studies, Cooperstock et al 2011 and Soukaras et al 2012, developed mobile applications to inform a visually impaired person about nearby

points of interest (POIs). At this moment, the focus was given to present the Cooperstock et al work. In order to present a solution that would improve and facilitate visually impaired people pedestrian navigation and environment awareness, Cooperstock developed a mobile application named "In Situ Audio Services" (IAS). This application did not have the purpose to assist the user navigation, but to allow him to explore and discover and urban area without having a predetermined destination in mind. At the same time, the user is presented with the awareness of preexisting POIs. [Cooperstock et al 2011]. For this accomplishment, the application provided two modes, a Walking mode and a Stop & Listen mode. The first one was designed to act as a "radar" mechanism, which means that while the user is walking through the streets he is not interacting with the device until, in a range of 150 meters, he crosses a POI and sound is triggered and the user is guided by the audio spatialization, with intensity from near to far. The other functionality, had the opposite intention of the Walking mode. In Stop & Listen mode, the user is not walking and is more focused to actively explore the surrounding area just by interacting with the screen device, thumbing up or down the screen in order to discover nearby or far locations. The existent audio representations of a location in the application, were categorized in three forms: Spatialized category name (a sound rendered by a text-to-speech (TTS) system for categories as "restaurant" or "shop"); Spatialized category audio icon (short sound representative of a location, such as a glass for a bar or a drum beat for entertainment); and Non-spatialized details (spoken audio with information about the location, as its full name and distance). [Cooperstock et al 2011]

Other audio augmented reality navigation tool of interest, was the application produced by Schweickhardt. He developed a mobile application towards a need he considered important for a tourist when it is his wish to discover a city through a bike ride. This way, the tourist has to find an available bike, unlock it and select a destination. Then, to calculate and inform the user of the navigation path, the mobile application, based on GPS localization, provides the user with landmarks (such as traffic-lights, buildings, bridges) based on audio announcements. Since one of his goals was to provide more security during a ride by bike, there was no tactile interaction with the smartphone, and the navigation path was exclusively announced by audio landmarks. Throughout his development and testing, Schweickhardt received a positive feedback by its users and concluded that landmarks on audio form, in comparison to direction guiding by meters or cardinal direction, facilitate, are easier to understand and deliver a more satisfactory tourist ride. [Schweickhardt 2015]

In the context of this dissertation, there is a developed platform that explores augmented reality through sound. SonicMaps is a mobile application based in sound geolocation and provides to the user GPS audio tours, and is available in two solutions: SonicMaps Editor and SonicMaps Player. This platform allows the user to create his own audio guides, playlists, games, by uploading audio files to a hosting service as, for example, Dropbox or Skydrive, and through the Editor application, he can place sounds in the desired real world locations. Finished this process, the user can publish and share his project online and the other users can access to it and experience the audio composition when they walk in those locations. It also has an option to use a 3D audio engine, which improves the audio perception according to its position and distance, and also introduces a Dynamic Content Server that uses server-side scripts to manage the project's components according to dynamic environment variables, like time, date and atmospheric conditions. [SonicMaps]

2.3.2 – Augmented Reality development kits/tools

Currently, in a developer perspective, the tools to start and achieve an AR product/application, are measureless because the market has many different options to offer. As stated before, the main target of AR products is the visual, graphical perspective, so features such as 2-D image/3-D object matching and tracking, face detection, SLAM, and location tracking, as well as 3-D model rendering, animations and gestures detection, are the most common manner of applying AR [Roukounaki 2015]. In order to start a project, a development SDK/tool needs to be picked according to their advantages and disadvantages, and considering which would be the most adequate for the project in discussion. Therefore, a description of some of the more popular AR development kits is presented.

- **Wikitude**

Wikitude is a free and commercial AR SDK cross-platform tool that supports and provide a wide range of features for AR development. It includes image recognition and tracking, 3-D model rendering and animations, location-based services, video overlays, offline and cloud services, augmentation and visualization of text, images, videos, HTML, sound; display screen and camera functionalities, and is available for Android, iOS devices, Smart Glasses and has plugins for mobile development tools such as Unity, Cordova, Titanium and Xamarin. It is, by every means, a great and powerful tool to develop AR applications. [Wikitude].

- **Qualcomm Vuforia**

The Vuforia SDK is a software platform that focuses its tracking methods in images and patterns. This means that Vuforia presents features as multi-target detection, target tracking, virtual buttons, smart terrain, and extended tracking. The SDK has a variety of target types, so it emulates 3-D tracking methods by detecting targets such as images, objects (cubes, cylinders) and text, and it also offers a cloud service (Cloud Recognition Service) when the application requires the recognition of a large amount of images or when the update process of the database is very frequent. The platform is available for Android, iOS, and Unity3D. [Qualcomm Vuforia]

- **Total Immersion AR Engine**

This augmented reality technology is a commercial tool with a wide variety and amount of users worldwide. It is a cross-platform and is available for web, Windows, Android and iOS. The features presented by this AR tool are local image recognition, video streaming of images and 3D objects recognition, 1D and 2D barcode recognition module, 2D visuals and 3D textured objects tracking, face tracking focused on eyes and mouth detection, and location based services. Also, sponsored by their 3D and Physic engines, it renders 3D objects, visuals and animations, and pre-recorded videos. [Total Immersion]

- **ARToolKit**

The ARToolKit was one of the first kits that emerged in the market for AR products development. It is a multi-platform tool and supports square markers, 2-D barcode, multimarkers and natural feature tracking. As an extension to the marker feature, it has a corner detection approach for marker tracking. For last, the ARToolKit provides video and optical see-through augmented reality, being the first where virtual images are overlaid on live video from real world, and the second one, when generated computer graphics are overlaid on a view of the real world. Despite its apparent lack of features and poor documentation, it is still one of the most used SDK's and it is available for Windows, Mac OS X, Linux, Android and iOS. [ARToolKit]

- **Metaio**

The Metaio SDK is now known as Apple inc, and is available in a free and commercial option for the user. The SDK supports 2-D image, 3-D object, face and gesture recognition, SLAM and location tracking, barcode and QR code scanning and also offline and online service. The developers of Metaio SDK also created their own scripting language for AR purposes, the AREL (Augmented Reality Experience Language), which allows the using of HTML5, XML, Javascript and other web technologies to develop AR apps. This solution is available for Android, iOS, Windows PC, Google Glass, and Unity3D. [Metaio]

2.3.3 – Overview of the Augmented Reality Evolution and Market

As previously mentioned in the beginning of this chapter about Augmented Reality, the technological evolution of mobile phones introduced a new playground for the exploration and expansion of AR products and services. The constant launching of smartphones and tablets with better and improved components, higher processing capabilities and sensors, provided the opportunity for people to experience and create AR products [Tractica 2015]. Although the awareness of this fast and vertiginous growth of AR technology by the mainstream audience is recent, applications of AR are not new, its background is related with vastly years of computer science development, and even prior to that as the following timeline graph presents (Figure 7):

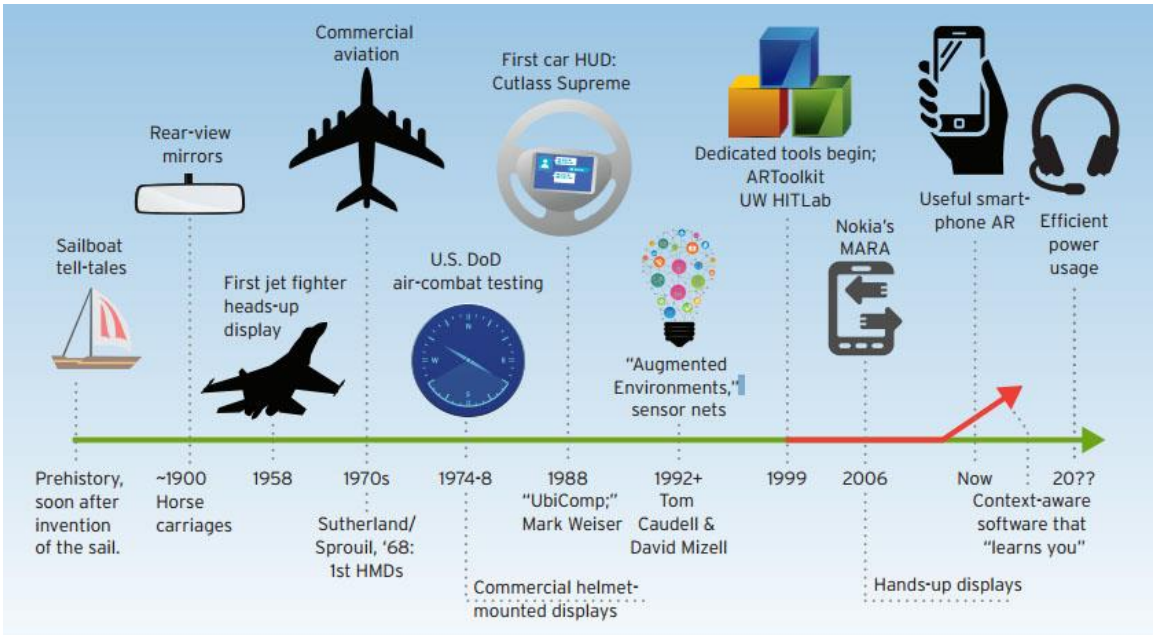

Figure 7 – Augmented Reality Timeline. [Venkatasubramanian 2015]

Along with the proliferation of smartphones and tablets, the mobile augmented reality market has grown because of several factors: the negative reputation of its products being gimmicky has been fading out; the users enjoy the fact that adding simple graphics such as text or shapes to reality, still allows them to believe in, and experience reality; and the point that with the wide range of AR development tools and kits available, it became easier, less expensive, and intuitive to any type of user create his own applications [RivelloMultimediaConsulting].

With the growth of the AR market, and the way augmented reality and virtual reality are related with each other for their similarities and differences, these two technologies are put together in the same technical field. In reference to the analysis of this market, a statistical exercise by Digi-Capital predict that in 2020 the revenue of AR/VR could achieve the global of 150 billion dollars (Figure 8), which is representative of the importance this market is collecting in the technology field and in the consumers/users attention.

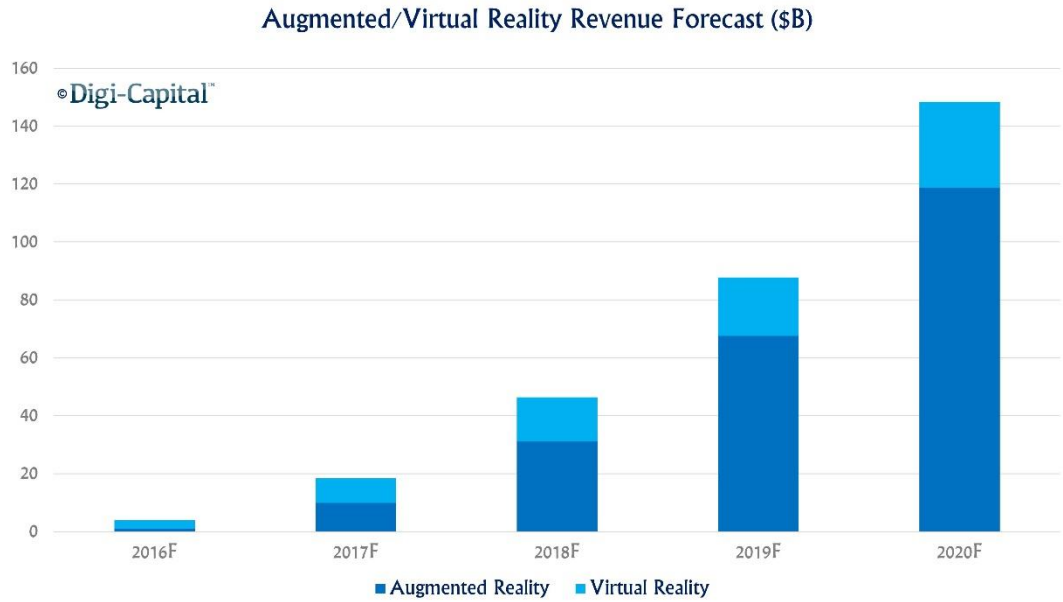

Figure 8 – Augmented/Virtual Reality Revenue Forecast. [Digi-Capital 2015]

The rise of the mobile AR market, both in number of people that use augmented reality apps, or by the financial and economic impact that is being revealed, are changing its own market and the categories that AR products embrace will not be restrained to navigation and gaming applications [Koetsier 2013]. According to Juniper Research, by the year 2018 there should be around 200 million people that uses mobile AR applications, dispersed in several categories (Figure 9) [JuniperResearch 2013].

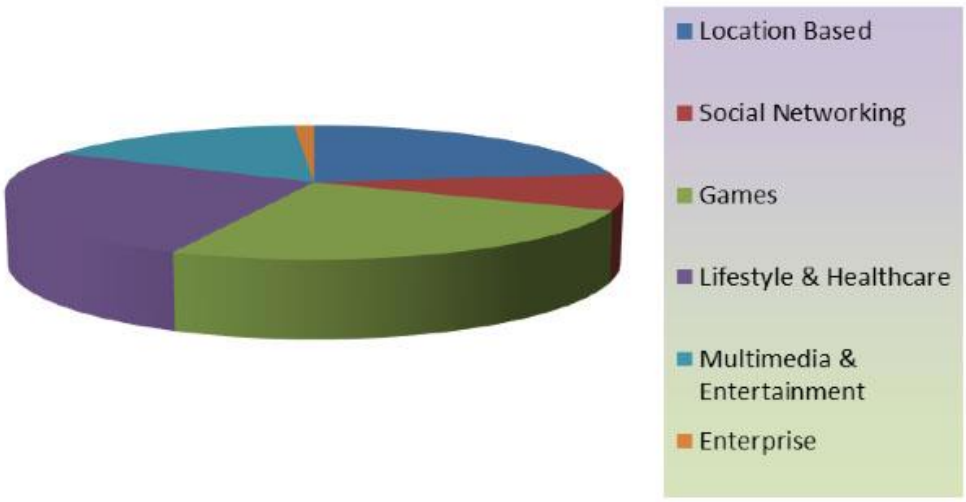

Figure 9 – Mobile AR App users split by app category in 2018. [Koetsier 2013]

This statistics shows that even in the following years, mobile AR location based applications and games still cover almost half of the categories of mobile AR products. Additionally, other categories emerge and reclaim their share in the mobile AR market, mostly lifestyle and healthcare, multimedia and entertainment AR apps.

This insight of the mobile AR market, showed that the industry is consolidated and aware of its importance, potential, and infinite possibilities for future applications and growth.

2.4 – Overview of the Mobile Operating System Market

Currently, the market of existing and available hardware platforms for users' interaction is, without a doubt, dominated by the mobile devices. This growth is real, not only because of the possibilities the mobile platforms technology provide to the users and how it changed our daily lives, in a ubiquitous perspective, but also because the lifespan of the personal computers is longer and the constant improvements in the smartphones hardware allowed this twist in terms of what platforms we choose to use [Piejko 2015]. The following graph gives an illustrative representation:

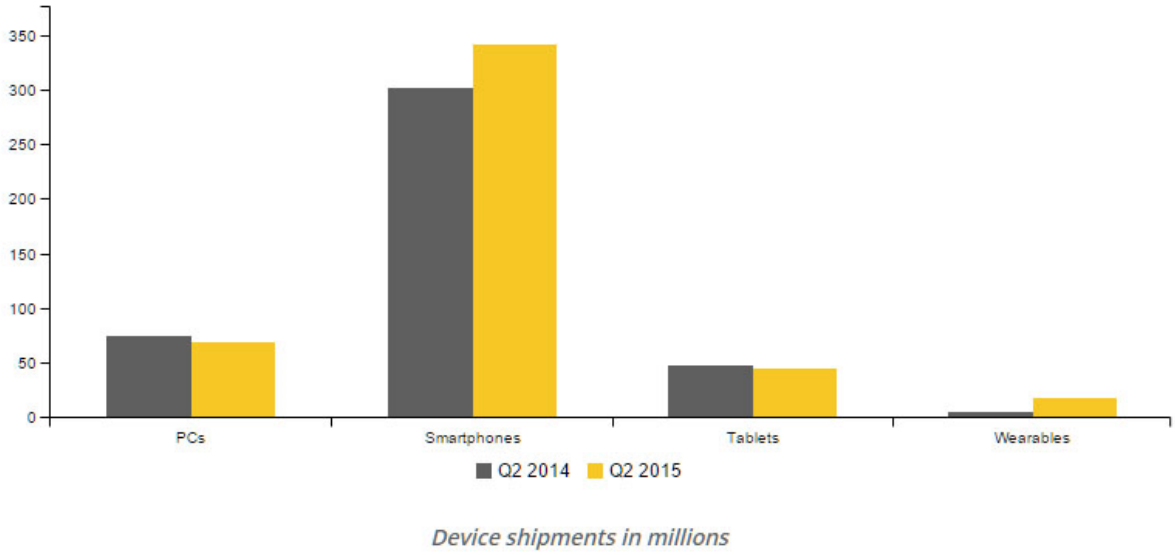

Figure 10 – Devices shipments in millions [Piejko 2015]

This thesis had the purpose to develop a software product with the mobile devices as a target. Therefore, a study of the mobile market provided the data about the trend that is currently observed in the mobile operating systems market share [IDC]:

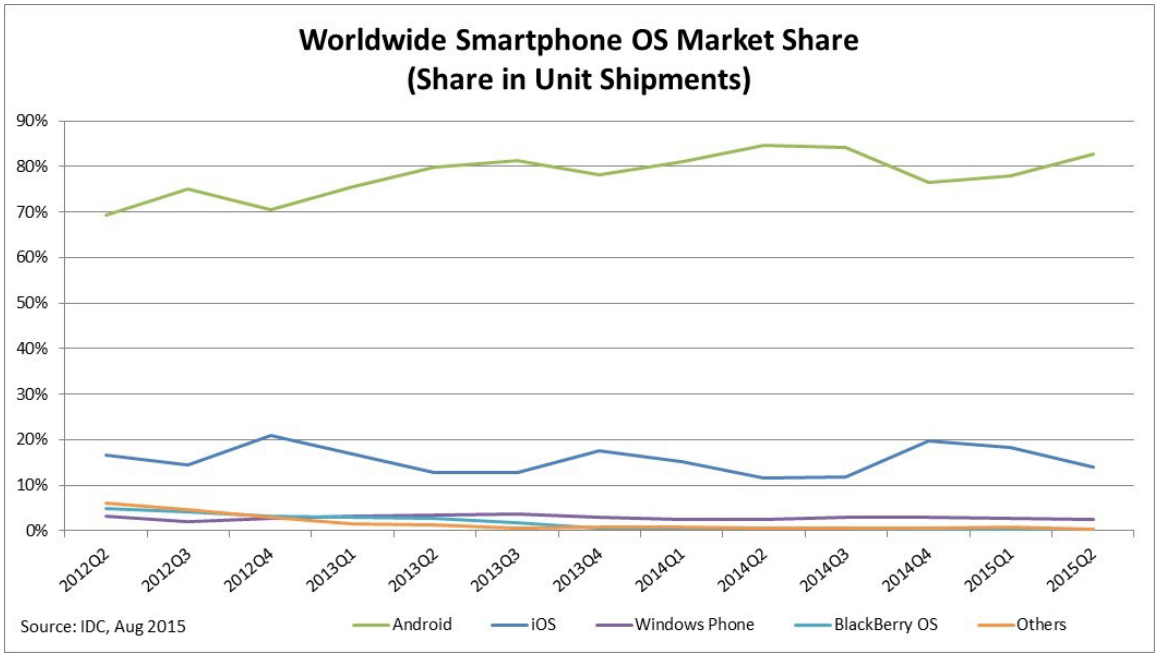

Figure 11 – Worldwide Smartphone OS Market Share [IDC]

Period	Android	iOS	Windows Phone	BlackBerry OS	Others
2015Q2	82.8%	13.9%	2.6%	0.3%	0.4%
2014Q2	84.8%	11.6%	2.5%	0.5%	0.7%
2013Q2	79.8%	12.9%	3.4%	2.8%	1.2%
2012Q2	69.3%	16.6%	3.1%	4.9%	6.1%

Source: IDC, Aug 2015

Table 1 – Worldwide Smartphone OS Market Share [IDC]

Although there are several operating systems available in the market, the predominance and prevalence goes to the Android and iOS devices, with the lead being taken by the Android platforms, which, as illustrated in the above statistics, became a trend for its continuous market share increment over the years. Android devices dominate the mobile market and it was an important decisive factor for the development of this project.

2.5 – Previous Experiences

In this section, several previous works performed by other colleagues will be presented in order to provide the viewer with a more insight vision and overview of what is the concept and context that is behind the elaboration of this dissertation. Firstly, an overview of Tiago Agostinho Adventure Platform will be given, followed by the research and work developed by Valter Alves in Sound Design in Games, and finally the presentation of the Dynamic Soundscape Composition model developed by Durval Pires.

2.5.1 – The Adventure Platform

Adventure is a project designed as a platform for a quick design, creation and management of multiplayer Augmented Reality Games, being these games able to explore visual and aural AR techniques, as well as GPS and QR interface mechanics [Roque 2012]. Augmented Reality, Pervasive Gaming and Gamification, are recent concepts and this platform is a step up in the way those concepts merge and can be applied to the creation of games for mobile devices.

These platform has, per basis, a web component, and since these games are intended to be played in the open world, the smartphone's technology come into scene, through Adventure's client application [Agostinho 2013]. Smartphones are nowadays powerful tools that allow the users to perform a wide range of operations and interactions within it and with the outer world. This way, as mentioned above, techniques as Augmented Reality, location and direction tracking (GPS and compass) and QR tags, are used in Adventure and it provides the platform with resources for the creation of Pervasive Games.

The structuring of the games in the Adventure platform is based on a modified Petri Net model [Araújo 2009, Scholarpedia 2008]. So, having that as base, transitions are actions, places are dubbed as resources, and their linkage is named by bridges or connections. Every player has his Petri Net state and the resources or interactions are shared through the game to their players or team members. This way, the player actions allow the execution of several events [Agostinho 2013]:

- **Point & Click**: when a player is near a georeferenced point, he will see an AR overlay when pointing the device at the visual target and then finishes the action by touching the screen;
- **Listen & Click**: the player by hearing a sound, and using his hearing sense, points the device in the direction of the sound source and touches the screen;
- **QRCollect**: the player can collect game tokens from the environment or other players by printed or on-screen QR codes;
- **Dialog Message**: a message is displayed to the player composed by an image and a textual component;
- **Dialog Answer**: a message is given to a player and he has to answer a question for narrative purposes and user interaction;
- **Timed Event**: when a time condition is met, an action is triggered, enabling other dependent actions;
- **Periodic Action**: when a time lapse is passed, an automatic action is triggered starting chains of repetitive actions or verifications;

- **Enter Proximity**: if a player enters, or exists, the radius of a location, this action is triggered.

Besides this actions, in order to enhance more the platform itself, its augmented reality purpose and to increase social interaction and gamification (pervasive games basics), some other features are presented:

- Geomessages: the player can place in a certain location a small text note (like a checkpoint or a trivia quiz);
- Token transfer: the player can give his own tokens to other players by QR code, enabling the need for the players to physically encounter themselves to trigger some actions;
- In order to seek motivation in achievements, goals inventory and rankings are displayed even to increase sociability;
- Chat System: this feature increases gamification, by being public and shared between all the players in the game.

One feature that had some emphasis was the Editor one. It was needed to increase the "playfulness" of the game, allowing the users to create and edit their own games especially with the mobile devices ability to perform those actions in a more *in loco* and experiencing way. [Agostinho 2013]

As for the architecture of the Adventure's platform, the following diagram represents a simplified version of it.

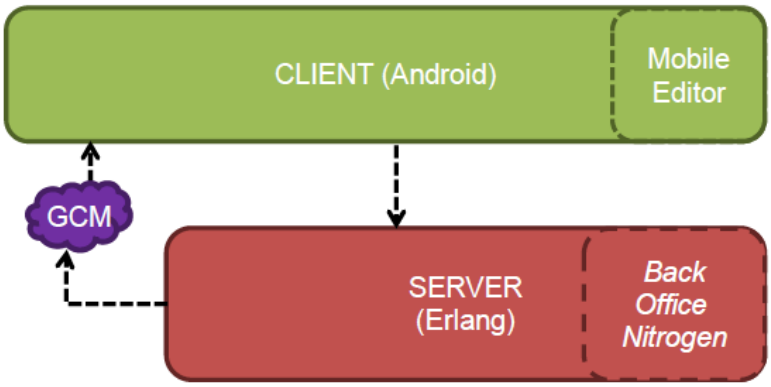

Figure 12 – Simple Diagram of the Architecture. RED – Server; GREEN – Client; PURPLE – GCM Cloud; ARROWS – HTTP communication [Agostinho 2013]

On a light approach to the diagram, the client has the Mobile Editor classes, the server contains the Back-Office implementation in Earlang (via Nitrogen) and the Google Cloud Messaging system is also used to push messages from server to clients.

To evaluate this platform in a pervasive context, through the use of a smartphone, three concepts were defined:

- Coimbra by Night is a multiplayer, augmented reality game, with competition, where people complete challenges and launch them to others, all throughout the nocturnal establishments of Coimbra;

- PIDE vs Revolucionários is a multiplayer, augmented reality game, team-based, where people take on a role (either the regime police or the insurrectionist) and their goal is to search the city for clues that might give them the identity of who they have to find;
- Mystery of Alta is a singleplayer augmented reality game, with narrative, where the player has to communicate with game characters through the University of Coimbra in order to know about its history and traditions.

Finally, for a better insight on the Adventure's platform, some screenshots are displayed of a creation of a Point and Click action:

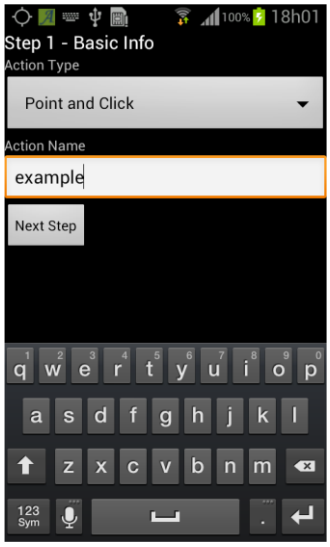

Figure 13 – Point and Click – Step 1

Figure 14 – Point and Click – Step 2

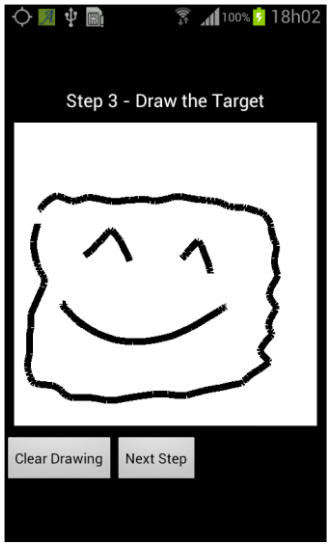

Figure 15 – Point and Click – Step 3

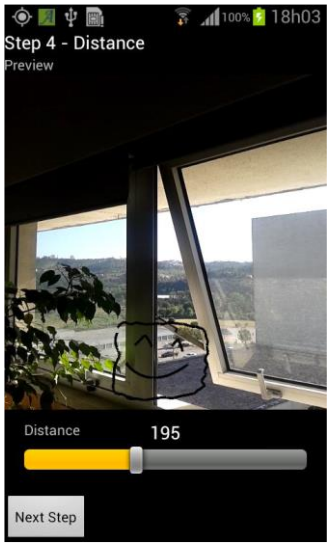

Figure 16 – Point and Click – Final Step

2.5.2 – Sound Design in Games

When enrolled on the development of a game, several aspects and components of that development labor are considered when it comes to the game design. What currently happens, is that the field of sound design is not developed or given attention in a proper way [Alves et al 2010]. This aspect is, on one hand, diffused by the way game developers face the exploration of sound in their projects. If the reference is of a major game development company, despite nowadays their attention to sound design being greater, almost being at the level of sound design in cinema, when it comes to small independent game projects, the sound design area is aimed for a low exploration of the same.

This happens because being an independent game company, the resources, including number of co-workers, budgets, are low, and they do not have the time, the budget or the expertise to dedicate themselves to the sound design. That is a major difference between a major mainstream company that delivers high quality products (games), in which there is a good amount of professionals dedicated to the development of the game, including the sound design field, in comparison to a small and independent group of developers who do not have the resources to act as a big company. Although it is still a not widely known field, the expertise in sound design in games is mostly owned by senior professionals – the sound designers. In a major game development company, these sound designers play an important role since they have the time and direction to focus on the sound design of the game. Even if sometimes the sound design is left as one of the ultimate tasks to be completed, being the game in final stages of development, the sound designers most of the times have to design the sound to fit into the project, when the sound design should already be included from the beginning in the specific game design. That is an issue because games are so focused on presenting fabulous visuals and looks, that sound design stays behind and not having the recognition it should – and this is a reference to major companies which have access to plenty of resources in order to do it in a right way. In an independent game, sound design is almost left behind, because of the lack of know-how or restrictive budgets when trying to use or incorporate sound design tools in their projects.

Having this scenario in mind, and influenced by the restraints in exploring sound in independent games and by the less importance given to sound design exploration in games, some approaches came into field in order to try to help the sound design issues in small and independent game developers. There is where Alves' work became influential.

Inspired by the issues that were mentioned above regarding sound design, and influenced by the subject of Acoustic Ecology, he delivered a holistic approach for sound design in games even in the context of several aspect of the game design, such as the narrative, characters, inventory, game mechanics, etc. Perceiving the game as a whole, the approach to sound and his influence in the game experience should be taken from the beginning, being an integrated part of a game design, it should be perceived as a way to empower the experience, and not for the audio tracks to be "just" there. [Alves et al 2010]

Focused in this goal of contribution to a "healthy" sound design in games, Alves developed a pattern language as "*a form of presentation of proven solutions to recurrent problems in a specific context, accompanied by references and assistance on the forces and/or consequences involved in their application. Each pattern is referenced by a common name or expression that usually becomes synonym with the concept or solution and, as such, enters everyday domain language among practitioners*" [Alves et al 2010, Alves et al 2013]. Therefore, and as representation of a pattern language for sound design, Alves created a deck of physical cards that through handling and manipulation, had the

advantage of immediate social interaction and an output of rich data related to sound design. Currently this deck of cards is in its version 2.0, consisting of 77 cards, each one representing a design pattern from the collection [SoundInGames].

Developing this tool would benefit and increase the potential on how indie developers approach the sound design for their games, having a resource that is much more applicable to them that all the software or middleware tools that are available in the market to work with sound design.

Figure 17 – Example of dialogue's card front face and back face [SoundInGames]

Having as example the card presented above, the other 76 of the deck consist in the same kind of presentation. To work with all the deck while designing sound for a game, the technic used is displayed in the following scheme:

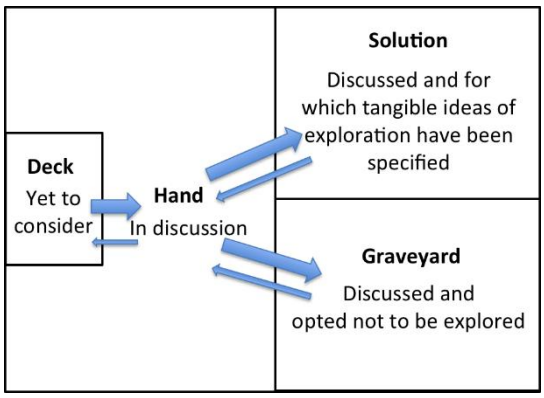

Figure 18 – Workflow of the deck of cards and its appliance to find the desired patterns for the game [SoundInGames]

With this workflow and approach, sound design should be in fact an integral part of game design, leading to some possibilities such as the sound becoming fitted to the game and not superimposed, providing a richer game experience [Alves et al 2011].

2.5.3 – Dynamic Soundscape Composition

As previously mentioned, the sound design in games is an area with some issues, and as presented by the concepts of Acoustic Ecology and the work of Alves', some improvements should be foreseen. The own characteristics of a game, their unpredictability in the game flow allied to the interactivity of the player actions and decisions, may cause situations where the context of the game and the soundscape that is heard, do not fit together. This is one of the problems encountered on sound design in videogames – particularly if the mechanic involved is of the kind "Event A triggers Sound A/Action B triggers Sound B" – this is the most common mechanic to found in games, even if today the complexity of games suggests that a lot of audio tracks is performing accordingly to what the player sees, hears and think. [Pires 2013, Carregã et al 2013]

This was the challenge encountered, how to apply a module that could deal with the dynamic nature of sound design. The players are part of this system because their actions over different entities along the game, produce acoustic expressions that might not sound right and not according to the designer's intention. To battle against this oddities, the game designers, or should be sound designers, have at their disposal tools of Audio Middleware, that try to manage this issues positively, but besides some drawbacks (costs, lack of know-how) these tools are not the solution for sound designers so that they can be able to predict and prepare all the possible game scenarios sound application. [Pires 2013]

Influenced by the theory of Acoustic Ecology, a soundscape composition promotes a natural balance between the soundscapes and the environment, where every sound can transmit the semantic associated to it. This said, the context on which a sound is heard is part of its perception, so the same sound can assume different meanings in different contexts, and that is what happens too in sound design for games. Having this in mind and inspired by the concepts of Acoustic Ecology, and by a holistic approach, a dynamic soundscape composition was elaborated consisting in a system that moderates the soundscapes accordingly to the events received from the game, being posteriorly applied heuristics that follow the characteristics of the soundscapes. Besides this dynamic module, an API was built to analyze the sound elements and to provide an easier task for the sound design. In order to understand some principles used in the API, a description is made:

- **Source** – represents the sound source, being the key concept behind the API. Each sound of the soundscape should have a source because it has properties and information that influences how the composition of the game soundscapes is made;
- **Layer** – categorization of sounds according to their semantics [Peck 2001]. There are five different layers: Ambiance, Dialogue, Music, Foley and Sound Effects (see Table 1).
- **Agent** – this concept is the association of a source to any type of game element (a character, for example);
- **Pattern** – although the concept of pattern was mentioned before in Alves' work, in this case patterns should be understood as sound behaviors that will be taken into account by the DSC module while maintaining the soundscape healthy.

- **Listener** – a listener refers to the "microphone" inside the game world, it represents what is heard by the player and is influenced by the listener's position and direction in order for the sound engine expose the 3D sound behaviors.
- **Context** – along with the "source", context is the next most important concept of the API. If in the game exists a large number of sound producing actions, this notion of context tell us which are the ones relevant to the player and the ones that are not.
- **Exclusivity** – exclusivity is attached to context. This is, if a context is exclusive, sounds out of the context are not heard at all, if the context is not exclusive, the sounds are attenuated and not totally muted.

As a brief wrap up, the API functionalities include:

- Creation, deletion and management of sound sources;
- Creation, deletion and management of contexts;
- Control over the position and direction of the listener;
- Creation and management of stand-alone patterns.

Layer	Ambiance	Dialogue	Music	Foley	SFX
Intention	Gives notion of place. Sounds of the environment where the player is.	Any kind of speech existent in the game. Offers several types of information.	Any kind of musical composition in the game. Helps to define the tone of each moment.	Real sounds that characterize an entity or event	Fictitious or imaginary sounds that are applied in a scene in order to emphasize the sound expression of an entity or event.

Table 2 – Sound Layers according do Nick Peck [Peck 2001]

After the exploration of the concepts included on the API, the system's main architecture is presented in Figure 12.

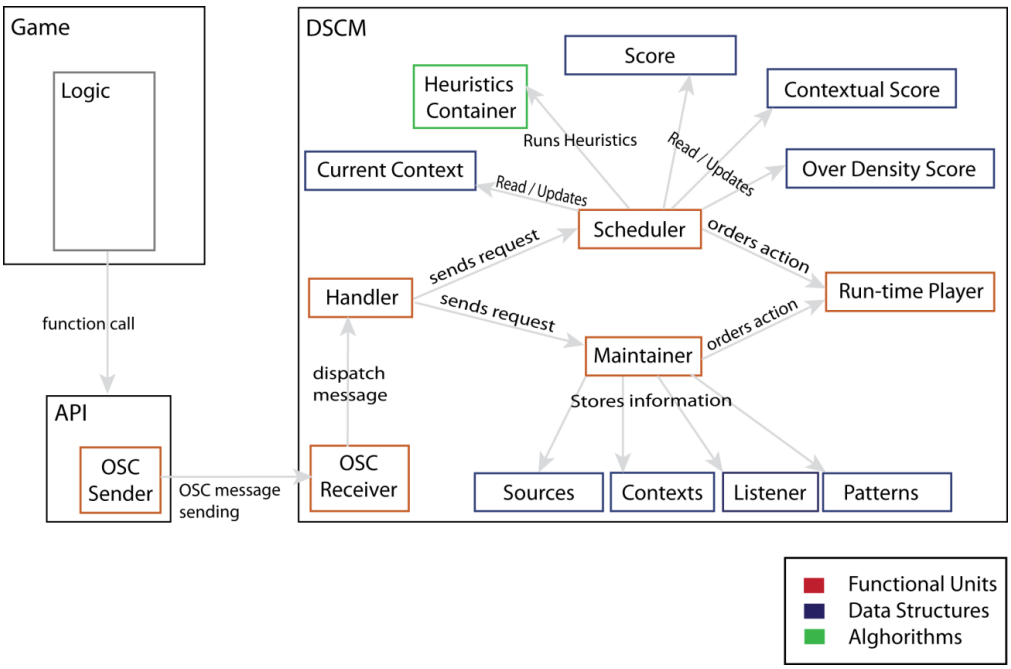

Figure 19 – Main architecture of the system's composition [Pires et al 2013]

To start explaining the system's architecture presented above, firstly we'll describe the three main boxes that compose the system. The box in the top-left corner represents all the code that is specific of a particular game project, including the game logic. The box located on the bottom-left corner symbolizes the developed API, with all the classes and methods that, for instance, creates a sound source or context, and is expected that developers call that code from the game logic. The big box on the right, represents the sound engine (DSCM). Now comes the interaction model inside this system. The communication between the API code and the sound engine is made by OSC (Open Sound Control) messages, which is a standard protocol for communication by messages with an arrangement similar to a URL.

When the game is in execution, the OSC receiver forwards the incoming messages from the OSC Sender to the Handler, and here the received messages are analyzed and according to their purpose, they are forwarded to the Scheduler or to the Maintainer. The Maintainer's function is to perform all the background work, which means, arrange the necessary resources to the process of composition, such as the creation, deletion and edition of elements (sources, contexts, patterns, listener, etc). To achieve these tasks, the Maintainer has to cooperate with the Run-Time Player because the data that the RTP needs to initialize is also stored in the Maintainer structures: Sources (soundscape source), Contexts, Listener (structure that maintains information about the listener position in the game world) and Patterns (types of sound that can be associated to each Source, which the DSCM has into account in the moment to decide how to act on the soundscape).

The Scheduler coordinates all the composition process by dealing with the start/stop requests related to sources and patterns, and even with changes in the active context. Every time a source is requested to be played, the Scheduler acts according to a set of heuristics, that take in consideration the Current Context and the active sources in the Contextual Score (structure that categorizes the actives sources according to their semantics). Note to the fact that along the composition process, the Scheduler can forward orders to the RTP, in order for this to render the sound accordingly to the heuristics. For this project, the RTP adopted was the FMOD API sound library. Therefore, the Scheduler makes use of three different Scores along the composition process: Score, Contextual Score and Over Density Score. The Score structure, stores all the sources triggered and that didn't stop or were requested to stop, even if the Scheduler had no influence on that. The Contextual Score stores only the sources that are active and that are part of the Current Context (the structure that has the soundscape that is actually being heard by the player. In the end, the Over Density Score is the structure that has the sources that cannot be heard in order not to increase to much the density of soundscapes being played.

2.5.3.1 – Heuristics Composition

With the purpose of dealing with the dynamic nature of the medium, a set of techniques were defined in order to guide the composition module. These technics have per basis a list of principles of sound design for games and of healthy Acoustic Ecology. The role of this heuristics goes by checking the sources that the game logic determines that should play and decide if, and how, those sources should be played. These decisions are determined by the Pattern associated to each sources, so we can say that the heuristics are behaviors that act as a response to the Patterns that can be linked to the sources.

The implemented heuristics in the project were:

- **Context** – this concept has the purpose to distinguish between sounds that are relevant in a certain instant, and sounds that are not. There are three types of context: the Layer type, where the sources inside the context depend on the selected layers; the Agent type, where the sources of that context are chosen accordingly with the agent associated to them; and the Ad-Hoc type, where the sources inside the context are freely selected through their name. To visualize this, in Figure 13 these three types of context are represented. The circles are sources that, from the game logic, must be played. The colors of the circles represent agents, being each column a layer representation. Alongside with every circle, it's the volume of each source.
- **Thoughts** – this heuristic is widely used in videogames nowadays, and their purpose is to reveal what a character is thinking of, his thoughts.
- **Silence** – silence is one of the most important and powerful tools to be used in sound design because its comprehension and interpretation isn't easy to achieve. It can be used to explore negative emotions or peaceful moments, and many others ways. That is why this heuristic tend to make an approach in which all the sources are attenuated almost entirely, with the exception of Dialogue and Foley layers.
- **Awareness** – this heuristic is used when game designers want to captivate the players attention for relevant elements during a period of time, after that the soundscape returns to its natural state.

- **Dialogue** – this heuristic gives relevance to sound sources that represent dialogue elements, leaving the Ambiance and Music sources attenuated but the Foley and SFX sources are totally muted.
- **Footsteps** – this is a type of Foley very important because it delivers many important aspects in the game, since the distinctiveness of the different characters and player movements, and that is why the associated sources never have their volume below a certain value.
- **Contextual Music** – this heuristic helps to characterize the different contexts, spaces, areas, and other game elements, and for that their volume has to respect a certain value.
- **Achievement/Failure/No Can Do** – this three are types of SFX widely used in games, and because of their importance during the gameplay, they have always to be heard, never allowing the player to "loose" vital information along the gameplay.
- **Encoded-Embodied** – this heuristic is inspired by the psycho-acoustic model presented by Walter Murch [Murch 2005], where a spectrum of "colors of sound" is presented, and each of the five colors of the model are mapped in the five layers that are used. Following the model and with the purpose of maintaining a good soundscape density, this heuristic does not allow the playback at the same time of two sources of the same color (layer).

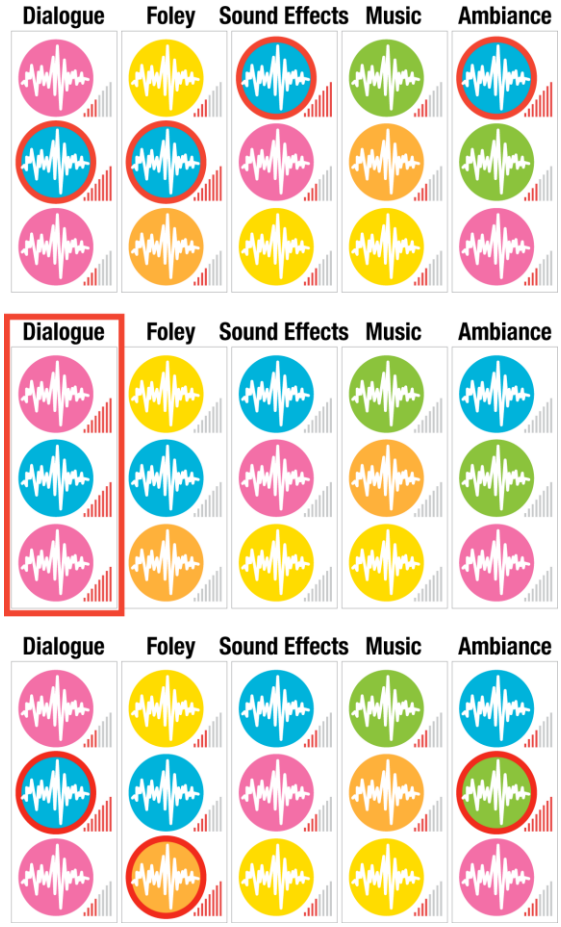

Figure 20 – Examples of the effect of the context heuristic [Pires et al 2013]

For last, after the reference to the DSCM and the API developed, to experiment if the DSCM would respond positively in a game testing scenario, it was applied to an adventure audio-only game (Blindfold), where the player has to be guided by his hearing in order to achieve and be immersed in the experience. According to the feedback given, the game acted perfectly for the testing role, mainly because the different contexts worked very well by distinguishing different moments of the game. [Pires et al 2013, Pires et al 2014, Carregã et al 2013]

Chapter 3 – Methodological Approach

3.1 – Research Goals

Our approach is based on the necessity to explore and deliver to the user (player) a perspective of sound design that follows the themes of Acoustic Ecology and a healthy soundscape composition in games. These purposes have been developed by former works and researches done in the field of Game Sound Design by, being this project supported and stimulated over those developments [Alves et al 2011; Agostinho 2013; Pires 2013].

Following concepts of Acoustic Ecology, Acoustic Design and Soundscape Composition, this project's main goal is focused towards the elaboration of a soundscape composition that creates and explores a relation between the environment (in this case, the city of Coimbra) and the user (player) that will engage and perform a walk through the soundscapes that were virtually allocated in the real world. We intended to explore more features and tools that would enable the elaboration and practical execution of this concept and experience, and for that accomplishment we needed to develop a mobile application (prototype) dedicated to explore and present the sound in an augmented reality system.

With this project, we intend to develop and test a proof of concept AR-based soundscape, interactive by walking according to concepts that Truax defined through his research and work.

Therefore, the dissertation had four main goals:

- Development of a standalone mobile application focused on an audio-only experience;
- Design and elaboration of a specific meaningful soundscape composition;
- Demonstrate that sound is a powerful sense/medium that activates and stimulates different dimensions of the human being;
- Validate an interactive audio-only mobile experience in the real world.

Having proposed and defined objectives, the research headed to the need of getting some questions answered, in terms of complementation and validation of the project's concept and experience:

- Was it possible for a user to motivate himself to walk around areas that he knew, just by sound stimulation?
- How would the users behave using an application for a sensorial experience?
- Would the user feel the need of achievement, victory, as typical of a game?
- Could the user be so engaged that accidently mixed realities?

Although the proposed mains goals of this project were announced, to validate the experience and conceptualization of this dissertation, these questions were essential for understanding and provide further supplement data that brought value and richness to the developed work.

To accomplish these objectives, the project follows a Design Science Research approach that is presented in the next section.

3.2 - Design Science Research

A Design Science Research (DSR) approach was followed by this project because of its methodological character, being its iterative and cycling channels of knowledge an advantage to the evaluation of the whole process. Instead of starting with a group of defined theories and principles that will not suffer much changes along the design process, this DSR allows the participants to contribute in a more active way throughout the cycles of research, design, implementation and evaluation of the data that has been coming as an outcome of the process. This process is not linear, so several iterations through it may and can happen in order to achieve the desired final output.

For this project, this methodology was considered as being the one to follow because unlike other methodologies, this project is oriented for the production of knowledge (with the community as target), and not only for the development of a proposed software. Of course the production of software is in this project's perspective, but that is just a part of the entire knowledge production process.

So, and according to the DSR framework approach (Figure 21), this project had some proposed steps and outcomes that will be presented in table 3.

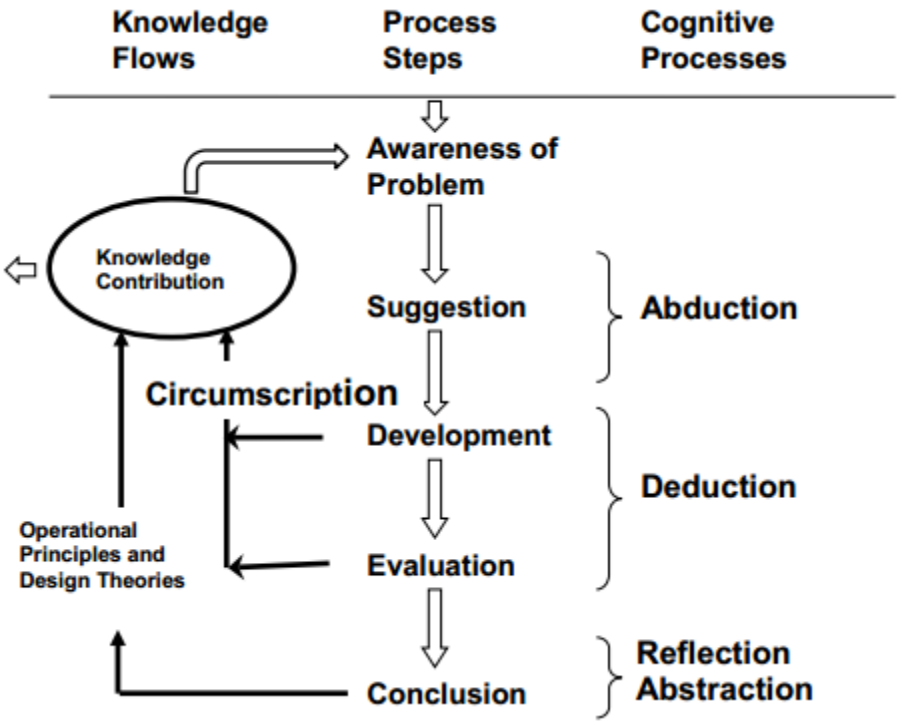

Figure 21 – DSR Framework [Vaishnavi et al 2013]

Step	Description	Project step's
Awareness of problem	In this step there is the awareness of the problem in hands, and it is expected to reveal new findings to the researcher. The output of this phase is a formal or informal, new research effort.	In the current project, this step corresponds to the State of the Art Report, the definition of the problem and methodology. Nevertheless, the collected and identified data could be redefined with others iterations of the so far gathered knowledge.
Suggestion	This phase, is supposed to be enforced by the perspectives of ideas and requirements for a solution that outcome from the previous step. In here, the solution approach is thought and presented, and through abduction thinking, there is a combination of the known premises with the purpose of creating a solution. It assures that the initial design and architecture proposals provide a plausible solution for the problem, not a certain one, therefore needing to be evaluated.	For this project, this step correspond to the task of presenting a Detailed proposal and research goals for the project, defining the solution for the problem as well as stating goals, requirements, assumptions and milestones for the rest of the project. A prototype solution is presented, as well as the principles for the design of the soundscape composition.
Development	In this step, the gathered knowledge for the solution should be used as an attempt to implement the proposed solution through software engineering processes. If an output is achieved, a software artifact is built. If doubts and implementation problems occur, new iterations about the problem should re-enter the iterative cycle.	In the project, this step corresponds to the phases that cover all the Prototyping state, since its design, implementation and initial evaluation.
Evaluation	This step consists on the evaluation of the development achieved before. For that, the artifact is tested and its results are compared and analyzed through a series of criteria's that are meant to be appropriate for the concept in study, and that were defined in Suggestion. If in this step the results are not satisfying or successful, a new cycle of knowledge and Suggestion refinement should take part. Otherwise, the knowledge obtained is used and discussed in the next iteration.	Reaching this step, in the project it corresponds to the task of Evaluation. Despite being the actual step for evaluation, this is occurring (informally) since previous iterations. During this Evaluation task a formal and precise evaluation of the artifact is executed according to the proposed Research Goals and objectives, with results being presented.
Conclusion	The conclusion of a research cycle, with all the amount of iterations that were needed. The outputs could be in the form of models, methods, and prototypes. In the same spectrum, cognitive processes of reflection and abstraction take place because it is presented the acquired knowledge throughout the project.	In this project, this step corresponds to the Statement of Learning where all the outputs and knowledge production is processed and presented in an adequate way. This represents the Future Work and Conclusions of the lessons learned and achievements of the project.

Table 3 – DSR's detailed process steps [Vaishnavi et al 2013]

3.3 - Activity Plan

For an overview about the first semester planning, it is recommend the observation of the Gantt Diagram in Appendix A. The diagram has all the tasks and activities performed through that time space.

As a starter, the first semester initiated with the research and following documentation that composed the State of the Art. This was surely the longest of the tasks since there was a great amount of information to understand and perceive as the foundation of the project to be developed. The State of the Art was integrating the following subjects/tasks: Acoustic Ecology, Soundscape Composition, Audio Augmented Reality, the Adventure Platform, Sound Design in Games and the Sound Design Engine. All of this subjects were dense and required some time to be fully acknowledged as a starter point for the next stages. Despite the State of the Art analysis took about two and a half months, at the end of the first month some details about the project had to start being discussed. This way, and being the Sound Engine [Pires 2013] developed in Unity3d [Unity3D] through the FMOD API, we started to think and define what could be a solution for the defined problem – what tools or frameworks to use in the case for porting to mobile devices – and some assumptions and milestones were starting to be defined. By this stage, the initial design of the project was starting to be developed and some solutions and requirements were being traced, with the consideration that the last task of the initial design was the longest. This happened this way because on this last task, it was proposed that an experimental prototype was delivered. That prototype consisted in implementing in Unity3D a test that included the sound engine integrated with the Blindfold game [Carregã et al 2013] and the player input being the user's real waking. The last month was dedicated to the elaboration of the Intermediate Report.

Being the implementation of the prototype the main task, it is expected the continuity of the work being developed. The prototype process will include the integration of the player input described before, as also the full integration of it with the game engine and the sound engine, delivering in the end the desired mobile application. In its later stages, evaluations of the prototype will start to be elaborated in order to achieve the best possible product. After that, an evaluation performance will be conducted over the prototype and with it, an analysis of the results according to the variables that will be defined. At last, in the statement of learning the actions to perform are the review and writing of the dissertation's final report.

Guided by the DSR approach, the initial milestones and objectives were achieved and the next steps started to come to the table for discussion. An initial solution or suggestion to the problem was made, having always in mind that the mobile application that is expected to be delivered in the end of this dissertation has to include the DSCM created and player input being the real user walking movement. At this phase of early experimenting and implementation, it was decided that the test to be made in a mobile device included two aspects: the Blindfold game with the DSCM integrated and the input of the player had to be the user's real walking movement. Leaving the Blindfold porting to mobile for later, the test started with the player's input issues. At this stage, a good amount of time was lost because despite Unity 3D has a well-documented and equipped API library for Android sensors, all the efforts made resulted in failure and it was not possible to achieve that goal. Although the resources in Unity 3D are plenty, including Android libraries and functions regarding sensors, there is a comprehensive lack of

libraries or resources that the native Android possesses. This way, and not being able to customize the mobile device sensors in order to display the player input as wanted, another approach was taken. This time, and considering only the walking paradigm between what the GPS tell us and what distance a person really walks, the idea of implementing a pedometer in Unity 3D was the next phase, since with this method it was possible to count steps (having minor deviations recalling to distances walked) and after that, utilize that script to work together with the mobile sensors and give the output desire. Unfortunately, by time constraints it was not possible to develop and test in time.

3.3.1 – Plan Corrections

In this chapter (3.3), is announced a proper activity plan for the whole dissertation period, which implies the planning of the first and second semester. The intermediate report exposed clearly what happened in the first semester.

With the problems faced in the end of the first semester towards the prototype development, the planning of the following semester had to be rearranged too. To clarity purposes, the initial planning and output of the first semester was maintained in the dissertation to provide a full understanding of the steps that were made and the exact evolution of the project.

Regarding the work planned for the second semester, as a clarification, it did not occur in the previous period (second semester of 2014/2015) but in the first semester of 2015/2016.

3.3.2 – Platform and Requirements

Along with the steps and stages processed along the first semester, there was a point where technical and specific decisions were to be made. In this case, the platform, frameworks, API's, that should be used to elaborate and implement the prototype for this dissertation.

First, the DSCM [Pires 2013] was designed and built in Unity 3D with the FMOD API. Since one of the main goals of this dissertation is the achievement of a prototype porting to mobile devices, an evaluation about the tools at our disposal was performed. This way, and after some analysis, it was considered that the best option was to proceed with and in Unity 3D. The reason for this is that the previously sound engine was already implemented in Unity 3D, with FMOD API, and considering exporting the engine to other frameworks was an option that required an extra effort in programming and in time consuming, having still the chance of a lot of complications and incompatibilities. These solution was though when discussing about the implementation for the Android system, because being FMOD such a specific library, it could cause major problems trying to re-implement it in Android, both as SDK and NDK. Stating this, the decision was to build the project in Unity 3D, even by availability of Unity 3D (no trial costs, unless it gets commercial delivered), and

because being a powerful cross-platform tool the application could be exported to Android or IOS with little effort and if desired.

3.3.2.1 – Platform and Requirements Corrections

In the previous point (3.3.1), is stated the definition and justification of the platforms and tools that were considered for the development of the mobile prototype of this project. However, the technical output given by the end of the first semester, was not as expected, and many development issues appeared. Consequently, and after new evaluations of the technologies, what we considered to be fundamental to achieve was a prototype that would enable the field evaluations as part of this dissertation objectives.

Considering the previous design of how this mobile application was going to be developed, two decisions were made and were final in terms of how this product would be achieved. Firstly, as was stated in the analysis made, the choice of the Unity3D platform was maintained, as for the objectives of this project, the application was going to be built for Android.

The other decision, was regarding the DSCM sound engine [Pires 2013]. The integration of this component was discarded. It was discarded because in more recent versions of Unity, its audio engine was already implemented with the FMOD API features, and for the proposed objectives of this project, the Unity audio framework provided all the features needed to implement and manage the desired soundscape composition.

3.4 – Milestones

For this project some milestones were defined as the result of a perspective evolution along time. Although some time constraints happened in the first semester, and due to the nature of this dissertation being a Design Science Research work, adjustments can happen in the milestones date and definition. As stated in 3.3.2, adjustments needed to be made because of the first semester output. This way, the milestones can be seen in the following Table 4:

Milestones	Sprint	Description
M1	September – November	State of the Art review
M2	October - November	Detailed Proposal
M3	November - December	Initial Design and Prototype
M4	December – January	Intermediate Report
M5	February (replaned)	Prototype with player input
M6	March (replaned)	Prototype integration in game engine
M7	April (replaned)	Prototype Composition
M8	May (replaned)	Prototype Performance
M9	June (replaned)	Evaluation Results
M10	July (replaned)	Final Report

Table 4 – Milestones table

Milestone 1 – State of the Art Review

For the time of this milestone, it was expected that all the themes regarding the State of the Art were covered by research and by sharing any doubts with the colleagues and mentor.

Milestone 2 – Detailed Proposal

From this milestone it was expected that an initial description of the problem to be handled, was made, and that some goals and milestones started to be framed in the best interest of the project.

Milestone 3 – Initial Design

In this milestone, the specifications brought from the last milestone were taken in advice because it started to arise a solution for the problem, the requirements that it would involve, and a project of architecture and prototype was discussed in a more formal way.

Milestone 4 – Intermediate Report

This milestone was the last of the first semester and it consisted in the writing of the intermediate report.

Milestone 5 – Prototype with player input

This milestone is defined by having in mind that at the end of February, this functionality has been implemented. Thus, it is expected that at that point there is a testing prototype where the player input and movement equals to the user movement in the real world.

Milestone 6 – Prototype integration in game engine

At this point, it is expected that after being able to complete with success the integration of the player input into the prototype, that the rest of the components could be implemented too in the prototype. This means that by this time, the prototype could be ready to be shaped as we expect.

Milestone 7 – Prototype Composition

This milestone is of extreme importance since it is the one where we expect to have a functional and tested prototype/product. By this it is possible to redefine or still operate some changes that could improve the desired experience, output.

Milestone 8 – Prototype performance

When checking this milestone, it is expected that the prototype is already functional by some terms, and that it is possible to start evaluating how it will be evaluated and what are the desired variables on which it could be analyzed. It is not desirable that many questions appears in this stage of the development of the product.

Milestone 9 – Evaluation results

At this milestone all the data collected from the experiences and analysis being made with the prototype, are supposed to be organized and posteriorly presented as results. It is the milestone that defines the end of the prototyping phase.

Milestone 10 – Final report

The present milestone is the last of the project. It includes the presentation of the statement of learning, which means that is the final step for the writing and reviewing of the complete final report.

3.4.1 – Second semester effective planning and definition

As mentioned in 3.3.2, corrections were made in the planning and scheduling of this project. The Milestones table had the desired planning of the activities to be performed, but it ended up not being applicable to the second semester.

First of all, the actual second semester happened in the first semester of 2015/2016, and this way the monthly timeline was different and the milestones were adapted.

The corrected Gantt Diagram is in Appendix B for observation.

This was the planning for the second semester activities that was scheduled, with the redefined milestones:

Sprint 1 - September: Prototype Redesign and Soundscape Composition.

In this stage, due to the problems that were mentioned in the end of the first semester, the need to establish and define the prototype development was crucial for the continuation of this project. So, in this sprint, the expected deliverables:

- Prototype final design and architecture;
- Draft of the soundscape composition.

Sprint 2 – October: Prototype functionalities development

For this sprint, the deliverables were:

- Prototype of the mobile application with Google Maps, GPS tracking that allowed the player input to be his real walking movement;
- Integration of the soundscape composition in the mobile application.

Sprint 3 – November: Final Prototype

For this sprint, the deliverables were:

- Final version of the mobile application, with its interface, player input, and soundscape composition;
- Final state of the soundscape composition;
- First complete field testing's;

Sprint 4 – December – January: Prototype evaluation and final report

For this sprint, the deliverables were:

- Evaluation of the prototype performance;

- Testing procedures;
- Analysis of results;
- Writing of the final report.

Chapter 4 – Design and Architecture Model

In the current chapter, the design and architectural choices for the implemented system, mobile application, are exposed in consideration for the expected outcomes for this dissertation: the soundscape composition and the prototype of an interactive mobile application audio-only based.

4.1 – Soundscape Composition Design

One of the main goals of this project, and the one that would be the crucial layer of the objectives expected to achieve, is the creation and elaboration of a soundscape composition, an acoustic map to be explored by the player.

Having as reference the theories and concepts of Acoustic Ecology, Acoustic Design, Soundscapes Ecology, the design of the soundscape composition had to be accomplished in the most adequate way, or else it would have no value or meaning in terms of its acoustic quality.

An important concept that was considered for the design of the composition, was the Sound Layers definition by Nick Peck [Peck 2001]. He divided sound in five layers: Ambiance, Music, Dialogue, Foley and SFX (see table 2). With this concepts in mind, the research and study of soundscapes was made in terms that the topics to explore in the soundscape composition, also reflected the concept of this sound layers.

The soundscape composition was developed with the context of the city of Coimbra in mind, mostly because it was the scenario were the mobile application would be tested and experimented.

Coimbra is an historical city in our country, whether for its ancient history and remarks, or by the University that is the main landmark of the city. To explore all these themes, a wide range of soundscapes could be considered, mainly because the audio richness of the soundscape composition would be higher.

To approach the appropriate design of this composition, it was taken in consideration the goals of this dissertation, and of the mobile application itself. The user was not going to interact physically with the soundscapes, he was not going to select what soundscapes to hear or not; but the case around: the soundscapes were going to interact with him, along his walking, without his previous knowledge.

So, in order to design the acoustic map where the soundscape composition would be disposed, the geographical map was delimited as follows:

In the area delimited in figure 22, soundscapes were introduced, virtually, in the development of the mobile application.

Figure 22 – Geographical area of the soundscape composition

To enrich the acoustic map, and introduce diversity to the composition, the soundscapes were based on the following themes:

- Academic students life;
- Academic/University traditions;
- Coimbra's football team;
- Botanic Garden;
- Medieval periods
- Students rebellion/manifestation in 1969;
- Expulsion of "Jesuítas" (Company of Jesus);
- Government related (prior to 1974);
- Personalities such as Padre António Vieira, Luís de Camões, Zeca Afonso.

Regarding this themes, the soundscapes were researched and selected according to them, and in the end there was a total of 64 audio files (*.mp3).

To accomplish the soundscape composition, and the desired acoustic map, the audio sources were treated with the Unity audio engine framework, with the management of the following components:

- Play on Awake;
- Loop;

- Volume;
- Pitch;
- 3D Sound settings;
- Volume RollOff Mode: Logarithmic RollOff, Linear RollOff
- Minimum Distance;
- Maximum Distance;
- Spread.

Besides this customization, and to manage more accurately the behavior of some soundscapes, scripting in C# was needed to control more effectively the acoustic behavior of the soundscape composition, while in interaction with the player movement and position.

4.2 – The Design of "Interactive Soundscapes"

The design of the prototype, the *Interactive Soundscapes* mobile application, was made considering the factors that were more important in order to reach the expected functionality for the experience it was proposed.

This way, an interaction model was achieved. This model defines how the users relate and work with the system, and in the context of this project, and being a prototype for sound experience, the interaction model was defined as presented:

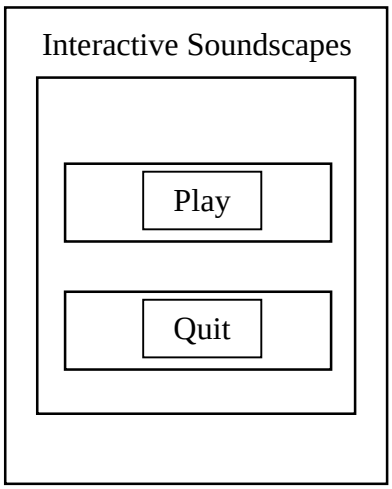

Figure 23 – First screen of the main menu prototype.

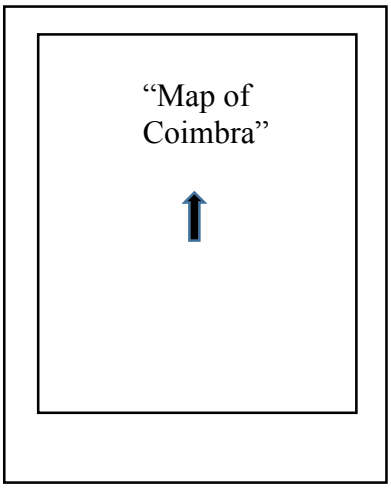

Figure 24 – Game screen. The arrow represents the player that navigates through the map of Coimbra.

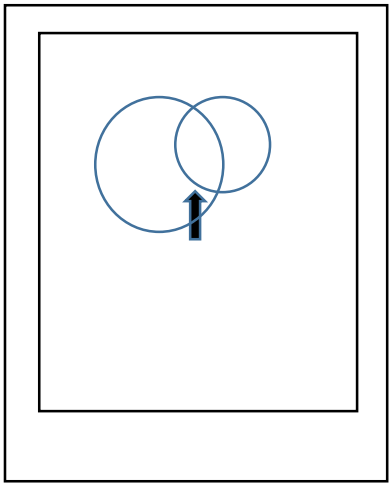

Figure 25 – Diagram that represents the player intersecting soundscape points.

The Interactive Soundscapes mobile application is an audio-based exploratory product, designed so the user do not have the need to continuously focus on interacting with the device. Only two screens are presented to him, because we considered that the experience would be more meaningful and valuable if the user only concentrated the attention on the soundscapes (and walking) as the main application interface.

The user initiates the application and only has two options, to proceed to the "game" or to quit the application. In the next interface screen he is confronted with the map of the city and with his current location. Nothing more is needed, because the soundscapes are virtually positioned in the map, and they will play as long as the user walks through them. For the purposes of this project, to include more visual information in the screen would not benefit the application and not even the research goals that we proposed to achieve.

4.3 – Interactive Soundscapes Architecture

The mobile application is built within the Unity3D game engine.

It is over this game engine that the application is developed, being the audio system managed by the own Unity3D audio engine which includes FMOD API features, and the MapNav ToolKit plugin [MapNav] for Unity allows the management of the Google Maps API, and the GPS, accelerometer, compass sensors. As this is a prototype, it is also a standalone application to test a concept of a future and more complete product. For that reason, there is no connection to servers or other web functionalities. For the design and research goals of this dissertation, it was not significant to have that type of functionalities.

A simple diagram displays the main elements of the designed application:

Figure 26 – Diagram of main architecture elements.

The following diagram represents all the elements and architecture of Unity game engine.

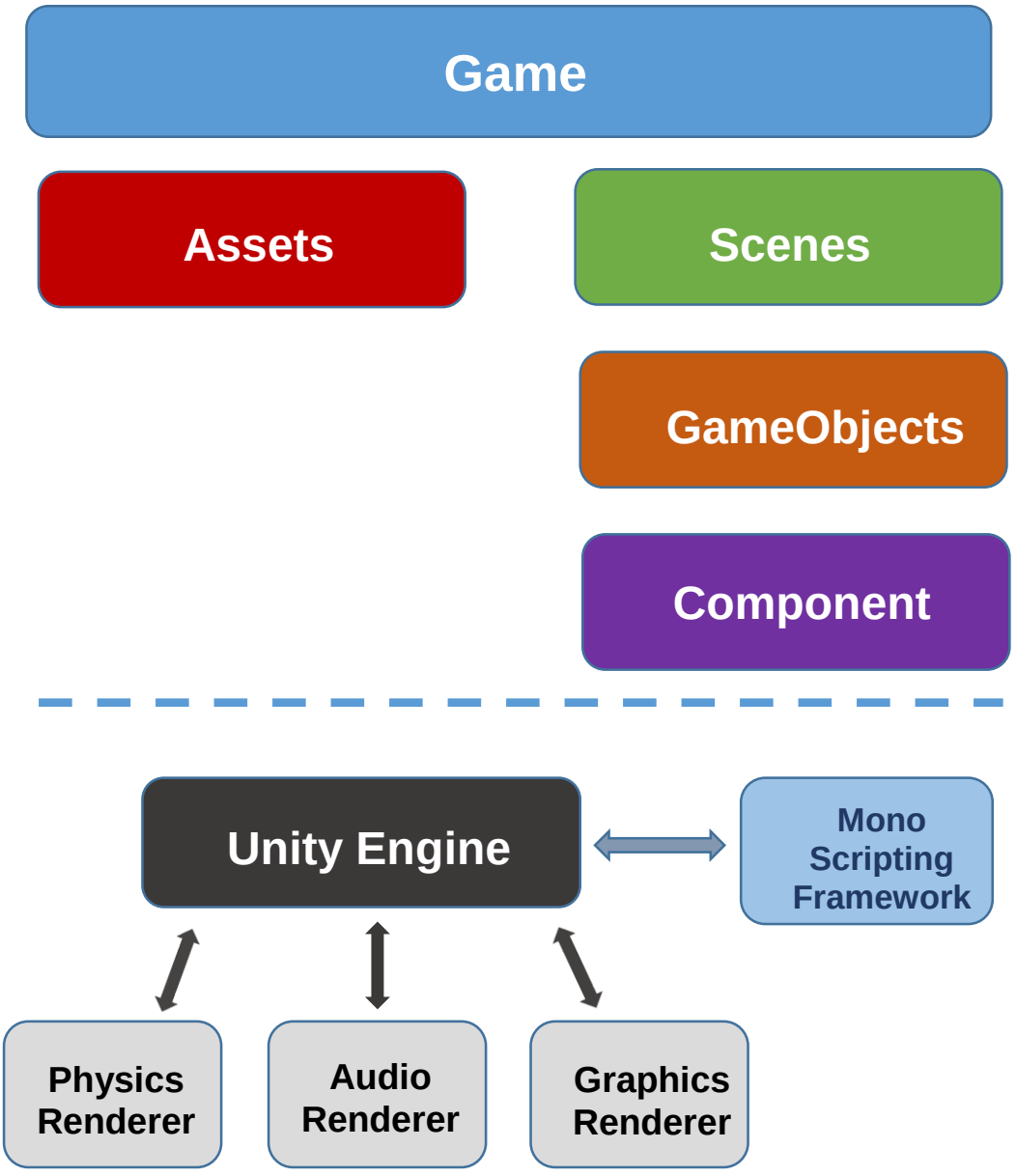

Figure 27 – Unity Game Engine Architecture.

To achieve the proposed research goals, the full architecture of the application is presented in a more detailed form.

In Unity3D, and in this project, each interface screen corresponds to a "Scene" in Unity. Each scene has GameObjects that are a component of the Unity Engine.

The first interface screen (Intro Scene), the Main Menu, is a scene with one GameObject (MenuManager), and it has a C# script (MenuScript.cs) attached that is responsible for the interface and the functionality of the buttons. The button "Play" and the button "Quit".

The next interface screen (Game Scene) is displayed when the user presses "Play" in the main menu. In this scene, the number of GameObjects is bigger because every soundscape point that is placed in the map, has a correspondent GameObject. For functionality purposes, there are four GameObjects: the Main Camera, the UserPointer, the Map, and the Init Screen. The Main Camera allows the scene to be viewed in a 2D perspective and to display in the interface the other GameObjects: the Map and the Init Screen. The Map is the most important GameObject because it is the one that displays the Google Maps Static API v2 textures, and has the MapNav plugin script (MapNav.js) attached. This script is essential because it is the one that provides the Google Maps functionality, and at the same time the management of the GPS, accelerometer and compass sensors, which allow the user to walk and watch his movement being projected in the application interface. The UserPointer is the GameObject that represents the player position and movement in the map, having an Audio Listener (which represents a "microphone" in a scene and allows the player to hear what is near him), and a Collider that when colliding with the Colliders will trigger the audio of the soundscapes. Finally, the Init Screen. This GameObject is responsible for displaying an intermediate screen between the Main Menu screen and the Game screen that informs the user about the GPS retrieving position, and the state of the map download. The InitScreen.js script is attached.

Regarding the soundscapes, there are a total of 54 GameObjects that represent each soundscape in the map. Each one includes Unity components as Audio Sources, Colliders and the scripts GetGeolocation.js and SetGeolocation.js that have the function to insert a soundscape GameObject in the Map GameObject, converting GPS coordinates to Unity units, placing the soundscape virtually in the Map.

The soundscapes GameObjects, have also C# scripts attached to control and define the behavior of some of the soundscapes.

The list of those scripts is:

- SoundscapesAmarelas.cs;
- SoundscapesBaixa.cs;
- SoundscapesBencaoPastas.cs;
- SoundscapesCarlos.cs;
- SoundscapesEstufaF.cs;
- SoundscapesEstugaG.cs;
- SoundscapesEstufaV.cs;
- SoundscapesFountain.cs;

- SoundscapesJesuitas.cs;
- SoundscapesLab.cs;
- SoundscapesLion.cs;
- SoundscapesManage.cs;
- SoundscapesMilit.cs;
- SoundscapesPlayAudio.cs;
- SoundscapesQueimaGrelo.cs;
- SoundscapesRepublicas.cs;
- SoundscapesSeVelha.cs;
- SoundscapesTorreB.cs;
- SoundscapesTrupe.cs

With this system architecture, is intended to achieve the functionalities that are essential to the product. This is, the map display, the user movement and his movement triggering the soundscapes points that are placed over the map. To provide the audio augmented reality experience in a mobile application, these were the functionalities required to achieve that objective.

Next, is present a complete diagram of the architecture of the system.

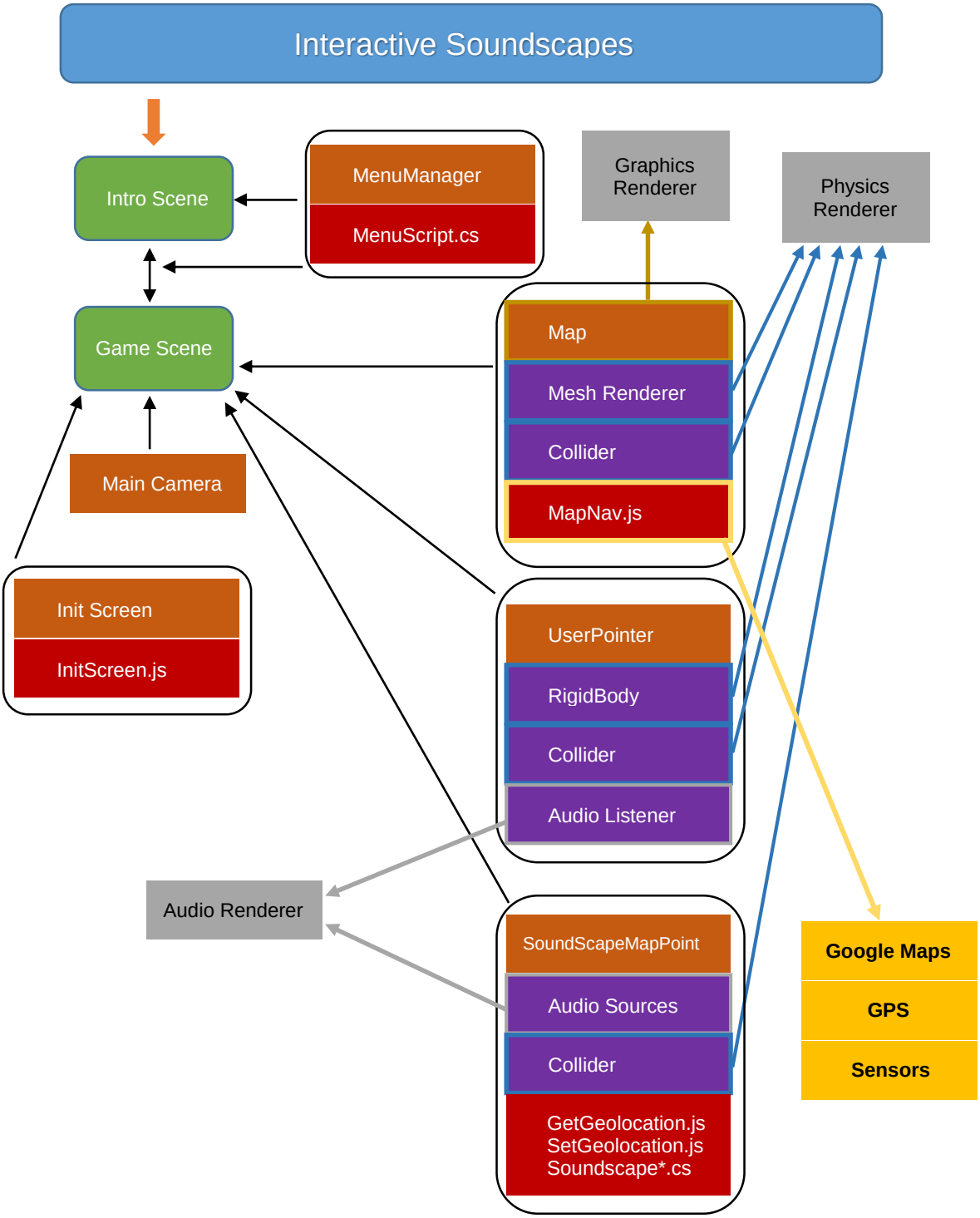

Figure 28 – Prototype System Architecture. Green – Scene; Orange – GameObjects; Purple – Components; Red – Assets(Scripts); Grey – Renderers; Yellow – Maps API and Sensors

Chapter 5 – Development Activities

The current chapter describes the activities performed along the development process over the course of the second semester of the dissertation.

In the following sections, the project's final production will be explained, regarding the elaboration of the prototype, the prioritization and work management, and the chronological description of the procedures executed in order to accomplish the software prototype.

5.1 – Prototyping development resolutions

As stated in the end of the first semester, several issues and uncertainties about the elaboration of the prototype were creating major handicaps in the desired software solution. Some resolutions were considered but none was satisfactory enough for the objectives we wanted to achieve with the result. In this way, an adjustment to this dissertation approach was made, and a solution was defined for the stage of development.

To accomplish the solution we intended, an audio-only interactive mobile application, decisions were made and some previously considered implementation aspects were discarded. The first decision was to not include the DSCM sound engine [Pires 2013] – the DSCM sound engine was built as a Unity3D plugin and works over the FMOD API. The reason supporting this step, besides know-how complexity and time constraints, was based in the fact that the development platform chosen for development, the Unity3D game engine, in its more recent versions, already had an audio engine that would fit the needs and features we wanted to implement in the future soundscape composition. The FMOD API features were already implemented in the Unity3D audio engine. So, regarding this resolution, the question with the tool needed for the soundscapes (audio) management was solved.

Another issue to be solved, was the implementation in the application of the location-based, GPS tracking, in Unity3D for the Android devices. Already in the first semester many issues and problems were encountered when trying to work with the available API library that Unity3D disposes for mobile devices sensors. With the technical constraints that we were facing, and the adjusted research goals focusing in the experiment results we wanted to achieve, the solution for this issue was the use of a Unity3D plugin for geolocation, the MapNav Geolocation ToolKit [MapNav].

At this point, the ideal conditions were gathered to begin with the proper development phase.

5.2 – Work prioritization

The issues that remained from the first semester regarding the definition of the prototype implementation, were the major concern to the progress of the project. This was without a doubt the main priority in the prioritization agenda of the prototyping development. Once this barrier was surpassed, the remaining steps were taken in order to pursuit the success of the project.

In this way, the next priority was to start with the elaboration and creation of the concept of the soundscape composition we wanted to obtain. Since this composition was to integrate in the mobile application, and it was to apply in the city of Coimbra, it was a challenge to unravel a selection of the themes or topics to explore and that seemed more adequate, plausible, interesting and with acoustic value in order to achieve a balanced and structured soundscape composition. While this task was in process, many hypothesis and ideas of soundscapes were emerging and arising from the knowledge we had about Coimbra and its history and traditions, so it became important to define a limited geographical area that would work as a layer for the soundscape composition and at the same time, as the spatial radius where the user would walk.

Although the design of the soundscape composition was crucial for research goals purposes and a continuous process through some time, as soon as we had a defined draft of the composition (with the locations and types of soundscapes), the project could effectively enter a new phase.

The next priority, was the construction of the mobile application prototype in Unity3D. As mentioned before, this product suffered a few adjustments about its implementation, and with a defined soundscape composition draft at this point, we had the development of the application in our sight. This way, implementing the application interface with the GPS tracking through the MapNav framework was a priority because we needed to observe and realize how functional and accurate was the GPS readings, using the Google Maps Static API, in the Unity3D engine. With the main interface and system functionalities adapted to the behavior that was expected and desired, the priority became the technical integration and designing of the soundscape composition into the application. At this point, again with the MapNav framework, the geolocation points that would represent the soundscapes needed to be introduced in the application system, in order to understand how the player input, the user walking, would function and play the soundscapes, so that some minor testing could take place and give the desired functional feedback.

Having this step achieve the output and success we wanted, the last and main priority was to create and integrate the whole soundscape composition in the application with the resources that Unity audio framework offers. This was a complex, time consuming process because the amount of soundscapes was considerable, and the way they would be disposed and personalized was of major importance for the research goals that were defined and desired to achieve. Considerations such as the soundscapes types, their geolocation and playback radius amplitude, volumes, audio spatialization and interaction, were properties that required, in an Acoustic Design context, attention, detail, and perception so that the sonic environment had the design and effect intended for the experiment.

Lastly, and to summarize, this prioritization schedule was determined as described above because the project focus, towards the dissertation research goals, predetermined how this scheduling had to happen. This means that after the resolution and definition of

the mobile application implementation, the leading priority was to create a coherent and complex soundscape composition supported by a reliable architecture of the system, allowing us that along the project's implementation we could manage, improve, and refine gradually, according to what seemed the best choices, the main feature of the application: the soundscape composition.

5.3 – Prototype Activities

In this section, the prototype activities developed throughout the second semester will be detailed according to the chronological order on which they were executed.

Sprint 1:

To begin with, and considering the importance of this component in the application, an initial design draft of the soundscape composition was made. This acoustic composition, had to include several aspects: the geographical area of Coimbra that would act as the game scenario and incorporate the selected soundscapes; the physical location points where the soundscapes were going to be virtually implanted; the themes or subjects of the soundscapes that we wanted to select and expose in relation with Coimbra's history, University/Academic life events, or other subjects that seemed relevant and that could improve the acoustic value and meaning of the composition. Following this directions, it was decided that the game scenario in the real world would be restricted to a total area inside the frontiers that integrate the following places:

- The Botanical Garden;
- The "Praça da República" and adjacent áreas "Republic houses", Gil Vicente Theater, AAC main building, etc;
- The "Alta" of Coimbra, where the University is located;
- The "Sé Velha" area;
- The "Almedina" tower and Moorish city gate;
- The "Baixa" of Coimbra, main streets;
- The "Couraça" strip;
- The Padre António Vieira street.

The map of the game scenario delimitations is as presented in the next figure:

Figure 29 – Geographical area of the soundscape composition

After the definition of the area of the game scenario, an ongoing background process of soundscapes themes and selection was already in course. The decided subjects that would be represented by the soundscapes were:

- University and Academic traditions (students social life and events);
- History and historical moments that took place in Coimbra, such as recent politics events, or references to ancient medieval periods.

With the aforementioned points defined, a draft of an acoustic map was elaborated with 31 soundscapes locations. (Figure 30)

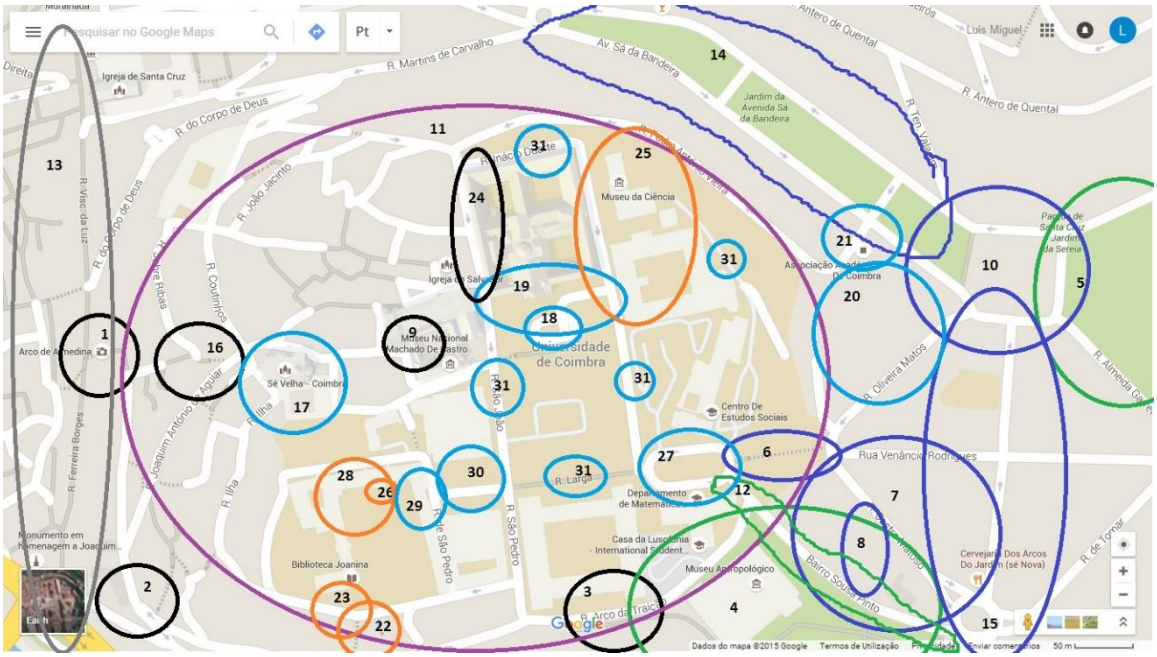

Figure 30 – Soundscape composition draft

Additionally, the presumed soundscapes located in the map, are presented in the following table (table 5):

MAP POINT	SOUND LAYER	SOUNDSCAPE
1	Music, SFX	Medieval battles
2	Music, SFX	Medieval battles
3	Music, SFX	Medieval battles
4	Ambiance	Garden environment
5	Ambiance	Garden environment
6	Foley	"Escadas Monumentais"
7	Foley, Music	Students' Republics/Fraternities
8	Dialogue, Foley	Night life/Party
9	Music, SFX	Romans/Ancient Roman city
10	Dialogue, Foley	"Praxes" / Freshman students
11	Foley	"Cabra" bell ring
12	SFX	Water flow
13	Ambiance,Foley	"Baixa" environment sounds
14	Dialogue, Foley, Music	"Queima das fitas" parade
15	Dialogue, Foley, Music	"Queima das fitas" parade
16	Music, Dialogue, Foley	"Quebra-Costas" – Medieval market/faire
17	Music, Foley	"Serenata"
18	Foley	"Queima do grelo"
19	Dialogue, Foley	"Benção das pastas"
20	Dialogue, Foley	"Assembleia Magna"
21	Foley	"FRA"
22	Music, SFX	Minerva stairs
23	Music, SFX	Academic prison

24	Music, SFX	"Jesuítas" battle
25	Ambiance,SFX	Ancient chemistry laboratory
26	SFX	"Via Latina"
27	Dialogue, Foley	1969 students manifestation
28	Foley, Music	"Sala dos Capelos" – cerimonial room
29	Music, SFX	1907 students strike
30	Dialogue, Foley	"Rasgança"
31	Music, SFX	"Trupes"

Table 5 – Soundscape composition draft points

By the end of this stage, we had a clearly identified and defined draft of the soundscape composition, several audio files of soundscapes, and we could proceed to the next development activity.

Sprint 2:

In this development stage, and with the output retrieved from the previous step, we could implement and develop the desired mobile application.

Working with Unity3D, being a powerful tool as it is, required the understanding and study of the resources available to further implement the interface and, more important, the audio engine that was the main framework to work with the correspondent soundscapes.

The interface of the application was based on two screens, which in Unity game engine corresponded to two "scenes". The initial screen had a menu that was designed to allow the user to enter the "game" or to quit the application. This screen was developed with C# language scripting, and the connection to the game main screen was also provided by the mentioned C# script. Being this a mobile application, when it came to interact with buttons, the input was the user touch. To implement the next screen, the game main screen, the MapNav plugin had resources that allowed us to incorporate some functionalities needed for this project. This way, and with the resource to Unity components, two GameObjects (Map and User Pointer) were applied. One, to provide the application with the map (textures from Google Maps Static API v2) and the other to function has the player in the map scene. Also, while the application made the transition from the initial screen to the game screen, and while the system was collecting GPS location data, and downloading the Google Maps texture, in order to present that information to the user and have a more appealing transition between screens, the need to insert another GameObject emerged. This GameObject (Init Screen) had a script attached (InitScreen.js) to it that displayed the above mentioned information.

Since the purpose of the project was for the user to walk around the city without having to interact with the mobile device, the interface of the game main scene should not distract the user from his walking and perception of the soundscapes. So, the definition of how this screen should be, was that the screen would only display to the user the map of the city, a pointer that showed him his position, heading and movement, and a small bottom menu with four buttons: refresh (GPS position); zoom in; zoom out; and a back button to the initial menu screen. The decision to include this buttons was based in the fact that they would not have an influence in the user experience behavior, for example, in distracting him of the experiment, but in providing the user with help, if needed, in terms of map visualization and GPS signal failures.

With this steps and functionalities accomplished, the integration of the soundscape composition was initiated. To perform this, a GameObject was defined as "MapPoint", and it was responsible for the virtual integration of each soundscape in the map. So, this GameObject was attached with an Audio Source component that would have the audio file, a sphere or box collider component to detect the User Pointer GameObject, and two scripts (GetGeolocation.js and SetGeolocation.js) that were needed to insert the GameObject in the map and converting Unity units to GPS coordinates. With the integration of each soundscape MapPoint, the Unity audio engine framework features (Play on Awake, Loop, Volume, 3D Sound Volume Rolloff Modes, Minimum Distance, Maximum Distance and Spread) were manipulated according to the desired purposes. Along with this personalization, and through Unity API, C# scripts were created and attached to the soundscapes GameObjects in order to provide a specific behavior like Trigger events, Coroutines, and effects as Fade In or Fade Out.

An important issue during this phase of development was that while the implementation was being executed, there was always occurring a new research, re-design and re-collecting of soundscape audio files. So, at this point, the initial draft of the soundscape composition had changed, and it would continue to change until the end of the next stage.

Summarizing, finishing this phase of the prototype development delivered an implemented and functional prototype of the mobile application, with Google Maps and GPS tracking integration, as well as an already playable soundscape composition integrated within the game.

Sprint 3:

Entering the final month of the development phase, the results obtained from the previous stages were satisfying because the prototype was working in its technical side, but there was still a lot of work to accomplish towards the soundscape composition.

The design of the acoustic map, the judgement of what soundscapes would constitute more value to the desired experience, some restrictions encountered in the Unity audio engine framework, and the whole elaboration of the composition towards a final state, was being delayed by the reasons described. But decisions had to be made, and some real testing's too.

At the end of the previous stage the soundscape composition actually built into the prototype was mainly constituted by sounds placed in the Botanical Garden, and in areas of the "Alta" of Coimbra such as "Largo Dom Dinis" and in the "Quebra Costas" zone,

this was clearly not enough to provide the experience we wanted, and surely not enough to accomplish the proposed research goals. The acoustic map was in this state, because of the uncertainty of what audio files to use to represent some soundscapes. Having many doubts, the focus in the experience output was crucial in order to complete the acoustic map. In this way, more soundscapes were defined and selected according to the subjects announced in the first stage of development, and the acoustic map became acoustically richer. Zones like "Couraça", "Sé Velha", "Sé Nova", "Padre António Vieira" street, "Praça da República", "Museu Machado de Castro", the University library and the "Rua Larga", from this moment on, had soundscapes associated. After this accomplishment, we had to struggle with the Unity audio framework again. Every MapPoint, every soundscape, with the framework features presented before, had to be configured in the most proper way so that the experience would be as desired. From volume levels, 3D audio spatialization, quality of some audio recordings and tracks, and volume rolloff modes, the configuration of all the soundscapes was very time consuming.

As soon as the soundscape composition was ready, field testing was required to understand how the application, the mobile devices, and the soundscape composition would perform from a technical perspective, and most important, how the user would behave and experience it. After these pilot test, the feedback and output was generally positive, from the point of view of both the application and the user experience. Still, and with the feedback received, some adjustments needed to be done with the soundscapes audio configuration, and with technical issues such as the application not playing audio sources when the screen got locked.

Finishing this stage, the soundscape composition was still updated, and regarding the prototype, technical adjustments needed to be made.

Sprint 4:

Although the soundscape composition had achieved its final state in terms of implemented MapPoint's and its whole acoustic design, some audio adjustments needed to be executed, such as volume levels, and the radius of the areas that were surrounding the soundscape source point. Unfortunately, the issue of the lock screen could not be solved due to time constraints, but interface details and scripting regarding the soundscapes behavior were corrected.

This way, the outcome of this stage was the final and improved soundscape composition (Figure 31), as well as the final prototype. The *Interactive Soundscapes* final application can be visualized in several screenshots in Appendix F.

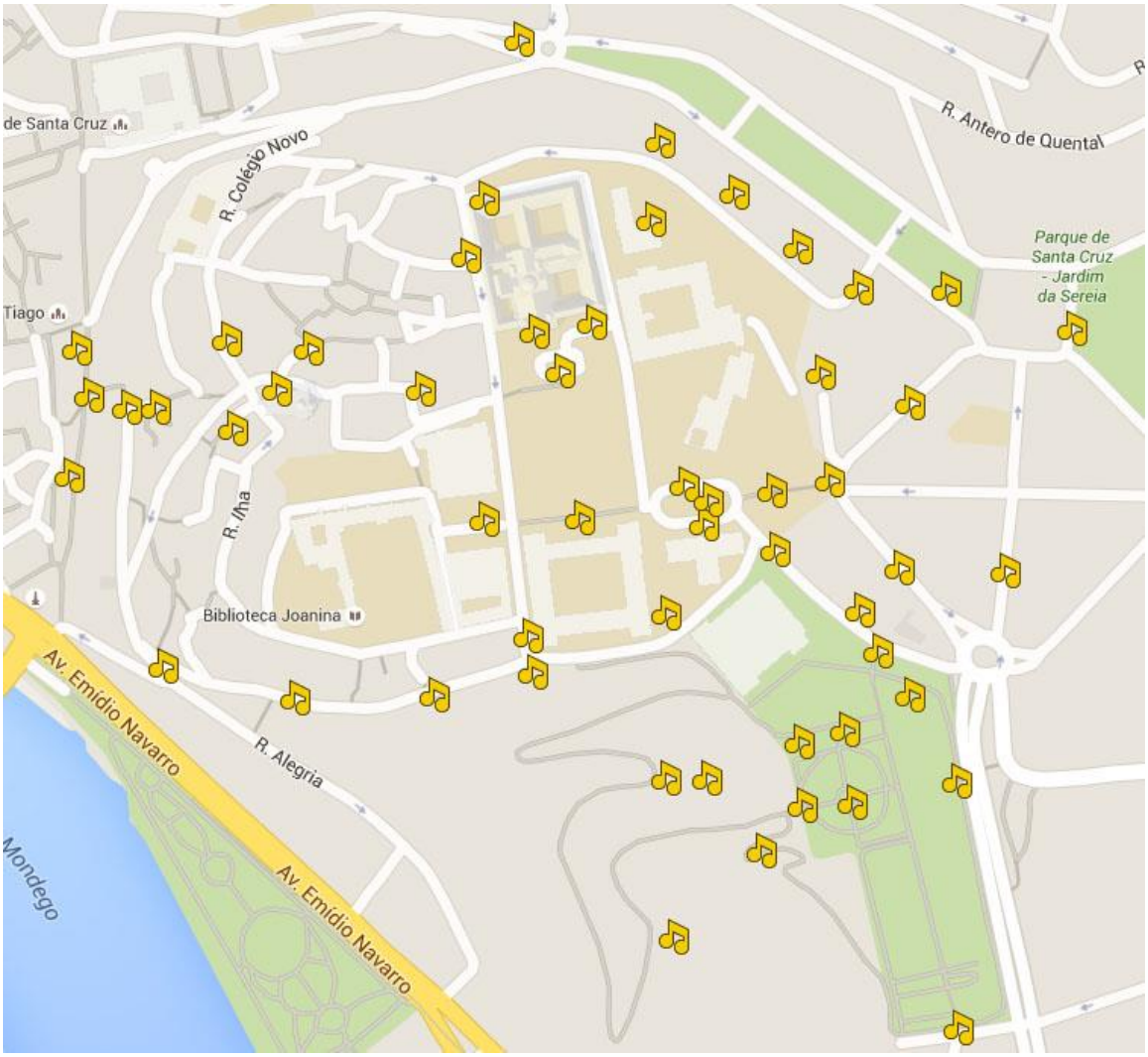

Figure 31 – Final soundscape composition map

In the end of the soundscape composition, the soundscapes were classified as described in the next table:

Soundscape ID	Nº of Audio Sources	Sound Layer	Category/Group
MapPointJardim	1	Ambiance	Botanic Garden
MapPointFonte	2	Ambiance, SFX	Botanic Garden
MapPointPortao1	1	SFX	Botanic Garden
MapPointPortao2	1	SFX	Botanic Garden
MapPointPortao3	1	SFX	Botanic Garden
MapPointBambu	1	Music	Botanic Garden

MapPointSBento	1	Music	Botanic Garden
MapPointMata	1	SFX	Botanic Garden
MapPointTropical	1	Ambiance	Botanic Garden
MapPointEstufaG	2	Ambiance, Music	Botanic Garden
MapPointEstufaF	2	Ambiance	Botanic Garden
MapPointEstufaV	3	Ambiance, Music, SFX	Botanic Garden
MapPointCortejo	1	Ambiance, Dialogue, Foley	Students/Academic Life
MapPointRasganco	1	Dialogue, Foley	Students/Academic Life
MapPointRepublicas	1	Dialogue, Foley	Students/Academic Life
MapPointPitagorica	1	Foley	Students/Academic Life
MapPointAmarelas	1	Foley	Students/Academic Life
MapPointSeVelha	2	Music, Foley	Students/Academic Life
MapPointMoelas	1	Foley	Students/Academic Life
MapPointBencaoPastas	1	Foley	Students/Academic Life
MapPointBencaoPastas2	1	Foley	Students/Academic Life
MapPointQueimaGrelo	1	Foley	Students/Academic Life
MapPointTrupe	3	Foley, Music, SFX	Students/Academic Life
MapPointMonumentais	1	Foley	Students/Academic Life
MapPointRuaPadreAV1	1	Foley	Students/Academic Life

MapPointRuaPadreAV2	1	Foley	Students/Academic Life
MapPointRuaPadreAV3	1	Foley	Students/Academic Life
MapPointBaixa	1	Music	Historical/Ancient Coimbra
MapPointElectricTroley	1	Foley	Historical/Ancient Coimbra
MapPointTorre	1	Ambiance, SFX	Historical/Ancient Coimbra
MapPointMedieval	1	Dialogue, Foley	Historical/Ancient Coimbra
MapPointFeiraMedieval	2	Music, Dialogue, Foley	Historical/Ancient Coimbra
MapPointRomanos	1	Music	Historical/Ancient Coimbra
MapPointJesuitas	1	Dialogue	Historical/Ancient Coimbra
MapPointJesuitas2	3	Music, Dialogue, Ambiance, SFX	Historical/Ancient Coimbra
MapPointLabChimico	3	Ambiance, SFX	Historical/Ancient Coimbra
MapPointTorreB	2	Ambiance, SFX, Music	Historical/Ancient Coimbra
MapPointCouracaA	1	SFX	Historical/Ancient Coimbra
MapPointCouracaB	1	Music	Historical/Ancient Coimbra
MapPointCouracaC	1	Music, SFX	Historical/Ancient Coimbra
MapPointDesfileMilitar	1	Music	Academic Crisis 1969
MapPointManif	1	Dialogue, Foley	Academic Crisis 1969
MapPointAlbertoM	1	Dialogue, Foley	Academic Crisis 1969
MapPointAssembMagna	1	Dialogue, Foley	Academic Crisis 1969

MapPointAteneu	1	Dialogue, Foley	Coimbra Politics
MapPoint1968	1	Foley	Coimbra Politics
MapPointZecaCasa	1	Music	Coimbra Musician
MapPointZecaAAC	1	Music	Coimbra Musician
MapPointCarlosParedes	1	Music	Coimbra Musician
MapPointAAC	1	Dialogue, Foley	Coimbra Football Team
MapPointOAF	1	Dialogue, Foley	Coimbra Football Team
MapPointCamoes	1	Dialogue, Foley	Random Coimbra
MapPointCamoesLeao	1	SFX	Random Coimbra
MapPointRuaPadrAV4	1	Dialogue	Random Coimbra

Table 6 – Soundscape composition description

Chapter 6 – Evaluations

This chapter of the dissertation presents the options and steps taken to elaborate the adequate strategy for testing the prototype, and to provide a complete evaluation of the project. There will be an explanation of the selected testing techniques and the reason why they were chosen, followed by the planning of the tests that was executed, including the scenario and conditions in which the tests were performed, and, lastly, the data and results obtained will be delivered and analyzed in accordance with the proposed research.

6.1 – Testing Techniques

For the evaluation purposes, and to obtain the information considered to bring value to the previously mentioned goals, it was not appropriate to choose directly one or two technics only to retrieve some data that could not be sufficient to evaluate the whole project itself. This way, and considering the conceptualization of the project and the different dimensions involved in its testing, a model (landscape) of user research methods elaborated by Rohrer [Rohrer 2014] was adopted.

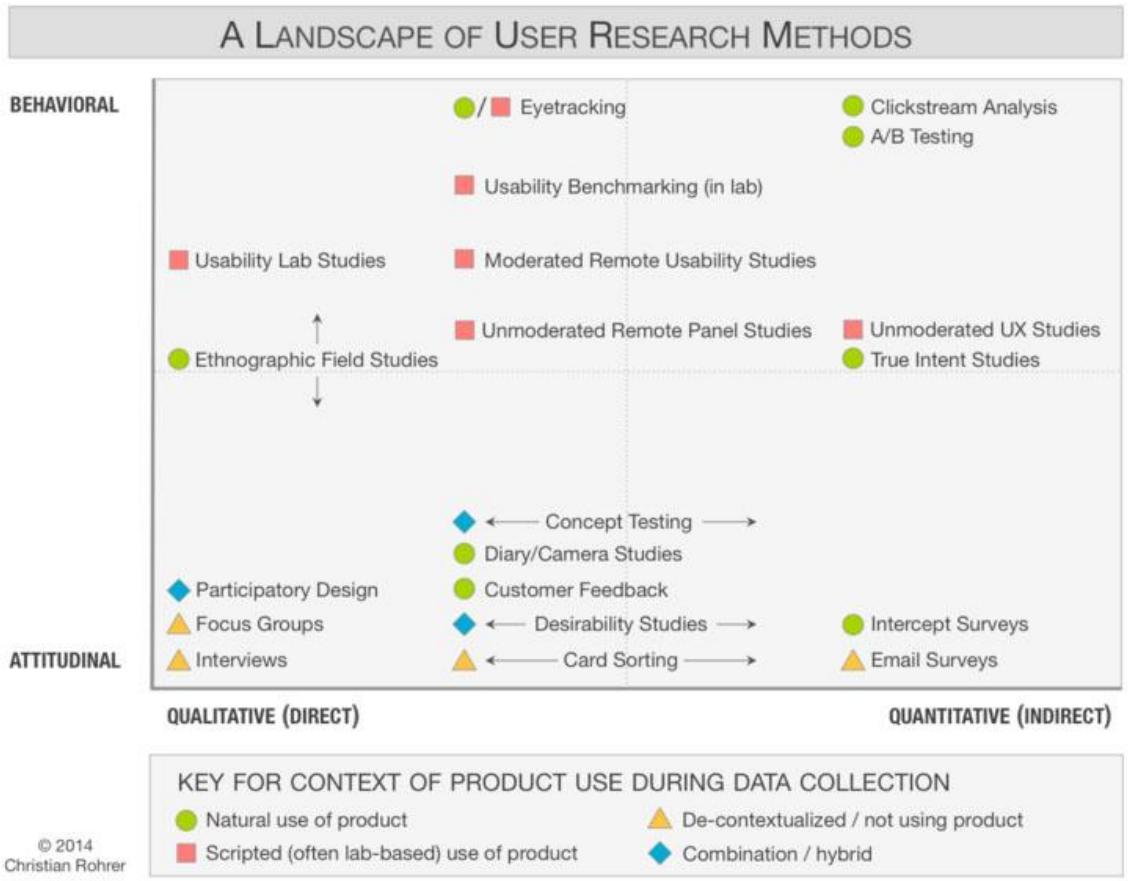

Figure 32 – Landscape of User Research Methods [Rohrer 2014]

This method landscape contemplates the dimensions which are considered to be imperative to achieve the best results possible from the experience provided to the testers. The need to evaluate attitudinal and behavioral components, qualitative and quantitative

data, and the context of use of the product, made the Rohrer model and the crossover of all these dimensions, the tool to choose and understand the needed technics.

The techniques chosen for the experiment were: a pilot testing [Shade 2015], usability tests, field-tests and an interview [Rohrer 2014]. There were several reasons to support this selection of techniques.

Firstly, and prior to the real tests to be conducted, individual sessions of pilot testing were performed in order to retrieve a first feedback about usability and performance results, and even too understand the behavior of the prototype and of the participant itself. This method was chosen with the purpose of getting real feedback that could lead into an improvement and correction of certain aspects of the prototype, as well as to give a first insight about the goals that were defined to achieve with this project.

Being a mobile application with real world interaction the product of this dissertation, a usability test could not be performed in a typical formal condition. The experiment took place at open field, through the city of Coimbra, so it was not in a controlled environment such as a room, being the participant possibly exposed to external interference. However, the importance of this technique has great value because it could be made without a large number of participants, the person who supervises the test has none or minimal interference and the data collected from the participants is unique and personalized. Regarding all this contributions, this was the only way to perform the usability test (which is directly related to the field test).

Field-tests are the major technique, in requirement and necessity, for testing and evaluation of this dissertation. Without a field test, there was no feedback and data to collect and posteriorly analyze. The prototype developed, the product of this dissertation, is a mobile application based in audio augmented reality experience, so its functionality and the behavior and attitude feedback of the participant are fundamental to gather information about the experience, in order to analyze and achieve the objectives and goals of this project, in accordance with [Rohrer 2014].

The interview method, with participants, was selected for two reasons: in the end of each test there was a questionnaire to be made to the participant, however, after the pilot testing was made, it was decided that a simple and short number of questions seemed insufficient to contemplate all the experience driven by the person, and more feedback was needed; secondly, the focus of this dissertation is the conceptual idea and design of an experience based on audio augmented reality, and while the field test, on its own, provides a great amount of feedback in the different dimensions that Rohrer refers [Rohrer 2014], having the person in a neutral environment after the test with no time constraints, but still immersed by the experience, was the ideal set to answer several questions with raw and authentic information. This allowed us to retrieve more information about the participant behavior, attitude and the experience itself, in qualitative and quantitative ways, which was fundamental to the evaluation.

6.2 – Test Planning

To perform and execute the tests, a plan had to be drafted. Considering the stage of the pilot tests was crucial to provide additional help to define how the real tests should be

performed, and what more to consider as relevant to the dissertation and to the test experience itself. This pilot fieldtesting was made by me (several times) and by two other testers that had no more participation in the testing of the developed prototype. After accomplishing this step, the other activities of the planning were defined. This way, to plan these tests, a group of five steps was followed:

- The design of how the experiment should run;
- Selection of participants according to a profile;
- The definition of a guide with the instructions needed to the participants perform the experiment;
- Throughout the experiment, the types of technical data that was retrieved from the prototype (smartphone);
- The elaboration of the questions that would be presented along the interview.

This planning had, in its core, the genuine steps that were considered to better deliver a good and reliable experience to the tester and, in the same measure, the mechanisms and tools that could provide the most useful and truthful feedback from the participants, as well as the data collected through the test that would allow an appropriate evaluation of this project, remarking the proposed objectives and goals of the concept of this dissertation.

6.2.1 – Design of the Experiment

Since a mobile application was being tested, and it is a concept of application that is towards an audio augmented reality experience, the test had to be executed on the field (a designed area within a specified range in the city of Coimbra), where the tester had to walk through the city expecting to have contact and interaction with the soundscapes that were implemented. As it is an experience with a full exploratory component, the tester had freedom of choice and of movement, in order for her/him to feel in control during the test, even though I was always present as a supervisor but with minimal or no interference at all in the test, my role was only to go along with the tester and observe his behavior and take notes when necessary. This is how the experiment was conceived – the participant starts the test, moves freely as long as he desires, and gives the order to finish.

6.2.2 – Participants Profile

Regarding the participants' profile, an amount of users was required to perform the tests and, in agreement with research goals of this dissertation, to embrace the soundscape composition and the experience as a whole. In terms of the appropriate number of participants for a usability test – even if a distinguished type as the one presented -, Nielsen supports that 5 users is an efficient tradeoff number for usability tests [Nielsen 2000, Nielsen 2012]. Although his ideas and studies strongly support those numbers, it can diverge up to more or less users, according to the type of test that is wanted. In the case of this project and the developed prototype, the focus is primarily on the user experience, the feel of engagement and immersion acquired through the audio output, the soundscape composition, and not so much on user interface issues or problems. Having this been stated, the defined number of participants was 7, being 6 male and 1 female. So, why 7 participants, and not 6 as regular or 5 as Nielsen supports? The answer is that due to the previously defined goals, objectives and achievements for this dissertation, there was a

need to explore the effect and impact of the prototype with this soundscape composition, with people that share similarly some background about Coimbra, but that at the same time, have diverse personal characteristics.

As mentioned before, these tests explore the dimensions previously described by Rohrer [Rohrer 2014], and the only considerable, not obligatory, requirement to participate was that they had to have some background about the history and traditions of Coimbra. The prototype was developed about and for the city of Coimbra, so it was predictable that the value of the experience had more meaning for those, than to a total outsider.

6.2.3 – Experiment Instructions

In order to achieve the most trustworthy results for further comparison and analysis, the participants had always to be confronted with the same information and the same explanation about the experiment they were prepared to start and engage.

Every test had only one participant at a time, an individual session.

Therefore, the briefing given to the tester before the beginning of the experiment was focused on several points as the following:

- The mobile application to be tested was of self-exploratory nature and its major focus was in providing the user with an interactive sound experience about Coimbra;
- The area in which the user could consider as "play area", was geographically in a range between Jardim Botânico, Praça da República, Associação Académica de Coimbra, Universidade de Coimbra, Alta de Coimbra, Arco de Almedina e Baixa de Coimbra;
- The experiment was conceived for the use of the smartphone with earphones;
- The test begun in front of Rotunda do Papa and under the known Arcos do Jardim, and the user was free to move in any direction. The test only finished when the user was decided to, and if certain of the decision, the test would end.
- My participation in the test session was only of companion and observation of the behavior and instantaneous feedback of the tester. I had no interference and influence in the decisions made or directions taken by the participant, or answering any kind of questions that, in my point of view, could compromise the experience before its terminus. The only issue I would interfere was in the case of the user was getting too far from the designed soundscape map.

6.2.4 – Data collected for evaluation

For the validation and evaluation of the performed tests, some specific data was collected to provide information that could be worked on and later analyzed to deliver and interpret the results. In each experiment, the duration in time of the test was gathered, as well as the register of the soundscape points that the user passed by the correspondent timestamp. Besides these, GPS location readings, the battery consumption, RAM usage and mobile data transfer was registered too. Further in this chapter, all this data and metrics were analyzed and discussed, delivering the results of the experiments.

6.2.5 – Design of the Interview

As for the final stage, the elaboration of the interview was a very important step because it would give a more complete feedback about the participant experience, and equally, more information in qualitative and quantitative form, which provided more accurate and essential data for the analysis of the results obtained. The feedback and speech of the participants was so important that the interviews were recorded, allowing the benefit that none of the information could be lost or not perceived.

According to the research goals and objectives of this dissertation, an appropriate questionnaire was elaborated. It can be consulted in Appendix C.

As enunciated above, these were all the steps that were considered and defined in order to achieve the best results possible.

6.3 – Test Scenario

The steps for the execution of the test were already mentioned in the previous sub-chapter (6.2), however, the test scenario was performed as follows.

First, it was required a mobile device with the Android operating system, GPS, accelerometer and compass sensors, the application prototype installed in the device, and earphones. Then, and being a field test, the participant joined me near the "Rotunda do Papa" and "Arcos do Jardim". At this point, with the GPS and mobile network activated in the device, a briefing of the experiment was given to the participant, as mentioned in 6.2.3.

From that moment forward, the participant with the mobile device in his hand, had total control over the experiment, once the decisions of directions to take were of his responsibility. I would only interfere if the participant was already out of the "play area" and with that action, getting "lost". Once the participant reached a moment of decision, regarding to end the test, he warned me and the experiment would finish.

After this, and to have a detailed feedback of the experience, an interview was made to the participant, according to the questionnaire elaborated in 6.2.5.

6.4 – Results obtained from the test activities

In this section, the results and data obtained from each test is exposed.

First, the duration time of the experiment and number of triggered soundscape points are presented because these were two variables considered crucial to the evaluation of the research goals, as it will be explained in the next chapter (6.5). Therefore, the following table presents the data obtained:

Participants	Time	Number of Soundscape Points
Tester 1	22min13sec	21
Tester 2	1h28min44sec	37
Tester 3	1h02min36sec	38
Tester 4	1h06min54sec	38
Tester 5	46min05sec	28
Tester 6	55min59ec	28
Tester 7	42min43sec	31

Table 7 – Field test results (Time and Soundscape Points)

Besides this data, the GPS location readings allowed that it was possible to posteriorly remake the route that each participant performed along the experiment. Those routes are presented in Appendix E.

From the mobile devices, important data according to the device's performance was collected in order to understand how, technically, the device would behave with the developed prototype. The table 8 presented the obtained data:

Participants	Battery usage (%)	RAM usage (Mb)	Data transfer (Mb)
Tester 1	15%	154,10 Mb	3,11 Mb
Tester 2	32%	185,22 Mb	7,76 Mb
Tester 3	22%	174,68 Mb	3,42 Mb
Tester 4	21%	180,33 Mb	4,16 Mb
Tester 5	24%	181,25 Mb	3,78 Mb
Tester 6	22%	179,15 Mb	4,14 Mb
Tester 7	30%	180,19 Mb	4,03 Mb

Table 8 – Mobile devices retrieved data

The remaining information was obtained through the questionnaire performed during the interview to each participant. In the next section the feedback collected from the interview and the results presented here, were analyzed in order to evaluate the experience and the research goals that were intended to achieve with this dissertation.

6.5 – Analysis of Results

The current section exposes all the results, feedback, and data that was collected and extracted from both the field tests and the questionnaire performed after the test, in order to perform an evaluation of the prototype performance and the user experience.

6.5.1 – Mobile Devices

In the field test of the developed prototype, four different mobile devices (Smartphones) were used:

- Vodafone 875;
- Qilive 4.5'';
- Samsung Galaxy S3;
- Samsung Galaxy S3 Neo;

None of the devices experienced any problem running the application, even with the hardware differences between them. The usage of the devices was as presented in the table 9:

Participant	Device
Tester 1	Vodafone 875
Tester 2	Samsung Galaxy S3 Neo
Tester 3	Samsung Galaxy S3 Neo
Tester 4	Qilive 4,5''
Tester 5	Samsung Galaxy S3 Neo
Tester 6	Samsung Galaxy S3 Neo
Tester 7	Samsung Galaxy S3

Table 9 – Mobile devices used by participant

Each of these devices had different system specifications, and it was considered that testing the application in different devices would provide valuable feedback in terms of the application compatibility and performance. The data obtained and presented in table 8 allow us to observe that despite the time interval of the experiment, and the number of soundscape points, the performance on the devices did not suffer major deviations from test to test.

6.5.2 – User's experience analysis

To obtain and achieve the research goals that were proposed, several variables had to be considered, and was with that premise that the evaluation methods were defined.

First of all, being this dissertation focused on an exploratory interactive audio-only experience, where all the control and power of decision was at the participant's responsibility, there was a need to define metrics that would evaluate if the experiment had achieved success in an initial and direct quantitative way. For that purpose, to evaluate if the participant was engaged by the experience, the time length of the experiment and the number of soundscape points that the user triggered by walking through them, were considered has two variables that would provide a glimpse on what that data could allow us to prove in terms of user experience. The metrics were classified as follows:

Time intervals	Number of soundscape points	Classification
0 – 15 min	0-10	Failure
15 – 30 min	10-20	Satisfactory
30 – 45 min	20-30	Good
45 – 1h min	30-40	Very Good
+1h	+ 40	Excellent

Table 10 – Evaluation Metrics for time and number of soundscapes

According to this classification, based in simple raw data, the participants performance in terms of this two metrics, allowed us to conclude that there was not any case of an experiment classified as a failure, as presented in table 11.

Participants	Time	Performance Classification	Number of Soundscape Points	Performance Classification
Tester 1	22min13sec	Satisfactory	21	Satisfactory
Tester 2	1h28min44sec	Excellent	37	Very Good
Tester 3	1h02min36sec	Excellent	38	Very Good
Tester 4	1h06min54sec	Excellent	38	Very Good
Tester 5	46min05sec	Very Good	28	Good
Tester 6	55min59ec	Very Good	28	Good
Tester 7	42min43sec	Good	31	Very Good

Table 11 – Analysis of the test results according to the evaluation metrics

The former results would already give a perspective of how the users enjoyed and have had a good experience with the developed application and the concept itself. For further and deep analysis, the questionnaires feedback provided the outcomes and information's needed in order to evaluate appropriately this dissertation.

This mobile application, and the soundscape composition elaborated for it, was produced in the context of Coimbra. That is why a background of the participant users was needed. With the initial two questions of the questionnaire, this background was checked as seen in the table:

	Tester 1	Tester 2	Tester 3	Tester 4	Tester 5	Tester 6	Tester 7
Q1	Yes/No	Yes/No	Yes/Yes	Yes/No	Yes/No	Yes/No	Yes/No
Q2	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 12 – Answers to the questions about participants' background

Briefing up, living and studying in Coimbra allowed the users to have more knowledge about the city and of some topics explored in the soundscape composition, which determined the attitude and mindset to perform and enjoy the experience.

In order to understand if the soundscapes the users listened during their experiment, corresponded to the soundscape points they triggered along the entire journey, they were asked to make that identification.

	Soundscape Points Triggered (nº)	**Soundscape Points identified (nº)**	**Ratio of Soundscapes identified (%)**
Tester 1	21	12	57%
Tester 2	37	23	62%
Tester 3	38	26	68%
Tester 4	38	27	71%
Tester 5	28	16	57%
Tester 6	28	19	69%
Tester 7	31	22	71%

Table 13 – Ratio of identified soundscapes

Based on these results, and in the observations made during the interview when their perception of sound was still strong and the emotional effect of the experience was visible, it is fair to say that the calculated ratios reflect the walking the users had, since it is natural that some soundscapes were not perceived because they were not aware of them.

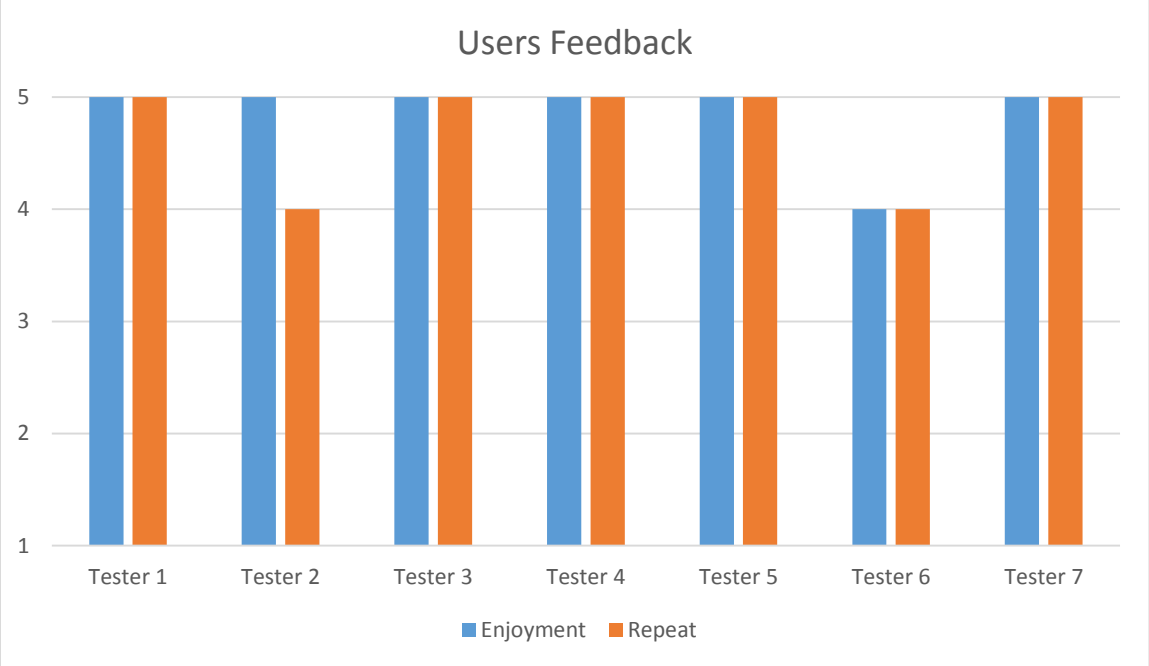

Figure 33 – Rating of users' enjoyment with the experience and repetition value.

The above graph contemplates the experience outcome of each user after the field test. They were asked to classify, in a scale of 1 to 5 (none-much) their enjoyment with the experience and if they would repeat it. As observed, the feedback given was tremendously

positive and it gave guarantees that some of the research goals for this project were being achieved. The results given in table 11 and from the above graph, allows us to verify that the elaborated soundscape composition provided positive feelings in the users, giving them enjoyment at the end of the experience and valuable repetition factor for the designed prototype.

With the same table and graph results, the first question proposed in the research goals for this project started to be validated. Evaluating from the time length of the field test, the soundscape points that were triggered and the quantitative feedback provided by their user experience in the graph, enforced by the 100% of "No" answers to Question 18, it is possible to observe that the users, with a mobile application and only depending on themselves and on sound sources, could have the motivation to walk, decide, explore, and re-discover known places, powered by the soundscapes that were being played and provided the user with an engagement and immersive feeling during the field test.

As an auditable complement for further analysis of results, the questionnaire/interview full answers and routes followed by the users were compiled in Appendices D and E.

The Figure 34, displays in a scale of 1 to 5, the intensity of the emotions reported by the users. This graph, is the one that exposes and reveals the true meaning and output of this dissertation, and its crossover with the research goals. The emotions, feelings, inner experience, that a person can achieve while using a mobile application that provides them a unique sound experience while walking through their surroundings. With this qualitative feedback from the users, more research goals were attended, because the emotions revealed demonstrate how sound as a sense or medium, activates memories, stimulates behaviors, and more important, provides a great share of emotions and feelings, leaving the person at the end experience totally overwhelmed by the inner impact that was submitted to.

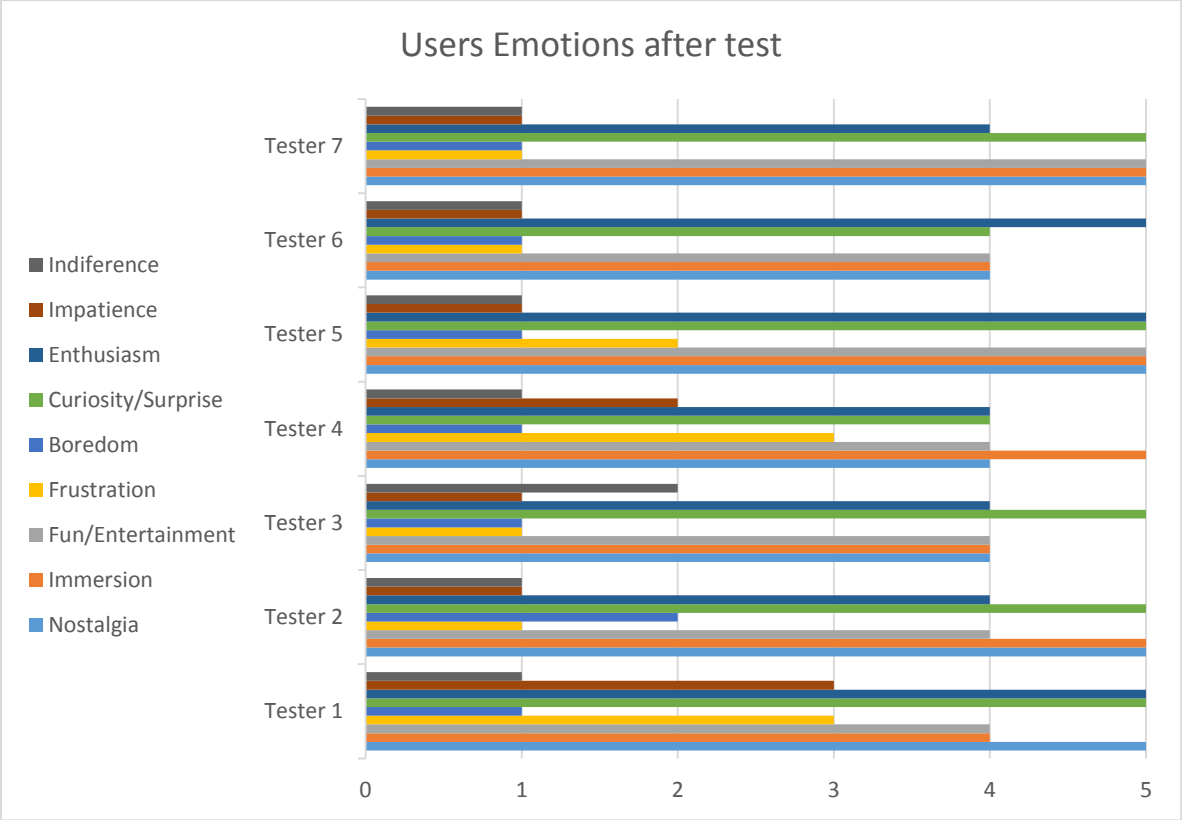

Figure 34 – Graph with the emotions experienced by the users'

As mentioned in previous chapters, the soundscape composition embraces several themes about Coimbra, and the soundscapes that represents those themes are about different periods and events that were not happening at the moment, but that happened in other timeline and space. Intentionally, that was an objective while structuring and elaborating the soundscape composition. As the above graph demonstrate, the combination of those soundscapes triggered various emotions in the users, and as part of that, the responsibility is of the soundscapes selected and of their occurrence in time and space.

When users where asked (Question 9) about that duality, they all had experienced that reality ambiguity, because they knew they were on a trip and that they got engaged and immersed in the sonic environment, realizing that they were in a physical space but at the same time, not mentally present, at least fully.

The analysis of the previous paragraphs allowed to gather more information and feedback that was determinant to achieve more research goals of this dissertation. The sound experience really had an effect on the users, they stated that mixing realities and "travelling" in time was something experienced in an effective way.

The stated results, the feedback collected, qualitative and quantitative, gave us a good insight on how the experiment with the mobile application delivered an experience that was not expected by the users. For me, as the observer of the tests, and after giving the instructions for them to test the prototype, I expected that at some point the users would be annoyed or asking too many questions, because they would want to act as I expected, or to "win" as if this was a game, but no. With the feedback I received on the field, and the results obtained and presented above, we were achieving the design and research goals.

Chapter 7 – Future Work

The current chapter presents some topics and suggestions to be taken as future reference about this project. Therefore, the following two sub-chapters are of great value for the information that is disposed for future work.

7.1 – Problems detected and proposed solutions

Before the application testing (Evaluation chapter), which was the phase were problems with the prototype were effectively detected by the users, there was already one existing problem mentioned in the end of the prototype development: when the mobile screen shuts down, because it goes into sleep or lock mode, the application enters a standby state, as it is part of the Android system, and when it resumes, the application comes up again and fully functional as normal. This was a problem because, while the GPS, accelerometer and compass sensors were still activated when running in the background, the audio sources (soundscapes) did not play anymore because the application entered a paused state. This was a major inconvenient not only in terms of usability, but also in terms of the soundscape composition experience for the user. Being the application developed in Unity, to go around this problem, a solution might be developing an external Android Plugin that could allow the Unity game engine to run Android applications in the background without a break in functionalities.

After the application has been tested by the several participants, one problem that they mentioned was a direct consequence of the previous stated problem: during the walk the users performed, they had to have the smartphone always in the hand because the screen had to be active all the time through the test. A possible solution for locking the screen and still run the application with all its functionalities, is proposed in the previous paragraph.

The other detected problem, was related to the audio playback. Sometimes the 3D audio spatialization did not work well, the application could not decide to which channels it should play the sound; on other moments, an abrupt cut (stop) in the playback of the audio track happened and of a sudden it started playing again or at the same time of other audio track; and sometimes the fade in and fade out of the sounds was not very smooth. In the end, this sporadic problems related to the audio playback did not affect the user experience. A proposed solution for this, since the sounds are only played when the user virtually walks by them, is to perform adjustments in the accuracy and reading of the GPS, accelerometer and compass sensors, because the device sensors are the ones that allow the movement input of the player in the game scenario.

7.2 – Additional features and different usages for the project

To the developed prototype, some features could be added in order to make it more complete and technically richer. The application is an interactive mobile audio-only experience, and based on a self-exploratory concept the user had no information of where the sounds were located because they were not displayed in the map screen.

So, an additional feature could be the representation on the map of the sound point's location. This could be done in a more direct or indirect way: the map could only display some markers that indicate where sounds were located; the map display could be divided in "hot" and "cold" areas, giving the user an idea of where to move or avoid; or the map could draw a smooth line over the streets or zones that would indicate that there were sounds.

In the case of soundscapes that the users did not understand or recognize, optional accompanying textual/graphical information could be displayed, also offering a path to the hearing-challenged population.

The application could also have a thematic option. This means that before starting the interactive walk, the user, according to its mood or destination, had the option to choose what kind of soundscape composition he intended to listen.

Another additional feature could be the possibility of any user, any person, personality, institution, to elaborate a soundscape composition based on a theme for a defined location, and distribute it in an open platform so that anyone could have access to it. This would provide a more social and multiplayer profile to the application.

Essentially, this project has a big potential in the tourism market. It could be used instead of standard audio-guides because the information it delivers is not so informative and descriptive, being more based in real sound recordings or even in representative soundtracks. This applies to tourists, to school's visits, or even when a friend or family comes to visit the city (Coimbra, in this case), providing a different contact and experience. Also, the application could be used in a videogame concept. A group of users could decide to take a walk and compete with themselves to see who identifies (their representation or meaning) more sounds, or even in a geocaching perspective.

Chapter 8 – Conclusions

This chapter was written to present the conclusions taken from all the work developed during the whole project. It was a personal and professional challenge to develop such work and reach the goals that compelled to the realization of this dissertation.

The main goal of this project was successfully achieved. A prototype of an interactive mobile audio-based application, in an augmented reality context, was developed, and evaluated through user fieldtestings', together with the achievement of other important research goals that were proposed in the beginning of this dissertation.

Based on Acoustic Ecology, Acoustic Design, Soundscapes Ecology and Sound Design the creation of a balanced, healthy, and meaningful soundscape composition was also performed with success.

According to Truax words, listening is "*the processing of sonic information that is usable and potentially meaningful to the brain*", and this was an essential factor that lead the elaboration of this dissertation. Listening is different from hearing, and the value that sound has in our lives, is of major importance. This is why the goals of this project were focused on the production of knowledge, because there was a need to know and understand how a mobile application in an audio augmented reality context, could affect and empower a personal and emotional experience.

The evaluation realized for this project, was of extreme importance to validate the research goals, the proof of concept that involved the user, and an interactive audio augmented reality mobile application. This validation was accomplished due to the results and feedback obtained from users. They reported having experienced emotions, and that was, without a doubt, the most valuable achievement with this work.

Still regarding the evaluation, it is fundamental to acknowledge that it allowed to determine that pervasive games and augmented reality through audio components was achieved.

Although the proposed goals were achieved, this dissertation allowed the exploration of one other component: my personal experience and knowledge.

Sound always fascinated me, not by music itself, for example, but how it has a strong impact in the human behavior and how we do not know how to appreciate it in an adequate way. That was what impelled me to embrace this project and to understand and achieve more knowledge and experience about this medium.

This way, during the elaboration of this dissertation I improved my mindset about sound experience, and acquired important knowledge about the following subjects:

- Acoustic Ecology
- Soundscapes Ecology
- Sound Design in Games
- Pervasive Gaming
- Augmented Reality

- Unity3D platform development
- Design Research Methodology
- Evaluation techniques, such as usability and field tests.

To finish, a mention to the fact the work developed and the final product and knowledge achieved, had suffered through the dissertation period several changes to its planning, and that although decisions and time constraints were always permanent factors, I was given enough flexibility to explore and cope with, all the personal and technical interferences that occurred during this project.

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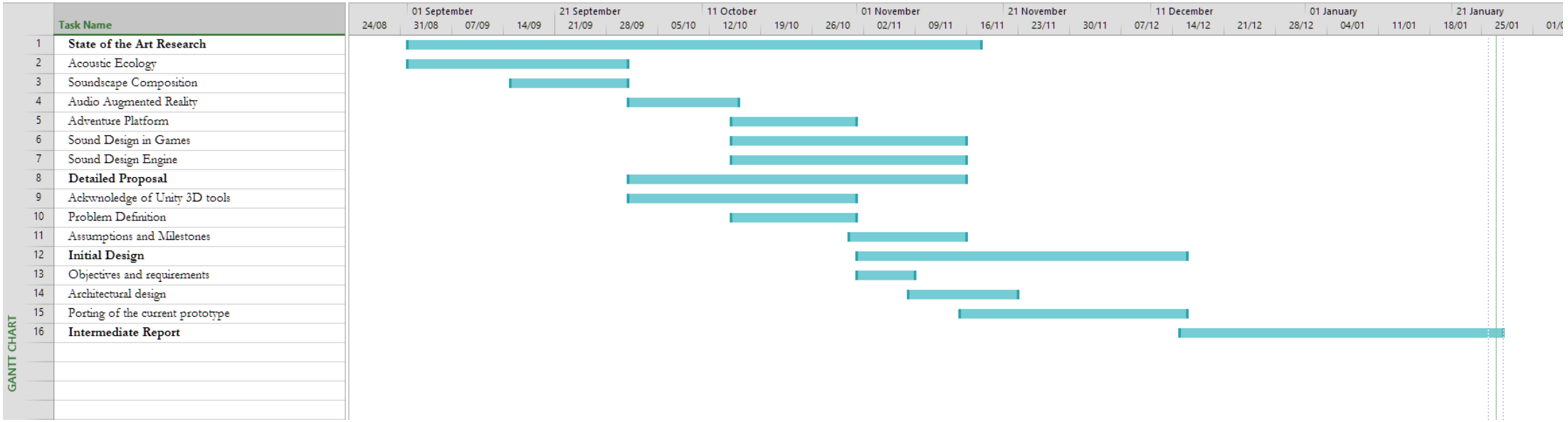
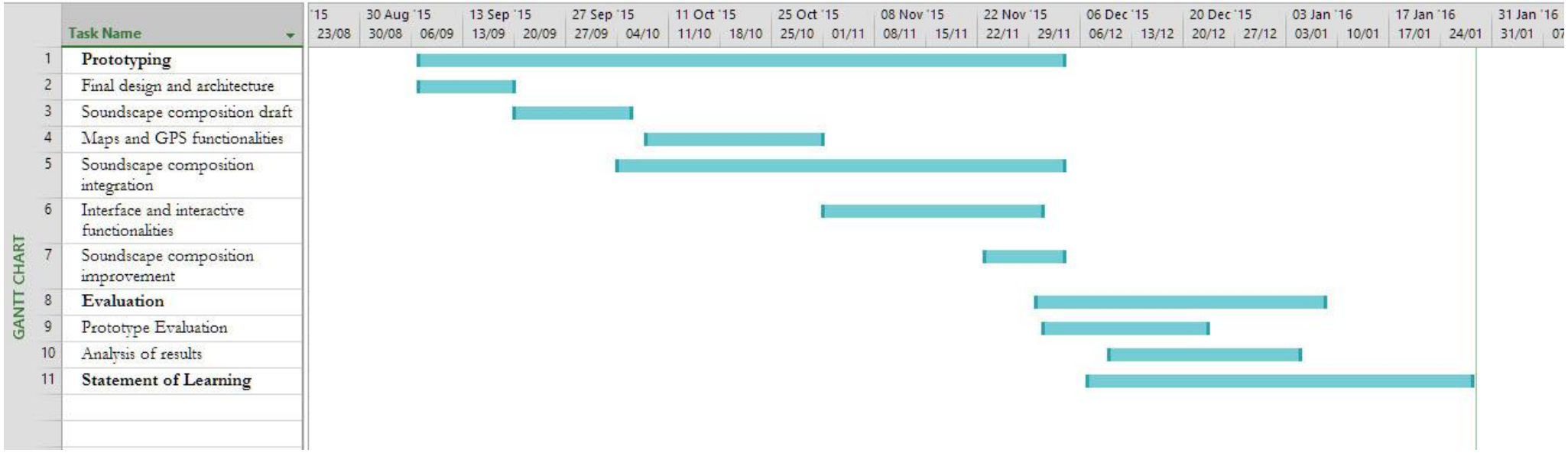
Appendixes

A – First semester Gantt's Diagram



B – Second semester Gantt's Diagram (Corrected)



C – Questionnaire for the interview

	Question
Q1	Do you know Coimbra? Are you from Coimbra?
Q2	Are, were you a student in Coimbra?
Q3	Which events/moments/soundscapes did you identify/recognize?
Q4	Which events/moments/soundscapes did you not understand/recognize?
Q5	Which event/moment did you like more/was your favorite?
Q6	Which event/moment did you dislike or did not relate to?
Q7	Did you want to know more details about something that you heard?
Q8	Did you feel nostalgia?
Q9	While performing the test, at any moment did you feel temporal/spatially dislocated/transported?
Q10	On a dislike/like scale of 1 to 5, how much did you enjoy the experience?
Q11	On a scale of 1 to 5, would you repeat the experience?
Q12	In what context would you use the application?
Q13	What did you like the most in the experience?
Q14	What did you dislike in the experience?
Q15	Do you think this experience could be applied to other cities?
Q16	If the app was free, would you download and use it?
Q17	If the app was paid, what price/suggestion do you have?
Q18	Would you like/prefer if the app told you in which direction you could/should move?
Q19	Suggestions for the functionality of the app?
Q20	Did you had some problems with the app? Which ones?
Q21	What emotions/feelings did you experienced during the test?

Table 14 – Questions for the interview

D – Participants answers to the questionnaire

	Q3	**Q4**
Tester 1	Manifestation, Alberto Martins, church and latin, battle sounds, guns, swords, a student serenate, football recording, musics of "tunas"(estudantina - traçadinho), "praxe", "praxe" musics , heartbeat, ´"bênção das pastas", "queima do grelo", "Carlos paredes", "cortejo/queima"	Church, battle, heartbeat
Tester 2	Random momentos in several parts of the city, some thematic, others historical. Crickets in botanical garden, "cortejo", heartbeat, "serenata - Sé Velha", "Moelas bar", horses "couraça", gunshots, revolution, battle, "pitagórica" music, students "repúblicas", 1969 student crisis, academic groups, medieval musics, "queima", football recording, music with a guitar, Luís de Camões, "rasganço"	Journey from "Portagem" to "Couraça", horses walking, the medieval musics, Camões reciting a poem, medieval speech, heartbeat.
Tester 3	Birds in botanical garden, "Repúblicas", "queima", "cortejo", drinking, football recording, horses, battle, fight, "Sé Nova", "queima do grelo", romans music, "Sé Velha – serenata", "Moelas bar", medieval, medieval market, ladies from the market, eletrics, trolleys, war, horses, fight in "couraça", church, latin, "Sermão aos peixes"	Horses in "Couraça"
Tester 4	"Rasganço", "Alberto Martins", "queima do grelo", football recording, "Carlos paredes", "cortejo", "Camões", "Cabra" bell, "Repúblicas", Botanical Garden, "Zeca Afonso", "Sé Velha", medieval área in "Almedina", "Couraça"	"Couraça" área, "Almedina" market
Tester 5	Football recording, "Rasganço", "queima do grelo", "bênção das pastas" speech, "Luis Cilia", 1969 crises, students rebellion,	"Sermão dos peixes", "queima" or "latada", arabian and medieval musics

	"queima", arabian music, "Cabra" bell	
Tester 6	Eletrics,troleys, "Sermão aos peixes", "rasganço", drinking, "queima", students rebellion, "Alberto Martins", "Assembleia magna", "Carlos paredes", ambiance music	Heart beat, academic rebellion
Tester 7	"Serenata", "FRA", "rasganço", students rebellion, "Alberto Martins", arabian music, "Padre António Vieira" street, romans music, ocean sound in botanical garden, horses, gunshots, battle, fight, football recording, "Carlos Paredes", "Pitagórica", "Sé Nova", "queima do grelo", latin speech	Arabian music, horses, battle in "Padre António Vieira" street

Table 15 – Answers to the questions Q3 and Q4

	Q5	**Q6**	**Q7**
Tester 1	"Queima", "cortejo", "praxe"	Speaking Latin	Yes
Tester 2	"Cortejo", sound of ambulances	Garden crickets	Yes
Tester 3	"Serenata" and "moelas bar"	Football recording	Yes
Tester 4	Sound of "cabra"	Night/bars sound	Yes
Tester 5	Football recording, "Sermão aos Peixes", "rasganço"	Instrumental tracks, too much noise	Yes
Tester 6	Botanical garden sounds, musical tracks, Carlos Paredes	"Rasganço", students protesting	On one hand, it's better to not know. On the other, yes, but I'm not if I want.
Tester 7	"Sé velha", "serenata -balada da despedida"	Speaking Latin	Yes

Table 16 – Answers to the questions Q5, Q6 and Q7

	Q8	Q9
Tester 1	Yes	Yes, for the sounds not recognized
Tester 2	Yes	Yes. I noticed. Events with different dates
Tester 3	Yes	Yes. The balance between the academic part and the medieval
Tester 4	Yes	Yes. Specially near "matemáticas" and the medieval fair in "Akmedina"
Tester 5	Yes	Yes…there is the feeling of immersion
Tester 6	Yes	It evoques the idea of being there in another context.
Tester 7	Yes	Yes. The memories of student life

Table 17 – Answers to the questions Q8 and Q9

	Q10	Q11	Q12
Tester 1	5	5	Turistic route, entertainment, informative. What I did not know stayed in my memory
Tester 2	5	4	I had the will to visit some places to see what sounds could be in that place. I enjoyed to explore, searching for sounds to look for. Would use in a touristic way, to know more about the palces, and as a videogame, because I wanted to understand what was the sound about, pausing, and turning back to see if there was more.
Tester 3	5	5	Turism – bringing someone to visit; context of videogame with other persons, who identifies more sounds.
Tester 4	5	5	Walking, alone or in group. Different of an audio guide because it has a soundscape perspective and not something descriptive. Ideal for a family coming to visit Coimbra. Someone arrives at Coimbra by train, grabs a taxi and during the ride listen to this sounds.
Tester 5	5	5	Turism. Better for cases when I know the city because it is familiar, and being introduced in the time and season by the music, sound, is totally different and there is a loto f immersion. Excelent way to rediscover the city.
Tester 6	4	4	Walking, daily routine, I play the app and go for a ride to experience the soundscape composition. If I was a tourist, I would want a more formal contact. Without background knowledge, he could not interpret.
Tester 7	5	5	Turism and information. Education.

Table 18 – Answers to the questions Q10, Q11 and Q12

	Q13	Q14
Tester 1	Having a walk and listenning to sounds around you, makes you travel in time and in your memories.	Phone in hand, cut between audio tracks.
Tester 2	Remember some memories lived in Coimbra. 3D sound gives direction and improves experience.	Phone in hand.
Tester 3	Takes you to the city by your ear. A journey of memories.	Cut between sound tracks.
Tester 4	The difference between sound intensity while approaching or evading, as between left and right. Good feeling when walking up "Couraça", listening and seeing the view. The fact of not being limited, being responsible for my own route and that is the most valuable in the experience.	Night life sounds can be annoying.
Tester 5	Rediscovering the city, the places, the views, the nostalgia.	Technical issues such as fade in and fade out, leveling of the tracks. 3D audio with problems, sensors get confused sometimes.
Tester 6	Different way to absorb a walking experience, it embraces us, and it is enjoyable to the senses. Gives some feeling of internal meditation.	Technically: sounds needed adjustments, maybe because of the sensors. Intensity does not change smoothly. I would enjoy more a musical and ambiance soundscape, not so much about academic life.
Tester 7	The way that a sound, just by listening to it, gives you a memory or emotion. Enjoyed how sounds adapt volume down and volume up.	Nothing to report.

Table 19 – Answers to the questions Q13 and Q14

	Q15	Q16	Q17
Tester 1	Yes	Yes	Trial period and then, I would pay
Tester 2	Yes	Yes	1€
Tester 3	Yes	Yes	With more cities, 2-3€, who buys one city will want to buy others
Tester 4	Yes	Yes	Being used in more cities. Between 4-5€ for app/city
Tester 5	Yes	Yes	1-3€
Tester 6	Yes	Yes	99cents for soundscape. for N soundscapes, N*99cents. 99cents for a package of one walk
Tester 7	Yes	Yes	2€

Table 20 – Answers to the questions Q15, Q16 and Q17

	Q18	Q19
Tester 1	No.	Giving hints about the route I could make, according to the sounds I heard.
Tester 2	No.	Representation of hot and cold areas in the map. When sound is strange, having a button to display textual information.
Tester 3	No.	I just need to know the global radius of action, where are sounds. Could have textual information when a sound is not recognized.
Tester 4	No, because it suggests in an indirect way.	The "charamela", "porta férrea", "morcegos da biblioteca joanina". The person can choose between different options: or a historical route, a night life route, an academic life route, and so on. I would like that all the places had a sound, because sometimes I felt lost without a sound.
Tester 5	No.	For someone not from the city, more instrumental sound and more exact facts, informative. And more soundscapes, more points in the map.
Tester 6	No, but know where	Geocaching mode. Choose between moods: historical, ambiance, academic life, religious theme.

	sounds are, not telling me where to go. I want to be in control of my walk.	Possibility to choose what I want to hear. If it was an open platform, the possibility that anyone could create a soundscape and turn it available for others to hear.
Tester 7	No.	Historical context, written text, but it is distracting.

Table 21 – Answers to the questions Q18 and Q19

	Q20
Tester 1	Having the phone in the hand.
Tester 2	Being lost without knowing what direction to choose. Lack of textual information in case of not knowing the sound.
Tester 3	Stops and cuts in the sound. Not having the phone in the hand, but else in the pocket with the earphones only.
Tester 4	Phone in hand.
Tester 5	Positional audio, track leveling, two tracks at the same time and level is confusing, absence of fade ins or fade outs.
Tester 6	Technically: adjustments in sounds, volume according to distance, and "bumping" in volume. Besides that, information to know where sounds are, which streets have sounds. Fade ins, fade outs, volumes, stereo.
Tester 7	The indecisions in the path to take, if I go this way or the other way.

Table 22 – Answers to the question Q20.

E – Participants route through the tests

Tester 1:

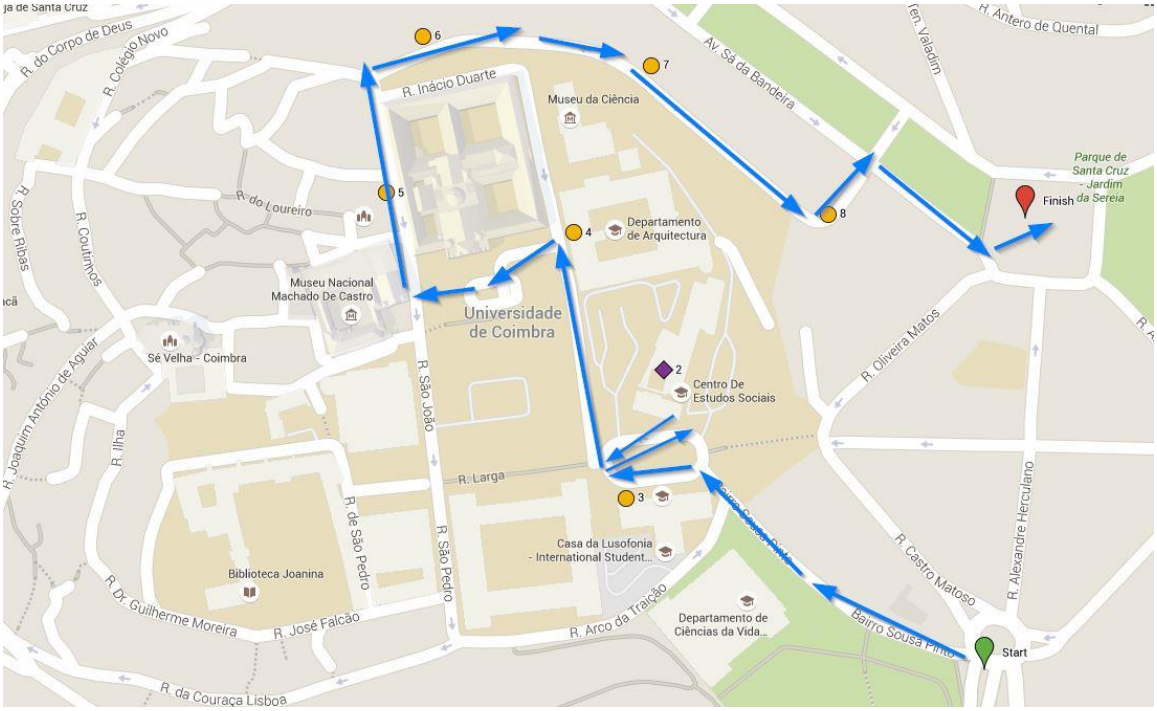


Figure 35 – Tester 1 performed route

Tester 2:

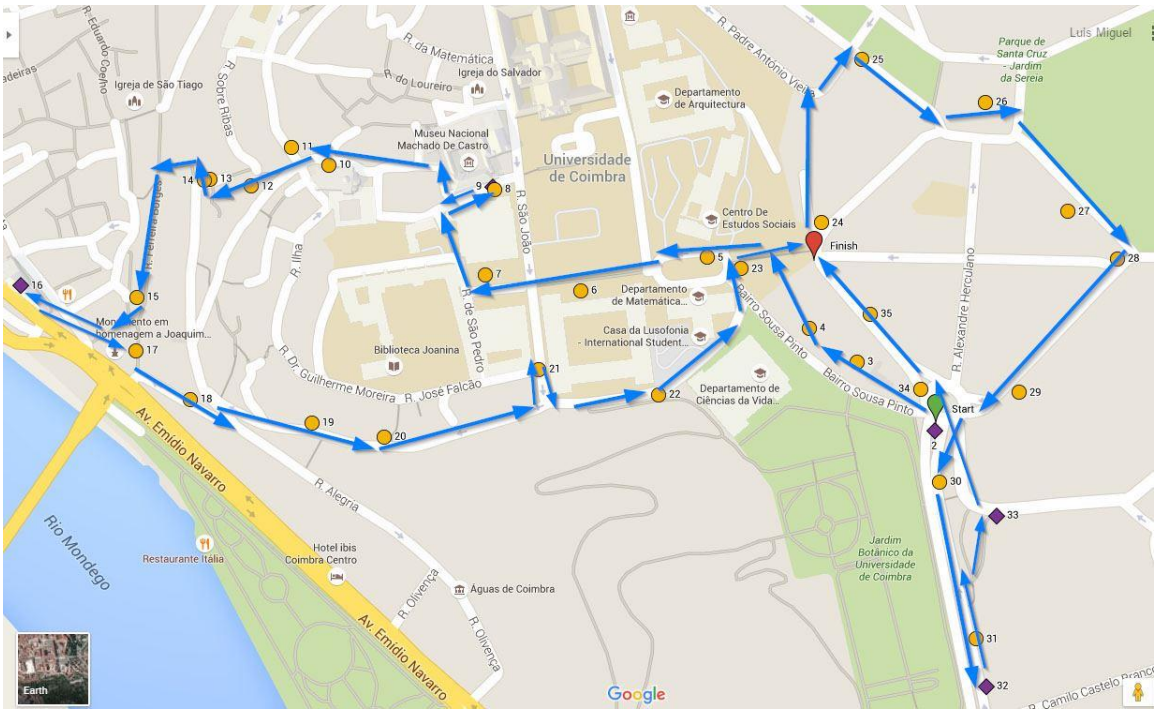


Figure 36 – Tester 2 performed route

Tester 3:

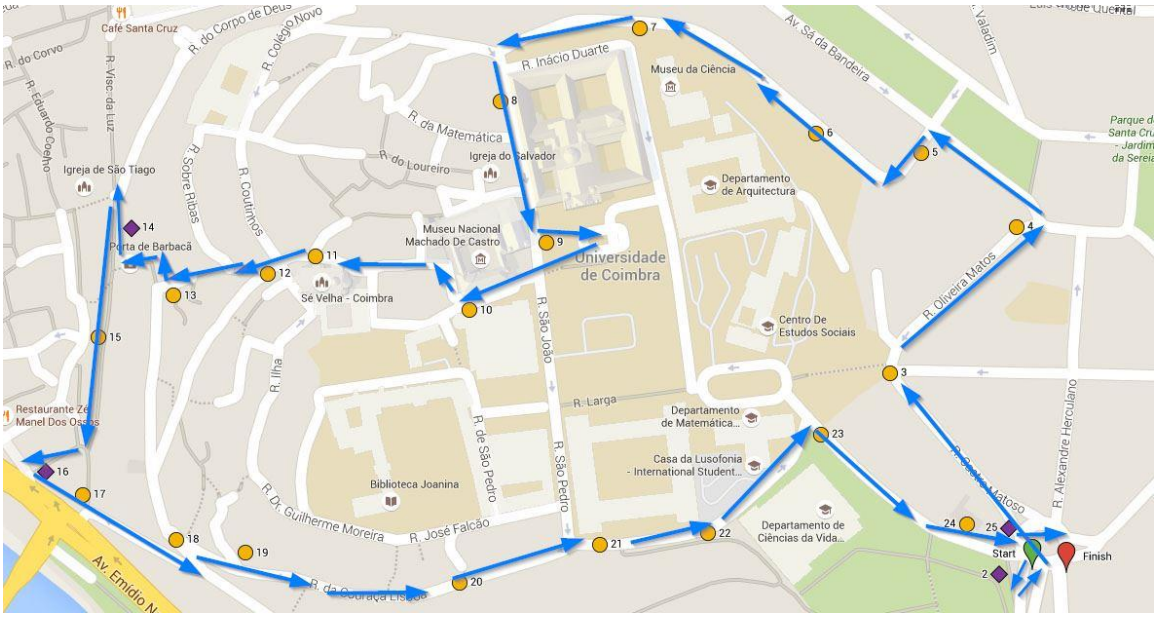


Figure 37 – Tester 3 performed route

Tester 4:

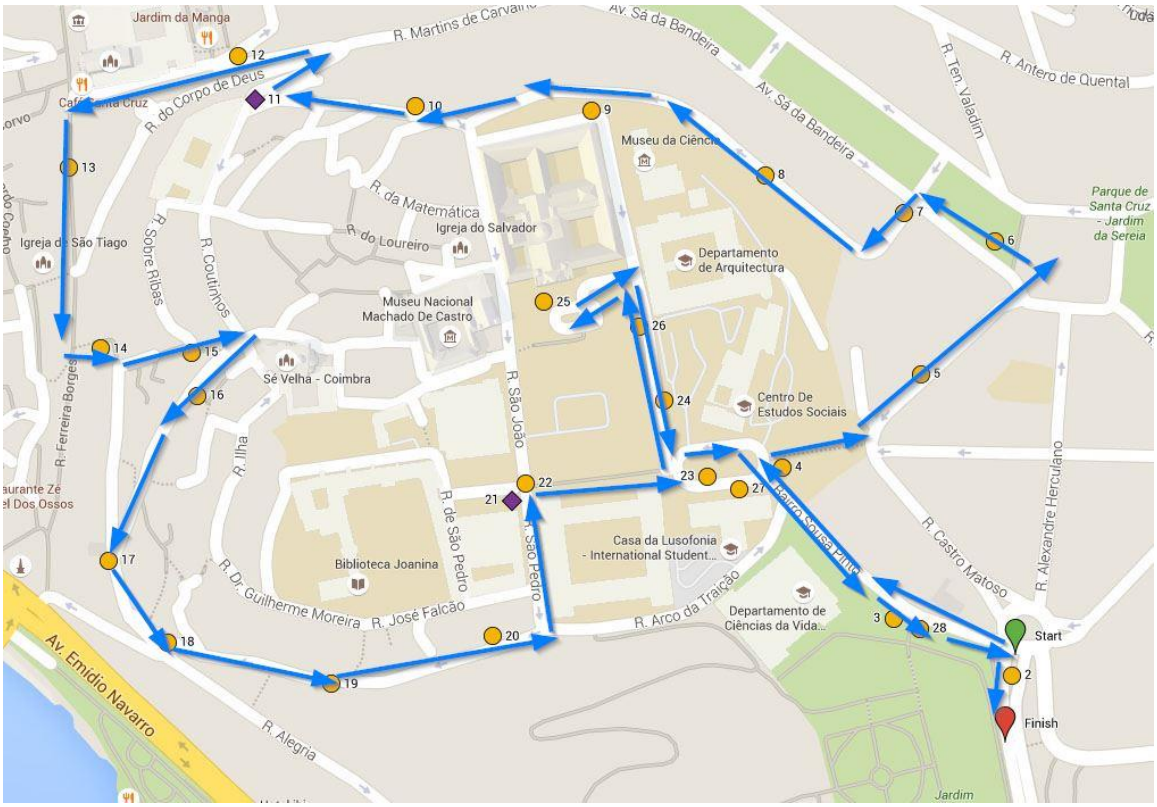


Figure 38 – Tester 4 performed route

Tester 5:

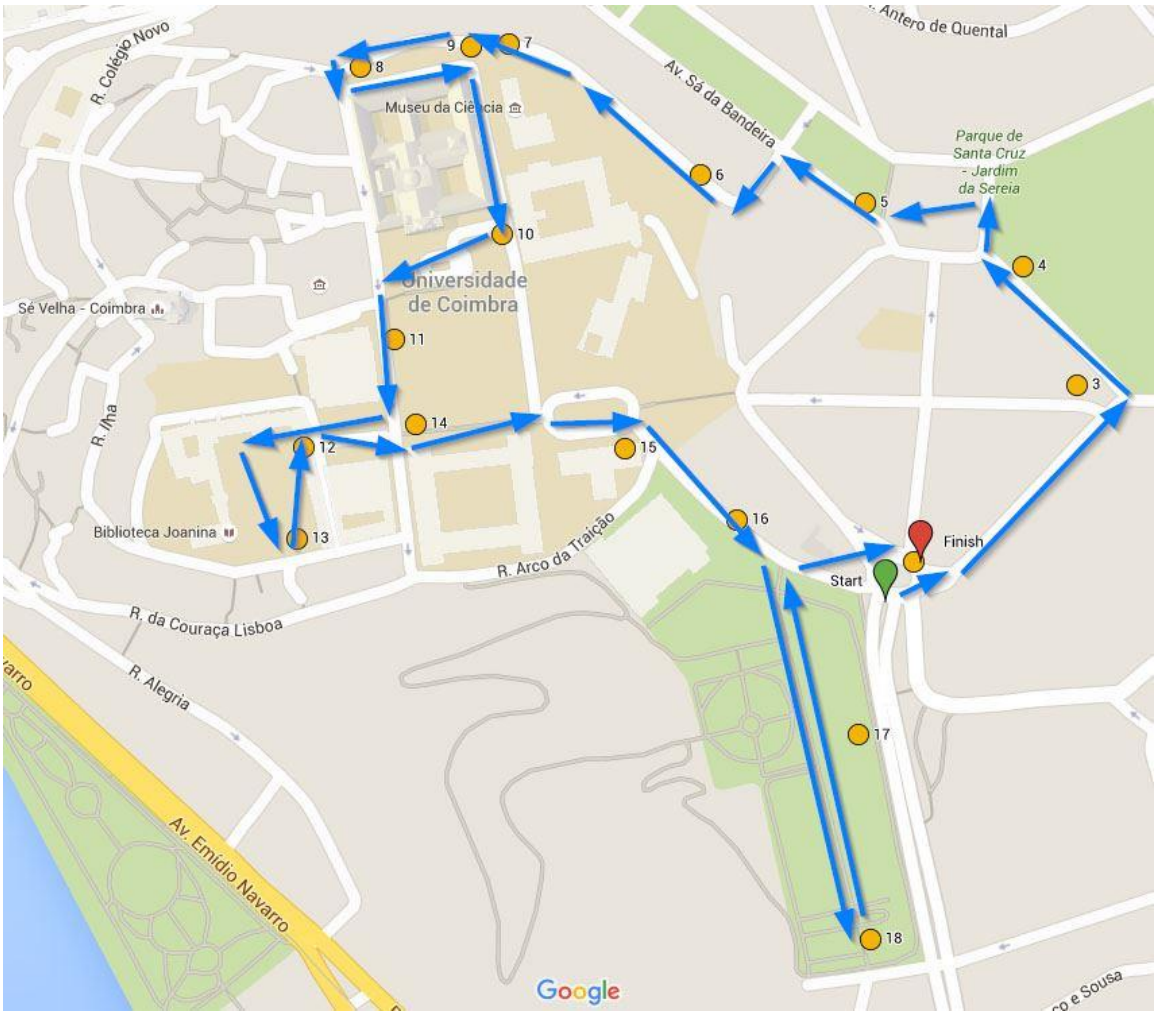


Figure 39 – Tester 5 performed route

Tester 6:

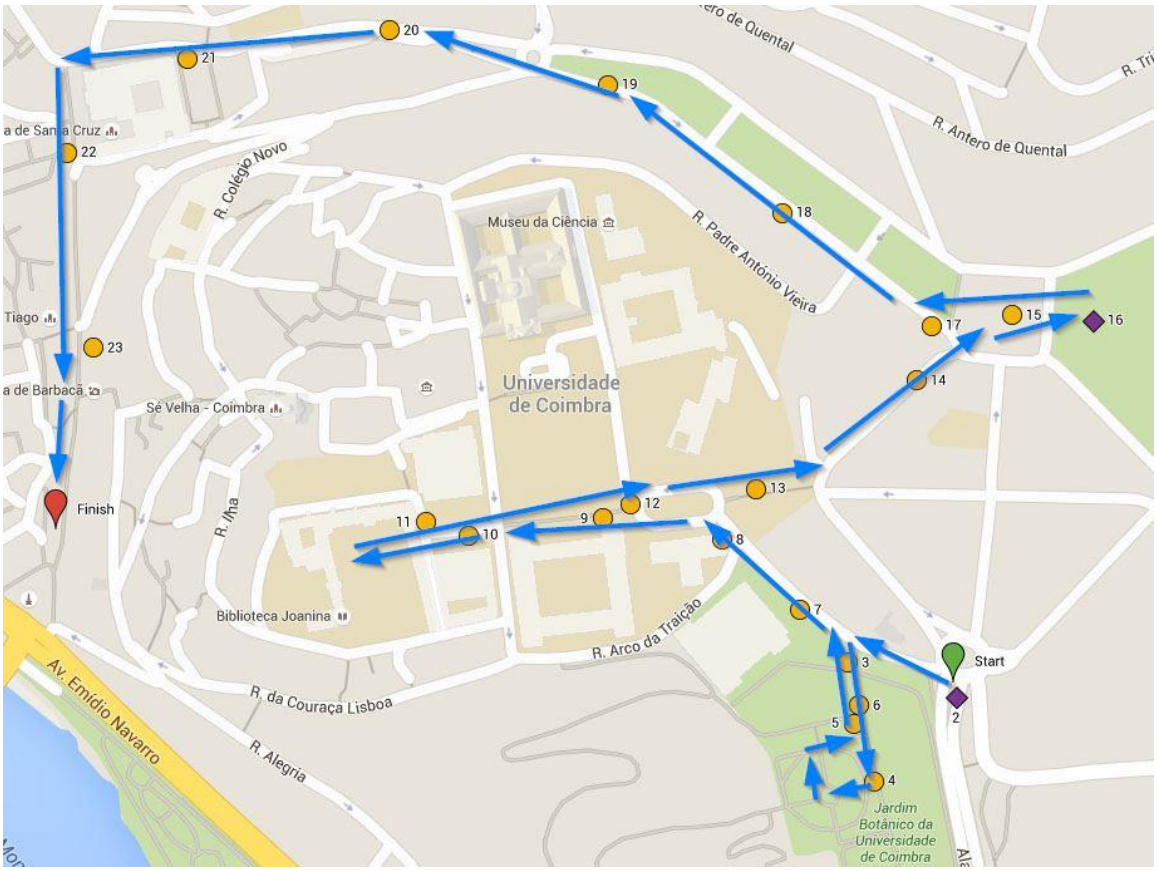


Figure 40 – Tester 6 performed route

Tester 7:

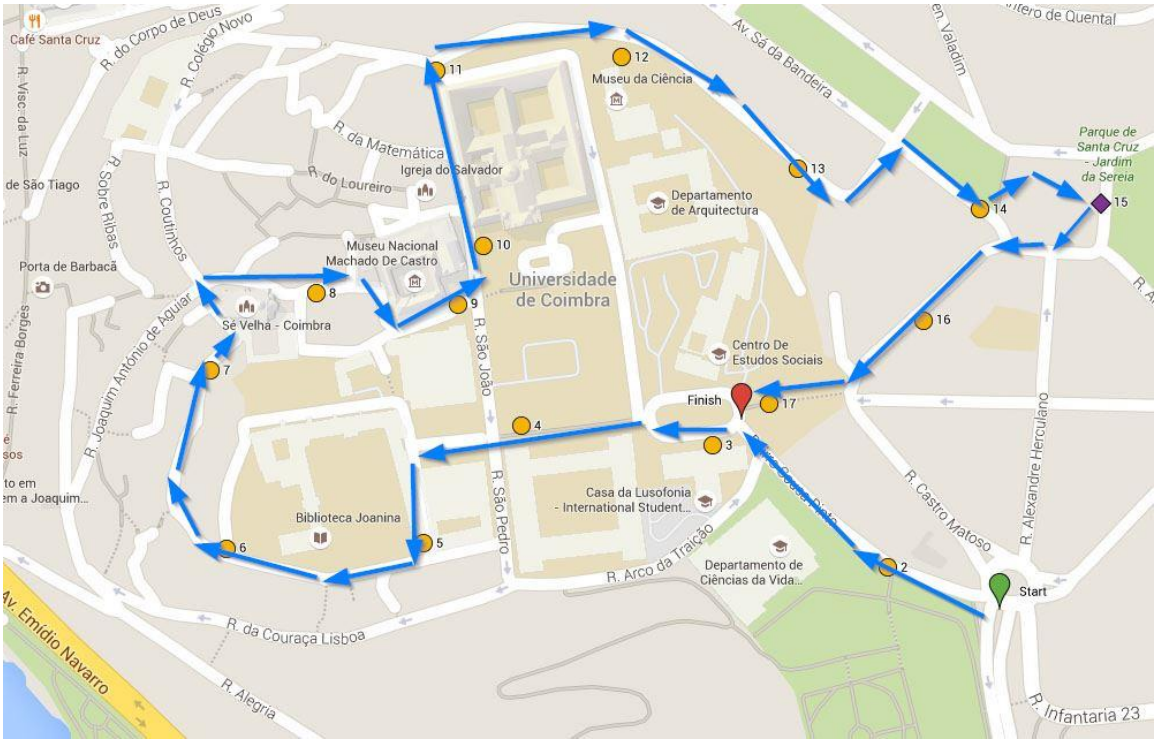


Figure 41 – Tester 7 performed route

F – Prototype Interface

Figure 42 – Game Main Menu

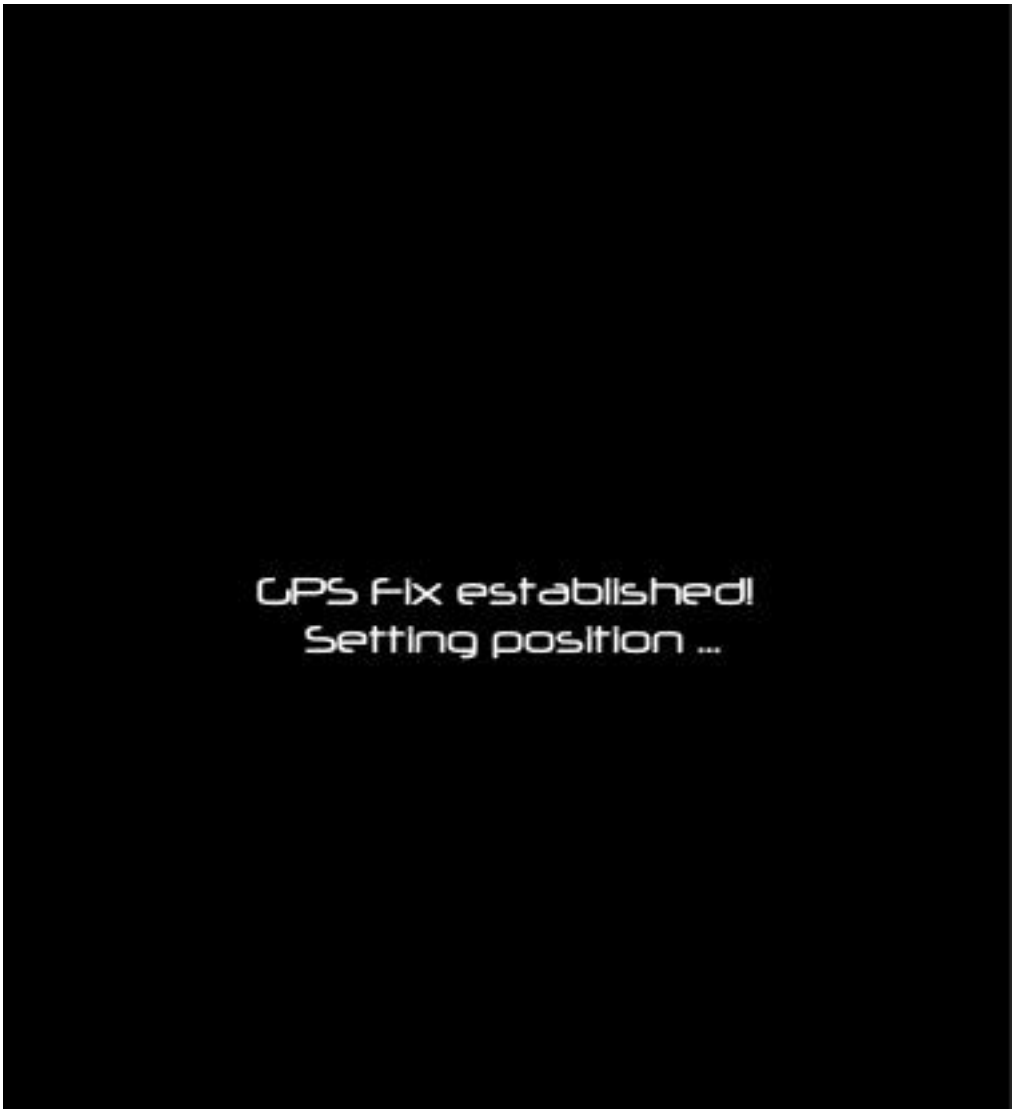


Figure 43 – Screen for fixing GPS position

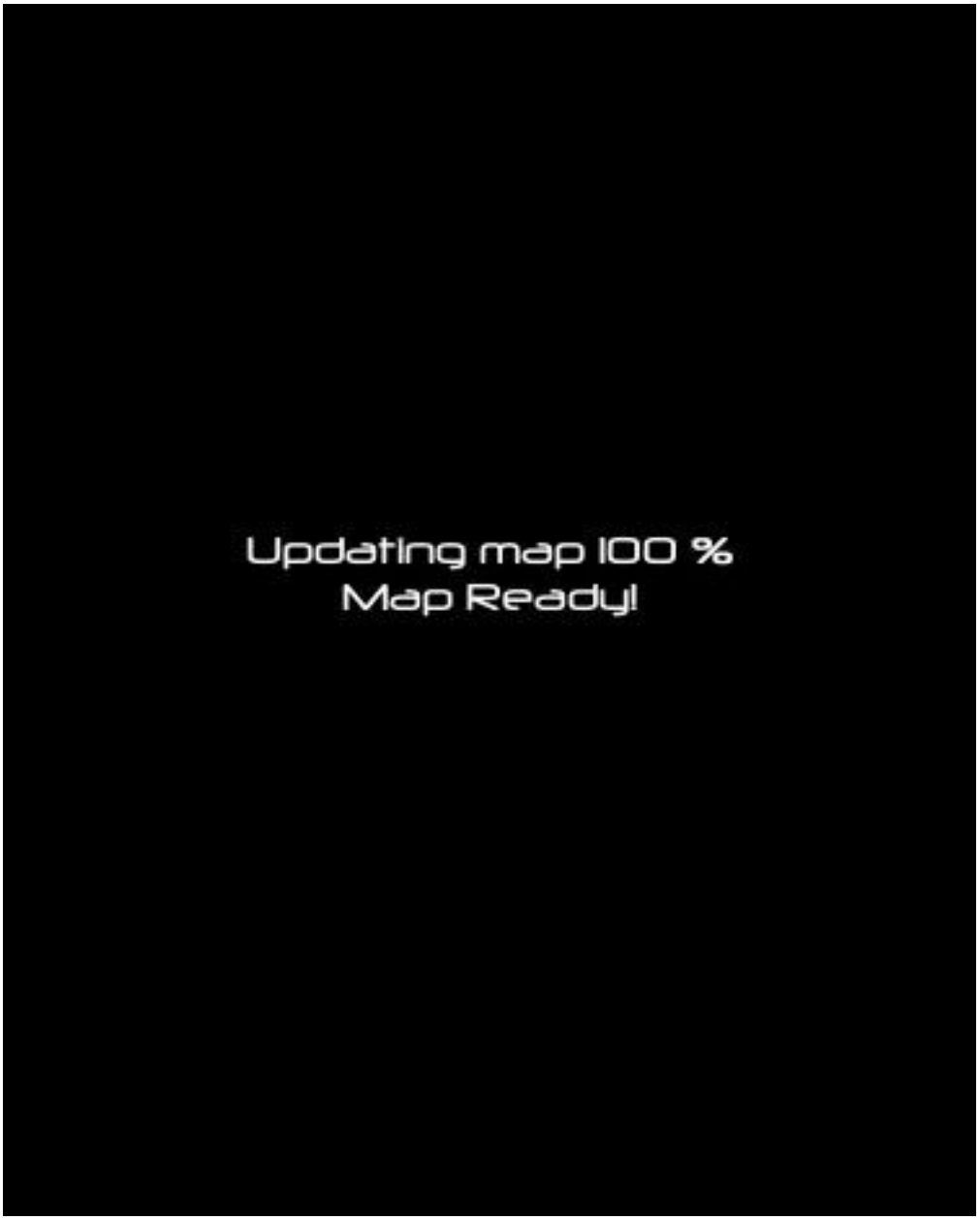


Figure 44 – Google Maps loading complete

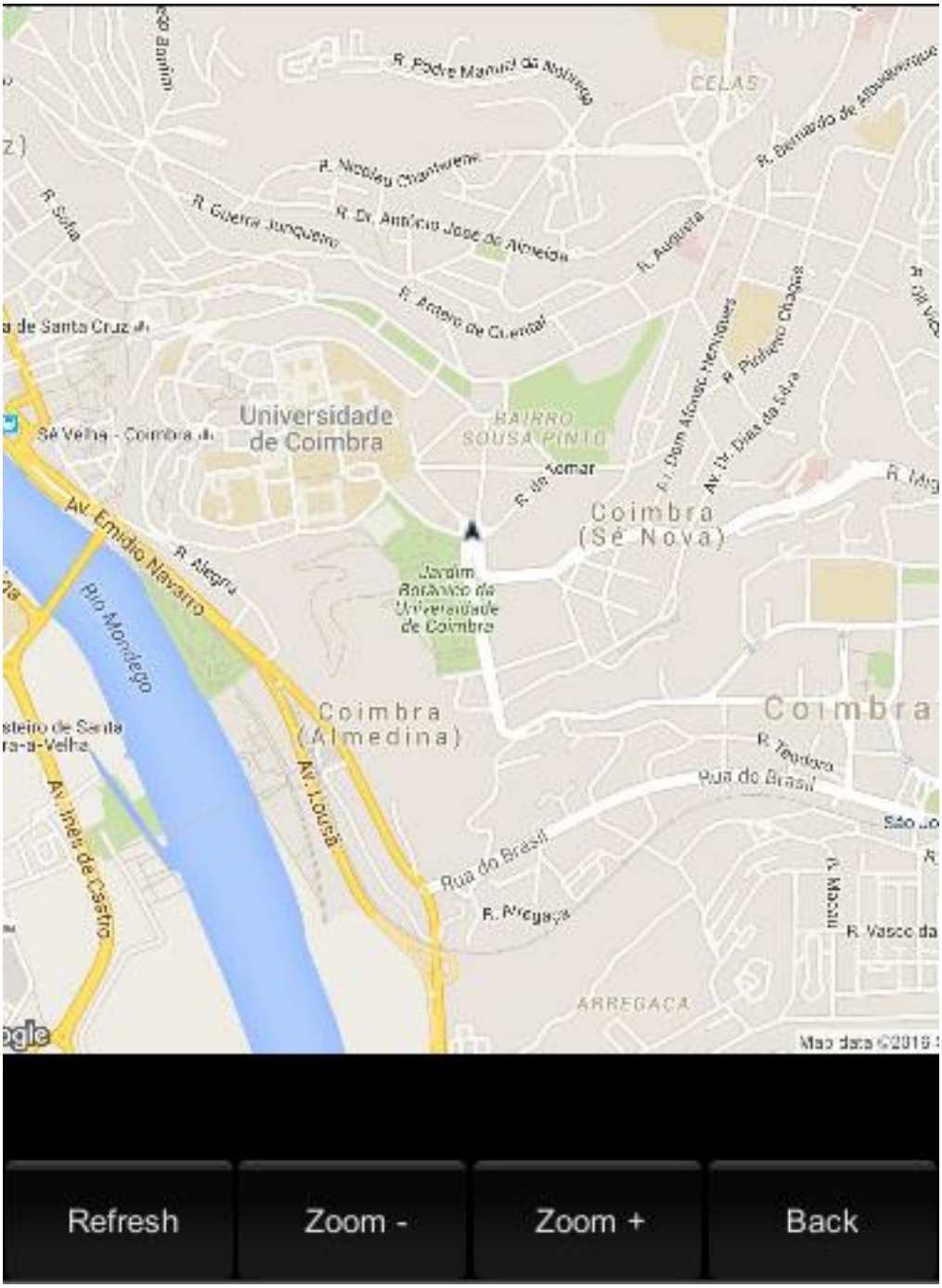


Figure 45 – Game Screen. The blue arrow is the player, and a bottom menu with functionalities.

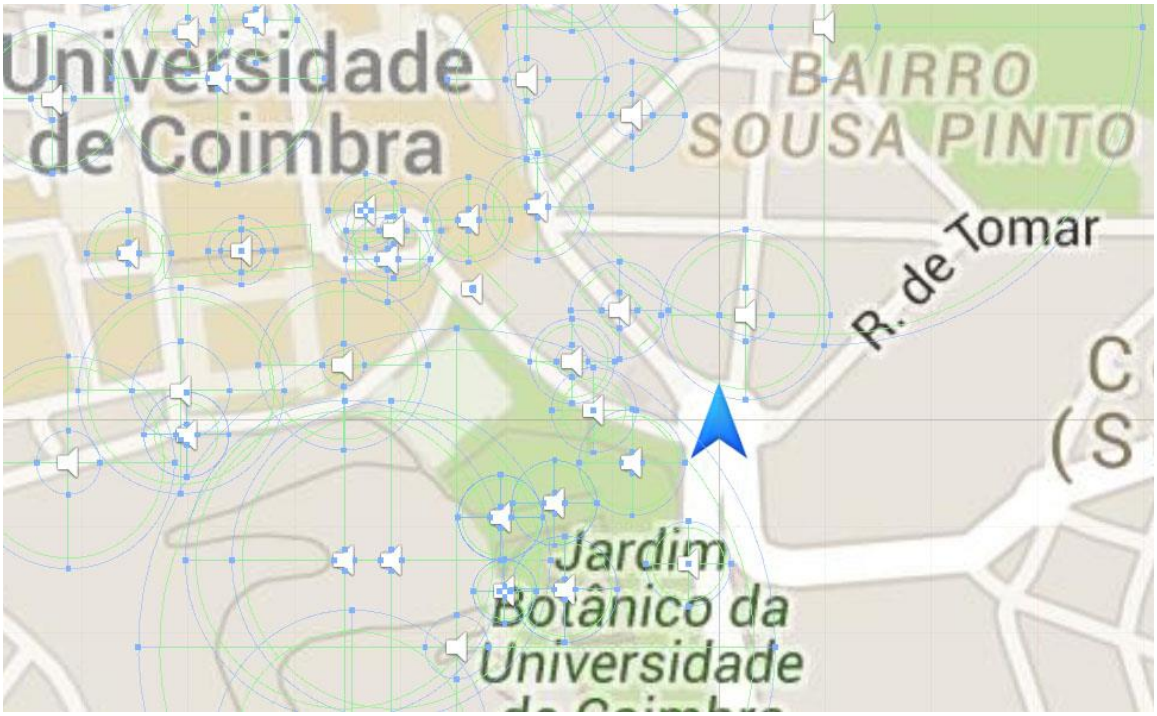


Figure 46 – Soundscapes position in the map with respective radius. Not visible while the player uses the application.

G – Glossary

API – acronym for Application Programming Interface, which englobes methods, protocols, tools and features to build software components;

Apps – abbreviation for Applications (software);

AR – acronym for Augmented Reality;

Assets – in Unity3D, an asset represents any type of item or file that can be used in a Unity project. It could be an image, a sound, a script, a font, a 3-D model, among others;

Audio Listener – it is a component of Unity3D that acts as a microphone device. It receives input (sound) from an audio source and plays it in the scene;

Audio Source – component that plays a sound, an audio clip;

Collider – colliders' are invisible components that define the shape of an object that will face physical collisions, for gameplay purposes;

Components – in Unity3D, a component is a functional item that provides a behavior and characteristics to a GameObject;

FMOD – sound effects engine for videogames and applications, with multiple features to manage and control sound and audio sources;

GameObject – unique items in Unity3D, being objects that represent characters, properties and that perform other functionalities when Components are attached to them;

GPS – acronym for Global Positioning System;

Maximum Distance – a 3D sound setting that represents the distance where the sound volume stops attenuating;

Minimum Distance – a 3D sound setting that functions in opposition to the Maximum Distance. The closest from the Min Distance, the loudest the volume of the sound;

Play on Awake – an audio source starts to play automatically when running a Unity3d scene;

Pitch – the playback speed of an audio file, slower or faster;

Rigidbody – a component of Unity3D that provides physical behavior to an object in a realistic way, such as gravity and reaction to collisions;

Scene – a scene is as empty space that could be the equivalent to a level in a game, once it will contain objects and items;

SDK – acronym for Software Development Kit, a programming package that allows the creation and development of software applications for specific platforms. It contains API's, programming tools, libraries;

SLAM – acronym for Simultaneous Localization and Mapping, an augmented reality game feature that is aware of its surroundings without any visual markers;

Soundscape – a soundscape is a sound, or group of sounds, that composes a certain acoustic environment;

Sound Layer – categorization of sound according to Nick Peck [Peck 2001] in Ambiance, Dialogue, Music, Foley, SFX;

Spread – the spread, diffusion of the angle of the 3D stereo sound in the speaker surroundings;

Volume RollOff Mode – determines the speed at which a sound fades and stablishes a relation between the source and the listener. The higher the volume, the closest the listener has to be before starting to hear the sound.

VR – acronym for Virtual Reality.