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Open-Source Georeferentiation for Resilient Communities

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Resumo

No mercado das comunicações móveis há uma variedade considerável de telefones móveis com tecnologia de posicionamento (localização utilizando GPS - *Global Positioning System*). Os dispositivos móveis com tecnologia de posicionamento podem identificar padrões em movimento e, por exemplo, recomendar eventos com base na localização dos mesmos.

O crescimento atual de dispositivos móveis habilitados com receptores GPS, câmaras, acelerômetros e acesso à Internet oferecem novas oportunidades para as novas aplicações multimídia. Tais aplicações permitem ajudar comunidades locais a partilhar recursos usando geo-localização, mapas interativos e realidade aumentada.

Atualmente, os serviços móveis podem ser reforçados com conhecimento do local, revelando as suas características e respectivos detalhes, proporcionando ao utilizador uma transição suave para os serviços sensíveis ao contexto. Este tipo de aplicações podem ser encontradas em diversas áreas, tais como informações sobre viagens, compras, entretenimento ou eventos.

A diversidade de eventos (culturais, desportivos, entre outros) que as cidades dos dias de hoje têm para oferecer, dificultando a sua escolha e levando a optar por um destes mesmo eventos seja uma tarefa complicada para os seus habitantes. Assim, a existência de uma ferramenta que divulgue e ajude na tomada de decisão de qual o evento a selecionar, torna-se importante e útil para todos. A combinação de telefones móveis e sistemas de recomendação contribuem para ajudar os seus utilizadores a efetuar a escolha relativamente a um evento, fazendo a seleção a partir de uma grande diversidade de acontecimentos. Assim, nesse âmbito foi desenvolvida uma aplicação móvel que atribui uma pontuação a um determinado evento com base nas preferências do utilizador, seus hábitos e sua localização. Eventos esses que serão ordenados por relevância numa lista ordenada e num mapa, metendo os eventos mais relevantes em destaque. A aplicação foi testada, avaliada e demonstrada, e está pronta para utilização.

Abstract

The impact of the current growth of mobile devices usage, enabled with GPS receptors, accelerometers, continuous Internet access, almost carried by the owner, gives the opportunity to create new relations inside local communities to support local resilience through an extensive use of participatory mapping (crowd-sourcing) and help local communities. Users can share resources and reduce expenses using geo-location, interactive mapping, augmented reality, and graphical user interface techniques.

This dissertation focuses on the design and construction of a mobile system that follows location and content-aware approaches on ubiquitous multimedia applications, performance evaluation of a weight algorithm for multimedia mobile events agenda. In order to deploy this concept for mobile events agenda the user behavior settings are analyzed. This analysis presents to users only information inside their interests and relevant to them. Knowing the users' behavior it is important to provide them the best information, and avoid irrelevant information. This relevance-related information shows their interests and, at the same time, relevant information concerning the users' localization. The application also provides new means to distribute new content and events. Besides that, an alert notification was constructed in order to alert mobile users of a relevant event.

Developing a mobile application that gives a score for each event based on user preferences and their location. Those events are sorted by relevance in an ordered list and a map. The application, developed for iPhone iOS operating system, has been tested, evaluated and demonstrated, and it is ready for use. An application for iPhone was developed to prove the above-presented solution.

Keywords

Mobile computing; Ubiquitous computing; Pervasive computing; Mobility; iPhone; iPhone applications; Multimedia Applications; Location-aware; Context-aware; Content-Aware; Localization; Global positioning system, Web services.

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Acronyms

API	:	Applications Programming System
GPS	:	Global Positioning System
GSM	:	Globally System for Mobile Communications
HTTP	:	Hypertext Transfer Protocol
IDE	:	Integrated Development Environment
ICT	:	Information and Communication Technology
LCD	:	Liquid Crystal Display
PC	:	Personal Computer
PDA	:	Personal Digital Assistant
SMS	:	Short Message Service
SOAP	:	Simple Object Access Protocol
SDK	:	Software Development Kit
URL	:	Uniform Resource Locator
UBI	:	Universidade da Beira Interior
XML	:	Extensible Markup Language
Wi-Fi	:	Wireless Local Area Network

Chapter 1

Introduction

1.1 Focus and Scope

Richard Matthew Stallman is a software and freedom activist, and computer programmer [1]. In September 1983, he launched the “GNU is Not Unix” (GNU) Project [2]. The GNU Project aimed to create a free Unix-like operating system. Richard Stallman is the leader architect of the GNU project. Stallman is a pioneer of the concept copyleft. Several copyleft licenses have been written by Richard Stallman, the main author, including the GNU General Public License, the most used free software license [3]. He has also developed a large number of software, highlighting Emacs [4], GNU Compiler Collection [5], GNU Debugger [6], and vast list of GNU coreutils [7] as the most used. He popularized the concept of copyleft, which is a legal mechanism to project the modification and redistribution of free software.

Stallman started a non-profit corporation, named Free Software Foundation. The Foundation has free software programmers and a legal infrastructure for the free software movement [8]. Its objective is supporting free software movements and promotes the freedom to create, modify, and distribute computer software. Free software can be studied, used, modified, copied, and redistributed without restrictions.

During the past two decades, the number of new developers and supporters has increased. The free and open source software community has been developing high quality software. The high quality software proved to be a serious rival to property software produced by commercial companies [9]. Now, the open source community has large repositories for open source projects for being shared and used by the users of the community [10]. One of the ideas of open source was that anyone that needed some specific

functionality wrote some code, shared it with others and in return got enhancements of the functionality [11].

The current growth of mobile devices enabled with global positioning system (GPS) receptors, accelerometers, and continuous Internet access, offers new opportunities for new mobile multimedia applications. Such applications can help local communities to share resources using geo-location, interactive mapping, augmented reality, and visualization.

The mobile market is an emerging mass market with little research data available for use. Consumers are changing their habits; the Internet players are adapting their content to fit new needs. Although the business model is restricted to cost-per-use, with operators maintaining a high cost and network restrictions to avoid the massive use, data portability for mobile devices has yet to take off. Mobile devices fulfil the true purpose of the Internet to offer better connectivity anytime, anywhere. The tendency of the wireless technology goes beyond the walls of houses, university buildings or hotels, and reaches the open spaces of nature or mobile spaces of trains and buses. The mobility that users appreciate to use on their mobile devices being able to speak everywhere and without the need for registration in a wireless local area network and can extend to other Internet services such as Web browsing, e-mail, news reading, online radio, or even watch streaming video and television.

Embedded technology is increasing every day in mobile devices. The use of mobile devices is increasing among users. They view, consult, and find more and more content on the Internet. Users can explore and take advantage of these new technologies to study people's habits, including the future prospects of this new world order, and with an eye on the future in order to create new forms of content distribution. With embedded technology, mobile devices have many resources, so people tend to use them to access the Internet content more often.

Mobile or portable devices such as mobile phones and personal digital assistant (PDA) devices are small and light, and can be transported anywhere.

Then, this dissertation will focus on mobile devices that have Internet connection and a small screen, such as cell phones and PDAs. These portable devices can perform quite number of tasks, such as short message service (SMS), email exchange, Internet access, gaming, Bluetooth and Wi-Fi connectivity, infrared, photo camera and video recording, music player, radio and GPS, memo recording, and, most important, make phone calls. Figure 1 shows the most used mobile device features by users, including SMS, email exchange, Internet browsing, social networks and read news.

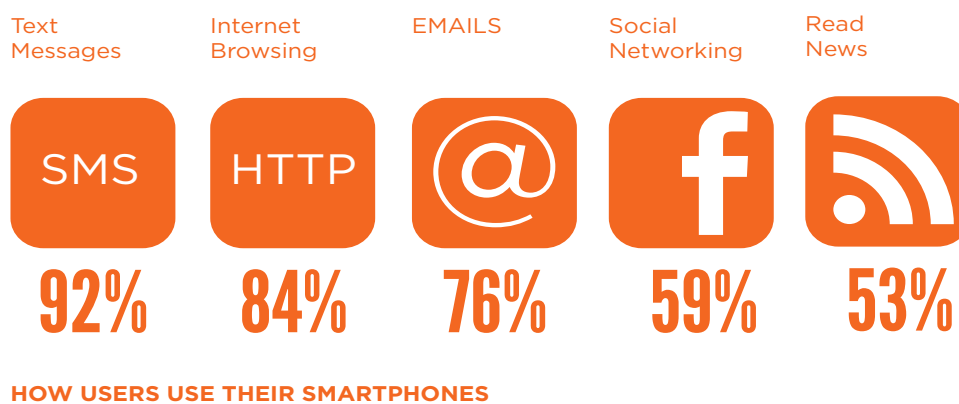


Figure 1 - Mobile devices applications usage in funtion of the number of users, in percentage [46].

Mobile devices also offer opportunities for a better and fast growing globally connected society, with social networks, blogs, and Web pages. These new approaches improved user-access to information through mobile communication. For clients/users, the main aspects and benefits are based on their interests regarding what they want to see and how to see it, speed and lower cost Internet connection. The benefits for mobile devices will affect battery, memory, performance of the processor and Internet connectivity [12]. The research community has been studying and developing new technologies, as well as new services and applications to enable ubiquitous environments based on the mobile technology [13]. Mobile devices improved communication efficiency enhancing user-experience [14]. This turns the mobile technology more widespread and the most common electronic device in the world. Nowadays, it is possible to say that mobile devices are the

future. Mobile phone companies will replace the desktop phones in North America by 2011, as shown in [15].

Mobile Internet or cell phones still requiring improvements regarding design and human-computer interaction. Areas such as entertainment and e-commerce are still limited by the screen size, so it is expected that mobile experience deserves its own design customized to their needs and best practices, efficiency, and accessibility. The small screen size of a mobile device does not correspond to a liquid crystal display (LCD) monitor with 22 inches. Portable devices are often used when people require information or use a specific functionality. The development of these screens and devices also brings new issues, paradigms, and semantics for the world of mobile applications [16].

When the iPhone appeared, it caused a revolution in the world of cell phones because it brought innovation to this market by integrating a phone, an iPod, and an Internet communicator. All in one combined with multi-touch, wide screen, and a user-friendly interface make the iPhone the most successful “technolust” [17] device of the world. The “look” of the device and the friendly user experience or “feeling” of the software now have a better “design”. The iPhone is currently benchmarked, being the device that other is trying to match. Some authors mention it is a device that Apple and Steve Jobs brought from the future with a Time Machine. The most important news related with the iPhone were the SDK and the App Store [18]. Customers have their life made easier thanks to the App Store; they can now download or purchase the applications using the iPhone, the desktop, and an iTunes Account. It is also possible to use the desktop application for Mac OS X or Microsoft Windows to synchronize and install applications later in their iPhone.

Currently, there are over 585,000 apps in the Apple Store, 450,000 apps on Android Market and 82,234 applications currently available in the Microsoft store. In the last three years has been developed over 300 thousand mobile applications, as can be seen in Figure 2.

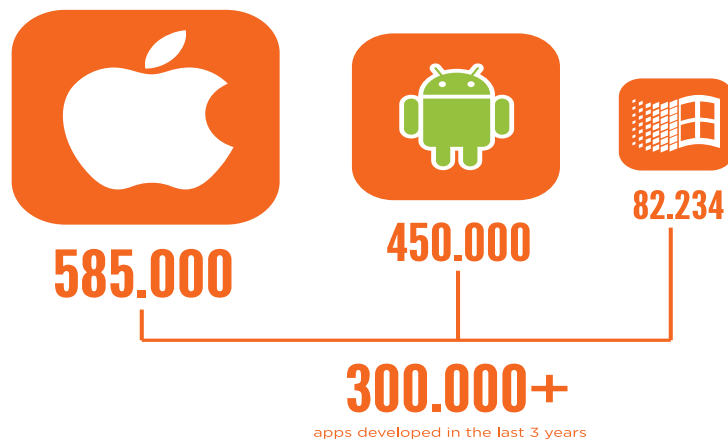


Figure 2 - Number of applications available in the market and developed in the last 3 years [47].

The total number of Apple applications downloaded on the apple store so far is 250 billion, on Android is 10 billion and finally on Windows applications is 217 million, as shown in Figure 3.

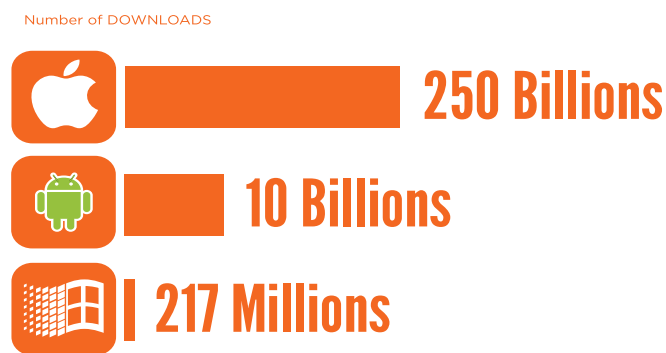


Figure 3 - Number of application downloads per major mobile operating system [47].

The iTunes Store was so successful that it sold more than four billion songs and maintains a catalog of more than six million songs [20]. The App Store is also very successful. It started with less than 500 applications and, in February 2009, it had more than 20000 applications [21] by April 2009 they were 25000, 35000 in May 2009, and are increasing every day [22]. Customers of the App Store downloaded more than 300 million applications and the

device had to be jailbroken through special software tools [19]. iPhone users did not bother with it and the operation was not fool proof because the Apple software updates could render it inoperable, requiring a complete replacement.

Mobile devices are getting smaller and powered up with add-ons, speed, and battery life. The possibility of realizing the vision of ubiquitous computing that was drawn at the beginning of the 90's is approaching [13, 23], combining it with the growth of short-range ad-hoc networks.

In the early 90's, Marc Weiser [25, 26] introduced his vision of ubiquitous computing. He presented a concept of a man-technology interaction with a complete abstraction of the user. However, Weiser's vision has a major difficulty taking into account the lack of technological support that at the time was not available such as it is available today [26]. A good example of ubiquitous technology is the Internet. Users access Internet only interested in information and services and not in the inherent technology. Users are connected everyday to several Internet access points without knowledge of protocol and network architecture used on a mobile device [27].

The ubiquitous collaboration between mobile devices and Web services is another form of intelligent applications that brings out the best of the two worlds, the server side resources and the client-side context and location [28]. The application is centred on content, where and how users want to see it, giving the location-, context-, and content-awareness. The information and context of the events on native applications allow a better visualization to the user, contributing to a satisfying physical exploration of cultural and information events [29].

Ubiquitous computing is the omnipresent relationship of things. Talking in terms of interaction, connection, management and information, creating calm and acting as quiet, invisible servants are the finalities of this technology. It should help human beings to expand their unconscious and intuition. Mark Weiser predicted the Internet would lead us through an era of "deeply imbedding computation in the world". "Clam technology" was the name given

to the approach to alter the place of this technology in our lives [30]. This wave of technology will have a big impact and change the place of technology in our lives, becoming increasingly its daily presence. Presently, every mobile device has Internet connection capabilities, which allow us to communicate with other devices and systems, creating a computational relationship between them in a calm ubiquitous context [31]. This designation of calm technology has the ability of going from the periphery of our attention to the center, and back again. Communicating with other devices, managing these relationships and empowering our periphery are some of the jobs of this technology [32]. Some mobile devices already have portrait modes and landscape. They need user interaction to do the changes; sometimes the user needs to change the application to perform that feature. This change of application sometimes involves the application closing.

Geo-location applications are becoming very useful due to an anytime and anywhere full connectivity. With them, the Internet goes a step beyond, overcoming the physical barriers imposed by building walls and by the limitations of network infrastructure. Nowadays, with mobile devices, it is easier to have access to all range of contents regardless of where user is, e.g. trains, buses, cars, restaurants, and public places. This means that users may perform a set of operations, like email checking, messaging, news reading, or even watching a television program without logging in a local wireless network [24].

Smart phones with GPS capability are becoming more widespread. This ability of the smart phones can be used as a personal navigator and a communicator device. There are various mobile navigation techniques to determine the location used on mobile multimedia applications [33]. Due to its portability and the vast range of applications, mobile devices are being appointed as the future when it comes to accessing multimedia content over the Internet. This access is made using Internet services in native applications. Adopting these techniques and concepts it was possible to develop an intelligent mobile multimedia application [33, 34].

The advent of mobile devices with location-aware and context-aware technologies such as, smartphones, cell phones, and tablets is changing users daily lives. They are capable of putting a pinpoint in our current location on a map or find information about a particular area. The number of applications that use GPS services and features is growing everyday [34]. GPS capabilities are all around us in mobile devices, but location-awareness with iPhone is changing everyone’s life. This device will put into the main stream the location-aware applications [35]. Pinpointing our location on a Google Map, tracking friends, giving a heads-up on what is going on in a given area of interest. The nearest place to eat, list of shopping areas near a user are some of the functionalities that it can offer users. For example, about 70% of young people (18-29 years old) use mobile devices to have access and to get local news for reading. With an aging generation mobile technology will become an important and powerful factor in the news industry [24]. In an urban environment about 48% of the residents use a mobile device to read local news. On the contrary, on a rural area only about 38% have access to local news, as may be seen in Figure 5.

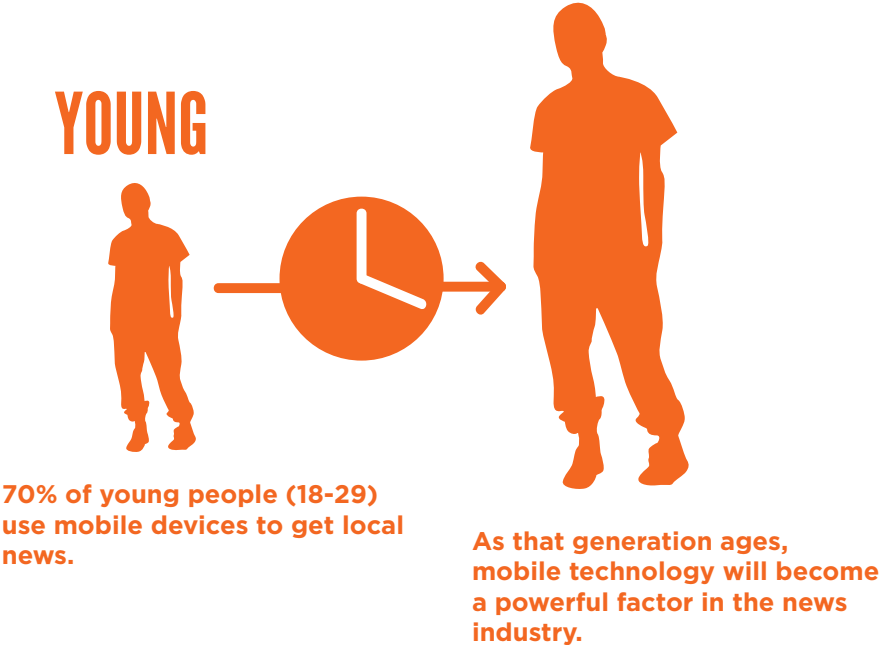


Figure 4 - Illustration of smartphone newsreaders by age [45].

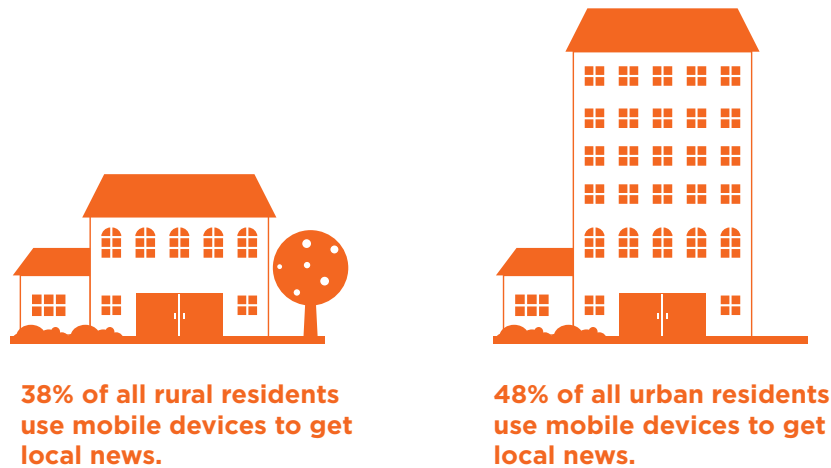


Figure 5 - Illustration of smartphone newsreaders by percentage [45].

In the Apple App Store people can find location-aware applications, such as *Loopt-Friendfinder* [36], application with virtual earth display, allows user to share his location with the community. *NearPics* [37] is a location-aware photo browser, and *Weatherbug* [38] is a location aware weather service with predefined cities. *Appetite* [39] is a restaurant picker based on your location. It can only choose a restaurant displayed on a map or only search a restaurant on a specific city. *AroundMe* [40] is an application that gets your location and allows you to choose the nearest bank, bar, gas station, hospital, hotel, movie theatre, restaurant, supermarket and taxi. Every day a new item is added to this list. An application for iPhone, called *N4MD - News for Mobile Devices*, is presented in [41]. This is an application to visualize the weekly news produced on the *Urbi et Orbi* newspaper of the University of Beira Interior, Portugal. The application *N4MD* runs natively on the iPhone devices and now, it is similar to hundreds of newspapers and magazines mobile applications.

Wireless capabilities are equipping mobile devices, and as users move in their physical and social surroundings, there are several contextual changes. Mobile devices have the capacity to communicate and deliver ubiquitous services, taking into account the environment, they adequate to the situation [29]. An important aspect of mobile devices is their portability and mobility. With the advent of wireless communication in mobile phones, smartphones, and tablets, ubiquitous computing has evolved as well. They take advantage of

their portability to have wireless connectivity almost everywhere [32]. In mobile computing there are still some technological hurdles to overcome, such as the variation on the quality of a wireless network, local access limitation, and energy constraints. These problems affect the user and also the computing experience directly [44].

Resilience is the capacity of an entity or a community to use its own resources to adapt to and resolve adversity in a positive way. It's a concept that is gaining some traction, especially when related to ecological topics, and also to the empowerment of local communities. Technology can play a major role in the resilience of a community, especially if a greater access to information by everyone can help strengthen the community itself. Another aspect that is worth to mention while, in smaller cities, generally the cultural organizations tend to have difficulties in reaching the public and consequently need better ways to communicate their projects. CityEvents, being a free distributed application and based on open source principles, can act as a tool to strengthen these organizations and help them to reach a greater audience, hence improving its resilience in a difficult socioeconomic environment.

CityEvents was targeted primarily to be an application for cultural events. However it can be easily rearranged to be a tool for improving the resilience of a community. It can act, for instance, as a geographical repository for all the important places in a community in case of an emergency.

1.2 Problem Definition and Objectives

Everyday, cities offer lots of events such as concerts, sport and much more, information flood is becoming in the last years a common reality. The user is reached by thousands of possible interesting information's, having great difficulties to identify the best ones, like concerts, restaurants, sports or cultural events. Having help to choose the most important and pleasing event becomes a frequent necessity. The current growth of mobile devices enabled with GPS receptors, cameras, accelerometers and Internet access offer new opportunities for new mobile ubiquitous multimedia applications. Such applications help local communities to share resources using geo-location, interactive mapping and several data representations. Mobile services can be enhanced with location-aware features. This dissertation investigates a weight recommendation algorithm for mobile, based on weighted formulas to perform a weight for each event. That weight is based on user preferences, location, and context.

The main objective of this dissertation is the design, construction, performance evaluation, and demonstration of a weight-aware algorithm for mobile events agenda. It should include Global Positioning System (GPS) for the user location, weight formulas to perform the calculations needed for the algorithm and give the property score for each event. The demonstration, validation, and performance evaluation of the mobile solution will be performed through a prototype, created for iPhone and was also accomplished a users survey in order to evaluate their experience with the system.

To reach this main objective the following intermediate objectives were identified and performed:

- Study of the related literature including mobile devices, geo-location events, ubiquitous computing, location-aware, context-aware, extended Booleans, and weighted means and norms;
- Requirements analysis;
- Proposal and design of the mobile system;
- Construction and deployment of a mobile solution for iPhone iOS;

- Demonstration, validation, and performance evaluation of the system on iPhone.

This work of research and engineering is expected to produce not only the desired API, but also provide the opportunity to disseminate the knowledge and software through a conference and a journal paper.

1.3 Main Contributions

The main contribution from this work is the study and proposal of a weighted awareness algorithm for mobile events agenda. A ubiquitous and easy to use mobile solution that provides real time awareness based information of local events and news was created. It embedded a location- and context-aware approach sorting and selecting personalized information in function of each user. Study and the implementation of a complete generic recommendation system, with both client mobile application and Internet service, and the verification of several re-normalization and data-fusion techniques applied to the specific case of news and events recommendation system.

The main contribution of the paper “*An Ubiquitous Mobile Multimedia System for Events Agenda*” is a mobile system that follows location and content-aware approaches on ubiquitous multimedia applications; it includes an application that allows users to choose which type of events he wants to see and also combine the visual layout of events on a map with the current position of the user, offering a perception about what it is closer to him.

The main contribution of the paper “*A Weight-Aware Recommendation Algorithm for Mobile Multimedia Systems*” is a study and implementation of a complete generic recommendation system and verification of several re-normalization and data-fusion techniques applied to the specific case of news and events recommendation system.

This contribution considering both location and context awareness, and a weighted aware algorithm for mobile events agenda, is planned to be

submitted for publication in an international journal. An earlier version of this article only considering CityEvents architecture, the communication with client and server side was submitted for *Wireless Communications and Networking Conference (WCNC), 2012 IEEE*, Paris, France.

1.4 Dissertation Overview

This dissertation document is organized in four chapters. Chapter 1, the current, presents an overview of the mobile market, mobile devices, ubiquitous computing, geo-located events and news, and location and context-aware issues in order to introduce and focus the topic of the work. It also identifies the problem under study and defines the objectives, highlighting the main contributions, and presents the dissertation structure.

Chapter 2 includes the first contributions of this work. It presents the CityEvents solution including its system requirements, specifications, and design. It also includes used technologies, software platform and system demonstration and validation.

Chapter 3 presents the evolution and extension of the work presented in the previous the chapter 2. It explains all the methods used to perform a score for an event, and describes weighted scoring algorithm for mobile information. Location and habit awareness scoring, comparing of habit-based and location scoring, combining context and location scorings, showing the final results and experiments. A survey to evaluate the user experience in order to receive a feedback of the users about the application design, functionalities, and performance was carried out. The demonstration, validation, and performance evaluation of this new approach is deployed on CityEvents application.

Chapter 4 summarizes the main conclusions and suggest directions for future work.

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Chapter 2

An Ubiquitous Mobile Multimedia System for Events Agenda

This chapter consists of the following article:

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An Ubiquitous Mobile Multimedia System for Events Agenda

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Abstract— The current growth of mobile devices enabled with GPS receptors, cameras, accelerometers, and Internet access offers new opportunities for new mobile ubiquitous multimedia applications. Such applications help local communities to share resources using geo-location, interactive mapping, augmented reality, and several data representations. This paper presents CityEvents, a mobile solution that provides real time awareness-based information of local events and news. The presented ubiquitous system is a simple and easy to use event guide, providing location-awareness and content-awareness ordering data to the user. The proposal was evaluated and demonstrated in iPhone devices and it is ready for use.

Keywords- *Mobile computing; Ubiquitous computing; Mobility; Web services; Multimedia applications; iPhone.*

I. INTRODUCTION

Mobile devices offer opportunities for a better and fast growing globally connected society with online social networks, blogs, and Web pages, among others. These new approaches improved user-access to information through mobile communication. The research community along the years is studying and developing new technologies, new services, and new applications to enable ubiquitous environments based on mobile technology [1]. Mobile devices improved communication efficiency, therefore enhancing user-experience [2].

Geo-location applications are becoming very useful due to an anytime and anywhere fully connectivity. With them, Internet goes a step beyond; nowadays, with mobile devices, it is easier to have access to all range of contents regardless of where people are, e.g. trains, buses, cars, restaurants, or public places. This means that users may perform a set of operations, like checking emails, messaging, read news, or even watching a television program without logging in a local wireless network.

The advent of mobile devices with location-aware and context-aware technologies, such as smartphones, cellphones, and tablets is changing people's daily lives. Features like, pinpointing locations on a map updated in real-time or finding user preferred information's in the surroundings. The number of applications that use global positioning system (GPS) services and new features are growing everyday [3].

Smartphones with GPS capability can be used as a personal navigator. There are various mobile navigation

techniques to determine the location used on mobile multimedia applications [4]. Due to its portability and the vast range of applications, smart mobile devices are being appointed as the future when it comes to access multimedia content over the Internet. By adopting these techniques and concepts it is possible to develop intelligent mobile multimedia applications.

The ubiquitous collaboration between mobile device and Web services is another approach of intelligent applications. That brings out the best of the two worlds, the server-side resources and the client-side context and location [5]. The application is centered on what the user wants to see, where and how he/she wants to see it, giving the context and content-awareness. The information and context of the events on native applications have a better visualization to the user, contributing to a satisfying exploration of cultural and information events [6]. This paper presents CityEvents, a mobile application that follows location, context, and content-awareness approaches. It also shows events categorized by type, location, and preference, using an algorithm sensitive to the user's behavior. The events may be shown in two distinct ways, on a table or on a map, including the user current GPS location. In order to attribute a score to each event, to determine user's preferences, the algorithm uses context and location awareness technology. The algorithm will provide tools that allow users to receive information taking into account his/her profile settings, in an automatous and transparent way. Using the location awareness module, based on GPS location, CityEvents will highlight (or high-score) the user-preferred information. The algorithm is capable to adapt to the current context without explicit user intervention.

The main contribution of this paper is an application which scores the events based on user's settings. The events are sorted by the user's preferences and shown them on a map if relevant. The user can also be alerted if his/her location is close to a high-scored event.

The remainder of the paper is organized as follows. Section II elaborates on the related work, addressing several projects and applications about the topic. Section III describes the CityEvents application while Section IV focuses on the application demonstration and validation.

Finally, Section V concludes the paper and point directions for future work.

II. RELATED WORK

The exponential growth of people using mobile devices leads to a constant improvement of smart communications. Nowadays, mobile devices are getting smaller, faster, with a lengthier battery lifetime, and a greater processing power. With these improvements, it is increasingly common to find all type of multimedia content (audio, video, and images) available through a variety of mobile applications. This section introduces the concept of ubiquitous mobile computing and describes several projects and applications developed for mobile devices in the last years, which were considered in the development of the CityEvents application.

In the early 90's Marc Weiser [7, 8] introduced his vision of ubiquitous computing. He presented a concept of a man-technology interaction with a complete abstraction of the user. However, Weiser's vision faces several problems when considering the lack of technological support, that at the time of its creation was not available as may be found today [8]. A good example of ubiquitous technology is the Internet. Users use Internet only interested in information and services and not in the inherent technology. Users are connected everyday to several Internet access points without knowledge of protocol and network architecture used on a mobile device [9].

An important aspect of mobile devices is their portability and mobility. With the advent of wireless communication in mobile phones, smartphones, and tablets, ubiquitous computing has evolved as well. They take advantage of their portability to have wireless connectivity almost everywhere [10]. In mobile computing there are still some technological hurdles to overcome, such as the variation on the quality of a wireless network, local access limitation, and energy constraints. These problems affect the user and also the computing experience directly [6].

Taking into account the available literature and mobile applications, several multimedia mobile applications that influence the construction of the proposed system are described below.

An application that allows users to obtain all the information about culture events in France, created by *i-Marginal* is called *CultureClic* [11]. With this application it is possible to check out an event location, access museums data sheets, and find out cultural events near the user's location.

Topsee is a mobile application that allows users to be fully updated with information about all the places in London [12]. It is possible to have an easy access to them, including restaurants, latest top shows, and culture events in the city.

A mobile application with the information about the Serralves foundation, called *Serralves*, is presented in [13]. With this application, users may have access to a constant updated schedule of activities (e.g., music and dance

exhibitions, seminars, and conferences) with information about the event's day, time, and location.

FCGulbenkien is an application developed for iPhone and Android, which allows users to access all type of information (exhibitions, concerts, events) about the *Fundação Calouste Gulbenkein* activities. It also gives access to news, contacts, schedules of each activity, and even online ticket purchase [14].

An application for iPhone, called *N4MD – News for Mobile Devices*, is presented in [15]. This is an application to visualize the weekly news produced on the *Urbi et Orbi* newspaper of the University of Beira Interior, Portugal. The application *N4MD* runs natively on the iPhone devices and it is now similar to hundreds of newspapers and magazines available for mobile devices.

The main differences between CityEvents and the above mentioned approaches and applications are the following: *i)* ordering events according to user's interests, based on the previously accessed events; *ii)* selecting the events list by restraining the categories; *iii)* events geo-localized on a map; and *iv)* giving more relevance to the events near the user's location.

The proposed system, called CityEvents, gathers contributions from the above-presented mobile multimedia applications, creating a more complete and comprehensive proposal in the context of mobile and ubiquitous computing.

III. SYSTEM REQUIREMENTS, SPECIFICATIONS, AND DESIGN

This section discusses the requirements of the CityEvents proposal, the system architecture, the used technologies, and its development.

A. System Architecture

CityEvents is based on a mobile ubiquitous application with multimedia contents that allows users to obtain useful informations about culture events. It may be used in a region, in a city, or even in a country, for larger events with national impact and interest. The current implementation it's optimized for local events in an area of 50-100.000 people.

The proposed system obtains data from a remote database with real-time updates through a Web service. That service supplies all the data on an eXtensible Markup Language (XML) file.

The user can choose a cultural event and see all the corresponding detailed information, as well as the event location on a map. It can also be easily found on a map with the available events by clicking on pin locations to access detailed information.

Figure 1 presents the CityEvents system architecture. The mobile application gets the data from a CityEvents server; at the moment the reply is not optimized for bigger areas, being a single XML file, real-time updated, for all the requests. Proper optimizations should be made if the application will run on a country/region-scale. The server collects information programmatically by getting localized feeds from safe

sources, or providing localization-enabled backend for specific groups of interest (Culture, Sport, etc.). The user will have full access to all events through a list and a visual map, as well as aware-enabled data sections or data orderings, depending on distance to the event and/or the relevance for the user.

For this first implementation, simple parameters are used to provide combined location and content-awareness. Events are ordered (and filtered in number) considering Euclidean distance from the GPS position to the event-position and the relevance to the user expressed in percentage of events seen for a specific category. Future improvements can be done in these algorithms to express the “likelihood” of the events, as defined in Section V.

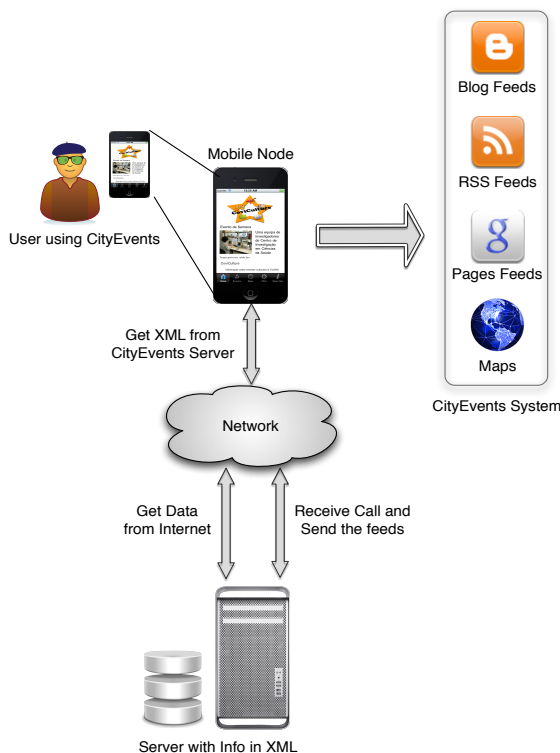


Figure 1. Illustration of the system architecture.

B. Used Technologies

Based on the nature of the proposed system and the available technologies and mobile devices, iPhone was chosen for the real deployment and demonstration of the proposed system. The native application CityEvents targets iPhone, a mobile device with iOS operating system, which is a software stack for mobile devices that contains an operating system, middleware, and main applications provided by Apple. The major solution for application development was Objective-C, using the Xcode, which integrates the development environment for creating applications for iPhone. Xcode includes the Xcode IDE, Instruments, iOS Simulator, and the latest Mac OS X and iOS SDKs [16-17].

The Web service created to perform the communication among clients and server uses Simple Object Access protocol (SOAP) messages over Hypertext Transfer Protocol (HTTP). The information between clients and the server is exchanged using an XML file.

C. Software Platform

This section shows the software platform of CityEvents and their main functionalities. Figure 2 illustrates the communication among clients and the CityEvents server. Initially, the application sends a SOAP request to the server, asking for all the available upcoming events. With this request the server creates an organized XML file containing all the upcoming stored events. The application receives the XML file and parses all data, filling the local mobile database. When this operation ends, the information is displayed on the screen. The data contained in the file includes a title, a brief summary, the corresponding image URL (uniform resource locator), a place, date, date of publication, and its author. When the user chooses an event, the application gets all the corresponding multimedia content sending an HTTP request. As soon as the multimedia content of that event is received, it is displayed on the mobile device.

In CityEvents, users may choose which categories want to view. With this feature, the application sends a new request to the server that returns a new XML file with it, performing a similar set of the above-mentioned operations.

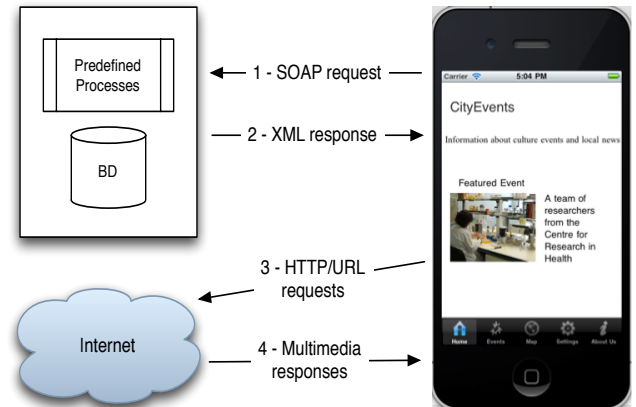


Figure 2. Communication between clients and the CityEvents server.

IV. SYSTEM DEMONSTRATION AND VALIDATION

CityEvents system includes a user-friendly layout using the user-interaction capabilities of the iPhone. The user-interface is shown along the CityEvents system demonstration presented in this section. Figure 3 shows the *Home* window of the application. This window displays several information (e.g. title, image, and a brief summary) about the week event, which is the most important category for the user. By clicking on the event image, the application leads the user to the detail page of the event. This feature

allows users to know which event is considered the main event of the week, without the need to search for it.

On the next tab bar, called *Events*, a list of events is shown to the user as presented on Figure 4. Displaying a list of events sorted by the user's preferences.

At the bottom of this tab, the user can see the number of events available in the list. In the specific case shown in Figure 4, the user may choose from a range of 361 events.



Figure 3. Home window.

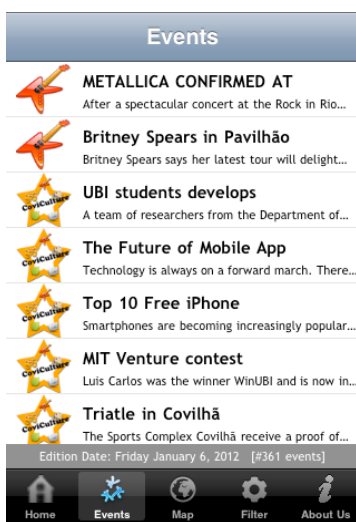


Figure 4. List of all available events.

When an event of the list is selected, all the event details are shown to the user. Figure 5 presents an example of an *Event Details* window. As may be seen in Figure 5a), the details include the event title (at the top), a brief summary, an image with the corresponding caption, the event date, the publication date, and the author of the post. At the end of the

view the user is able to see the description of the event (Figure 5b). When the description field is bigger than the available window area, the user is allowed to scroll the text in order to read it.

At the Settings tab (Figure 6a), the user may choose to see a specific category of events. This is made using a filter available at this tab bar. Figure 6a) also presents the list of the available categories to the user. Figure 6b) shows the result when the user chooses a category. The application will fetch only the user's choice and the information of these events. With this feature, CityEvents implements a cognitively distinct group of users.

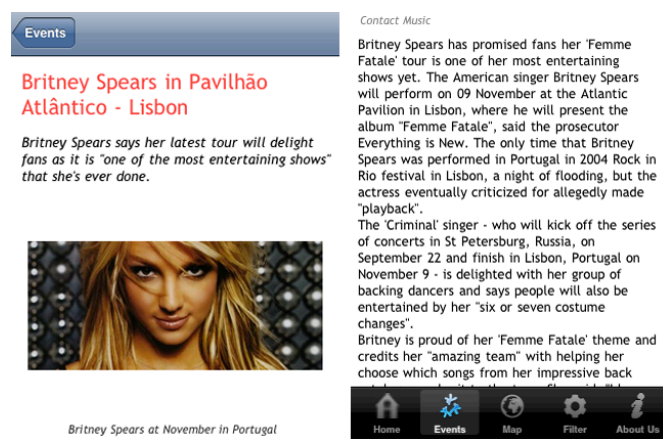


Figure 5. Example of an event detail.

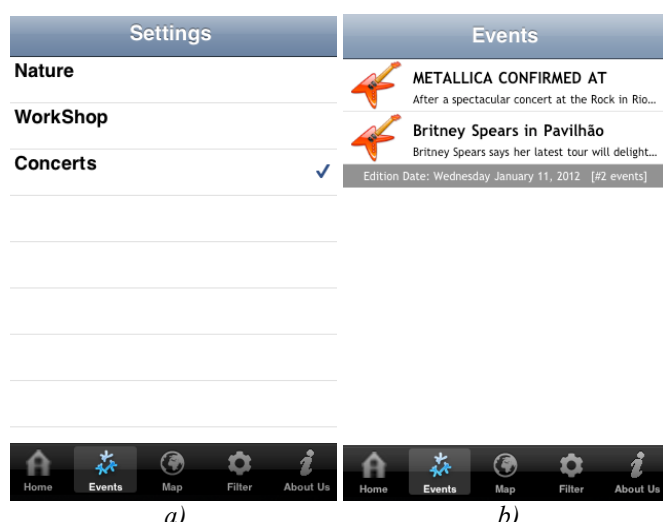


Figure 6. List of categories and corresponding events.

Figure 7 shows the *Map* tab presenting a map with the localization of a specific event. In this tab it is also shown all the available events, using pinpoints that represent the event geolocation. The nearby event is represented by a blue pinpoint. The user location is also shown on the map and is

represented by a red pin. When a mark is clicked, the user can read the title and a brief description of the event.

The CityEvents system was evaluated and performed as expected. The application was deployed in a real device and it is ready for use.

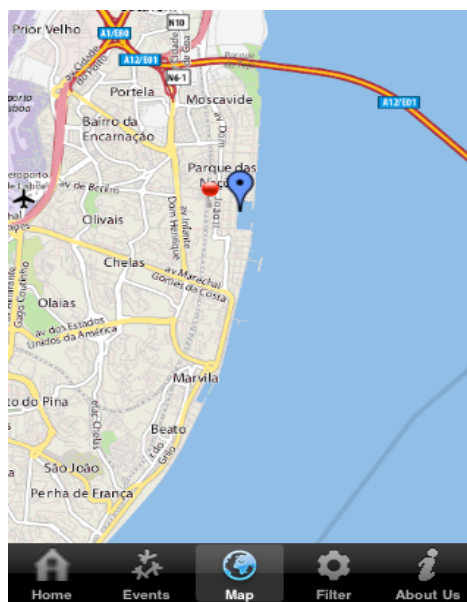


Figure 7. Example of an event location in a map.

V. CONCLUSIONS AND FUTURE WORK

This paper proposed a ubiquitous location, context, and content-aware mobile application, called CityEvents. It describes a mobile multimedia system for displaying geolocated cultural events. It provides the needed information to the user in an easy and intuitive way, catching the user's interests and trying to suggest nearby events presented in a visual map that offers detailed information on request. A list of events ordered by interest is also available.

The amount of data transferred between the client and the server is taken into account and is reduced by caching mechanisms, and a proper compression system on the server-side. The client will only make requests to the server if needed, in background threads in order to improve the user experience. The solution has been demonstrated in iPhone.

For future work, several improvements are to be kept under consideration: *i)* a list of favorite events for the user may be created, joining data from location and content analysis with advanced algorithms; *ii)* contents may be improved with more multimedia elements, such as, video, photo slideshow and audio. The mobile application can also be deployed in other mobile platforms, such as Android or Windows mobile.

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Chapter 3

A Weight-Aware Recommendation Algorithm for Mobile Multimedia Systems

This chapter consists of the following article:

Pedro M. Pinto, Joel J. P. C. Rodrigues, and Filippo Basso

Submitted to an international journal.

A Weight-Aware Recommendation Algorithm for Mobile Multimedia Systems

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Abstract – In the last years, information flood is becoming a common reality, and the general user, hit by thousands of possible interesting information, has great difficulties identifying the best ones, that can guide him in his/her daily choices, like concerts, restaurants, sport gatherings, or culture events. The current growth of mobile smartphones and tablets with embedded GPS receiver, Internet access, camera, and accelerometer offers new opportunities to mobile ubiquitous multimedia applications that helps gathering the best information out of an always growing list of possibly good ones. This work presents a mobile recommendation system for events, based on few weighted context-awareness data-fusion algorithms to combine several multimedia sources. A demonstrative deployment were utilized relevance like location data, user habits and user sharing statistics, and data-fusion algorithms like the classical CombSUM and CombMNZ, simple and weighted. Still, the developed methodology is generic, and can be extended to other relevance, both direct (background noise volume) and indirect (local temperature extrapolated by GPS coordinates in a web service) and other data-fusion techniques. To experiment, demonstrate, and evaluate the performance of different algorithms, the proposed system was created and deployed into a working mobile application providing real time awareness-based information of local events and news.

Keywords – Mobile computing; Ubiquitous computing; Location-Aware; Content-Aware; iPhone applications; Multimedia applications; Mobility.

1. Introduction

Utilization of mobile devices in everyday life has expanded rapidly over the past few years; consumers are changing their habits by using resources offered by the Internet, that is now always available in a click. Content-adaptation and context-awareness are more and more necessary, to be able to deal with the current information flood provided to the user [13].

The use of smartphones all over the world is growing rapidly, with a large adoption rate especially among teenagers and adolescents [34]. Mobile devices can nowadays natively support several kinds of multimedia, and mobile services are supporting the users with an exponential growth of specialized applications/services for almost every need: as a general thermometer can be used the number of deployed applications in the main mobile Markets/Stores present in Internet. The expression “*Information at your fingertips anytime, anywhere*” has been driving the mobile computing development in the past two decades.

However, mobile devices do not have the same features in what concerns to conventional information processing, such as PC's and laptops [20], especially in terms of computing power, HMI resources, general limitations of network, battery cycle, and other specific topics, becoming important limitations in mobile computing [22]. The rise of smartphones like the Blackberry, Android, and iPhone allow not only voice communication but also communications via SMS (Short Message Service)/MMS (Multimedia Messaging Service)/E-Mail/SocialNetworks. They also have the capacity to process intensive activities such as multimedia playback, document editing, and audio/video streaming via dedicated coprocessors. In spite of the inherent limitations, some authors are supporting the idea that conventional laptops will soon be replaced by smartphones and tablets [32].

Mobile devices provide a wide range of opportunities to a global society through online social networks, blogs and web pages, among others. New approaches to access information in mobility are being improved; over the last years the research community has studied and developed new technologies, services and applications to enable ubiquitous environments based on mobile technology [37]. The new generation of mobile devices has improved the efficiency of representation of the information, enhancing user experience [5]. Ubiquitous computing is becoming a reality with mobile computing, due to a rapid advance in wireless technologies and Internet [34].

The small screen size of the mobile phone does not help to read contents. It is difficult to present news efficiently or to display only the context of mobile news and events, capturing users' interest. Despite all the effort made to contribute to improved navigation and usability in mobile news, results should be improved constantly, not to decrease in popularity among users and result in a poor experience while navigating the mobile news [20].

Applications based on geo-location can benefit of a more stable Internet connection, enabling the user to access a wide range of server-side location-based contents, such as transport timetables, open restaurants or event calendars. Location-awareness plays an important role in the jungle of the context-awareness parameters, and everyday there are new apps using the global positioning system (GPS), its services and new features [37].

Joining ubiquitous mobile devices and web services brings into the user's hands the best of both worlds: resources and processing algorithms are server side while content-adaptation and direct context-awareness parameters are on client side [14]. The application focuses on what, where and how the users want to see and interact with the content provided. In general native applications produce better results than multi-

platform solutions, contributing to a satisfactory exploration of cultural events fully utilizing the resources of the device [4].

In this scenario, recommendation systems are important to help the user to make choices, identifying the best news in an ocean of potentially good ones. For every specific application should be identified several parameters, or relevances, that can influence the filtering/ordering choices, in order to provide to the users the more important information. In some content-adaptation methods where some hundreds of hits are possible to be meaningfully shown, like a map with clustered points, it is important to maximize *relevance* to have at least 100-200 results; in other methods of data-presentation, like the list of best sold apps in AppStore, it is very important to have very high *precision* in the first 10 hits. The main issue is to identify the best parameters and the best measures to be optimized that are to be utilized in the specific recommendation system; does not exist the best system, but different tunings depending on which results the system is focusing on.

To provide an environment for testing, demonstrating and comparing results coming from different algorithms, it was developed an application dedicated to provide news and events to a generic user, ordered with parameters coming from habits and instantaneous position. The habits chosen for this implementation were:

1. the frequency of visits of a pre-defined taxonomy structure;
2. the active sharing on social networks of elements of the same taxonomy .

Nonetheless within the same technological framework we could have included several other parameterizations, both direct (background noise volume) and indirect (local temperature extrapolated by GPS coordinates).

Relevance coming from these three context-awareness parameters are then combined, or fused, with some classical data-fusion techniques, to test different ways of

producing an ordered list of results. The following data-fusion methods were used and experimented: *i)* CombSUM, weighted CombSUM and *ii)* CombMNZ, weighted CombMNZ. One of the important steps leading to a successful data-fusion is the re-normalization process that was studied case by case, for each one of the three relevances.

The main contributions of the paper are the study and the implementation of a complete generic recommendation system, with both client mobile application and Internet service, and the verification of several re-normalization and data-fusion techniques applied to the specific case of news and events recommendation system [31].

The remainder of the paper is organized as follows. Section 2 elaborates on the related work about mobile recommendation systems. Section 3 gives a mathematical overview of the utilized re-normalizations and data-fusion techniques. Section 4 focuses on the application demonstration and validation. Section 5 gives a performance evaluation and results of the application. Finally, Section 6 concludes the paper and point few directions for future work.

2. Related Work

The possibility of materializing the vision of ubiquitous computing that was drawn at the beginning of the 90's is approaching [28] [35], combining mobile devices new features with the growth of short-range ad-hoc networks. In the early 90's, Marc Weiser [25, 26] introduced his vision of ubiquitous computing. He presented a concept of a man-technology interaction with a complete abstraction of the user. However, Weiser's vision faced several problems, mainly lack of technological support [26]. A good example of ubiquitous technology is the Internet; users are not interested in the underlying technology behind the Internet, but only in the information and all the

services provided by it [34]. Users are connected everyday to several social networks, without knowledge of protocols and network architectures used on a mobile device [27]. Mobile or portable devices such as mobile phones, personal digital assistant (PDA) and tablets are smaller and lighter, can be transported anywhere, and can easily fit in the suit pocket or briefcase. These portable devices have a good number of features, such as SMS (short message service), email, packet switching for access to the Internet, gaming, Bluetooth and Wi-Fi connectivity, infrared, photo camera and video recording, music player, radio and GPS antennas, memo recording, and, more importantly, make and receive phone calls. Mobile devices offer the opportunity to create a better and fast growing globally connected society, with social networks, blogs and web pages. These new approaches improved user-access to information through mobile communication [23] [46].

The research community has been studying and developing new technologies, new services and new applications over the years to enable ubiquitous environments based on the mobile technology [37]. Mobile devices improved communication efficiency, enhancing user-experience [18]. The exponential growth of people using mobile devices leads to a constant improvement of smart communications.

The ubiquitous collaboration between mobile devices and Web services brings the best of the two worlds: the server side resources and the client-side context and location [35]. The application is centered in the user preferences (where, when, and how), providing context and content-awareness. The information and context of the events on a native application offer a better visualization to the user, contributing to a satisfying physical exploration of cultural and information events [8].

Ubiquitous computing is one way to improve the computers usage [38]. The main goal of ubiquitous computing turns human-computer interaction invisible, fully integrating

the computer with the actions, and behavior of its users [39]. Computer systems that surround us are proactive and are linked together, or trying to establish links between themselves constantly. Ubiquitous computing requires Internet connectivity and this feature is often used and characterized for ubiquity [42].

Geo-location applications are becoming very useful due to anytime and anywhere full connectivity. Smart phones with GPS capability are becoming more widespread. This ability of smartphones can be used as a personal navigator and a communicator device. There are various mobile navigation techniques to determine the location used on mobile multimedia applications [29]. Due to their portability and vast range of applications, mobile devices are being appointed as the future Internet navigation devices. Native applications offer a good support for multimedia contents This access is made using Internet services in native applications [29]. By adopting these techniques and concepts it was possible to develop an intelligent mobile multimedia application.

The context-sensitive computing (Context-Aware Computing) has emerged as the field of ubiquitous computing, studying the relationship between changes in the environment and information systems [2], thus raising new technical challenges for implementation. In the computing context-sensitive computing (Context-Aware Computing) devices try to understand and to automatically capture the context where they are inserted. Offering a better interaction between the environment and the user. This interaction can happen in terms of hardware, software or communication [1].

In recent years, many platforms have been developed for pervasive and context-aware systems in order to support rich contextual features. Many of these systems are open and available [7]. An important aspect of mobile devices is their portability and mobility. With the advent of wireless communication in mobile phones, smartphones, and tablets, ubiquitous computing has evolved as well. They take advantage of their

portability to have wireless connectivity almost everywhere [23]. In mobile computing there are still some technological hurdles to overcome, such as the variation on the quality of a wireless network, local access limitation, and energy constraints. These problems affect the user and also the computing experience directly [4] [11].

Mobile devices with GPS (Global Positioning System) capabilities have been around for some time. Location-awareness in mobile and other devices is changing the users life [37]. Devices with such capabilities and location-aware applications will lead the mobile market [3], such as pinpointing the location on a Google Map, tracking friends, a geo-located event, giving the idea on what's going on in the user area. They can tell us what is the nearest place to eat, giving a list of all shopping or stores in the user area, tell us where to go for a party or cultural events, and other businesses [12] [16] [24].

Data fusion algorithms implemented (CompSUM, CompMNZ and their relative weighted version) are already found in the works of Salton and Fox [15] and improved by Lee's article three years later [24] where it's shown that in specific situations of Information Retrieval data-fusion it is very important the renormalization phase, not to incur in wrong evaluations of the best methodology. Several articles are proposing new methods, more complex and adapted from other branches of knowledge like neural nets, algorithms of democratic voting from the Social Choice Theory, logistic regression formulas. Other fusion techniques applied to other scientific areas shows new simple ideas as outperforming all other state-of-the-art techniques, because of new boundary conditions, and with no answer to how and which conditions act on the effectiveness of a specific technique, except generic statements [21]. Analyzing several results, it become clear that the classical CompSUM and CompMNZ are enough simple and effective, compared to other specialized formulas, and the work was focused on them. Renormalization techniques investigated were based on simple linear transformations

and an exponential transformation in the case of location-based parameters. Several parameters are found in literature, and mobile Information Retrieval is maybe the more creative and rich in relevance parameterizations; as an example in “*Music Recommendation Using Content and Context Information Mining*,” [38], uses context conditions such as location, time, air temperature, noise, light, humidity, and motion to make music recommendations that are sensitive to the user’s mood [13].

Inside the Apple App Store users can find location-aware applications, such as *Loopt-Friendfinder* [17], application with virtual earth display that, allows user to share their location with the community. *NearPics* [40] is a location-aware photo browser, and *Weatherbug* [44] is a location aware weather service with predefined cities. *Appetite* [3] is a restaurant picker based on user location; *AroundMe* [41] is an application that gets your location and allows you to choose the nearest bank, bar, gas station, hospital, hotel, movie theatre, restaurant, supermarket and taxi. Every day a new item is added to this list. An application for iPhone, called *N4MD – News for Mobile Devices*, is presented in [18]. This is an application to visualize the weekly news produced on the *Urbi et Orbi* newspaper of the University of Beira Interior, Portugal. The application *N4MD* runs natively on the iPhone devices and now, it is similar to hundreds of newspapers and magazines mobile applications. The system composed by CityEvents app and the online recommendation service is unique in its way of gathering an arbitrary set of relevance parameters, merge them into a personalized and meaningful global relevance able to filter and order events and news to fit the needs of a generic recommendation system. Several algorithms were tested and compared, and based on revised scientific knowledge, implemented in a working system that is able to investigate with little efforts other more recent algorithms and parameters.

3. Weighted Scoring Algorithm For Mobile Information Applications

Let's consider a system with N meaningful parameters that expresses some kinds of context-awareness relative to a specific user, and where, out of a huge number of atomic informations (news, events, or more in general documents), some should be provided to the user ordered and/or filtered in order to maximize precision, recall or some efficiency measure, utilizing at best the N parameters. A general system require a parameters re-normalization phase, where the parameters are meaningfully mapped to the $[0,1]$ interval, and a data-fusion phase, where the N parameters are joint into a single one, from which ordering and/or filtering can be provided, dependent to the specific content-adaptation provided by the mobile device. Weights are provided to allow the user requests personalization, and real-time perception of the differences that can occur if, for example, he considers location to be more important than habits or vice-versa.

In our work were analyzed three parameters:

1. *Location-based scoring*, giving a score relative to the Euclidean distance between the user and the position of the news/event; other types of distance can include the path distance following roads or cycle-paths, or estimated time for a specific vehicle to move from the user to the news/event position.
2. *Habit-based scoring*, the frequency of visits of a pre-defined taxonomy structure; in this case a flat categorization was a sufficient approximation, but a more complex structure provided with an internal metric will benefit of the same amplified benefits.
3. *Habit-based scoring*, the active sharing on social networks of elements of the same taxonomy structure; assuming a correlation between active sharing and interest, several measures can be built to provide meaningful relevances, in this case to simplify it was used the frequency of article sharing, grouped by the same flat categorization of parameter 2.

3.1 Location Awareness Scoring

Given the Euclidean distance (d) in meters between a device and an event, let s_d be the distance scoring; can be defined several simple scoring, useful for this implementation, can be defined as follows:

$$S_{d1} \equiv \max\left(\left(1 - \frac{d}{D}\right), 0\right) \quad (1)$$

$$S_{d2} \equiv e^{-\alpha d} \quad (2)$$

To define the constants D and α it can be noticed that they identify different exclusive scoring functions, with a specific physical meaning: for a user that commonly uses a bicycle (or a car, or just walks around the city), it's important to distinguish between events that are 100 m or 300 m away from his current position, while it's not so important if they are at 30 km or 100 km away; the same can be false for a user that commonly uses a car.

In Table I these constants were defined empirically, based on user feedback from a dozen of users.

Transport mode	D	α
Walking	2.000	2/2.000
By bicycle	12.000	2/12.000
By car	40.000	2/40.000

Table I. Location-based scoring parameters.

Taking in consideration the scoring system utilized by the user that is commonly walking, we highlight in Figure 1 it is highlighted how the factor D represents the

value from where s_{d1} gives zero scoring, thus considering identical all the events that are more than 2 km away from the user.

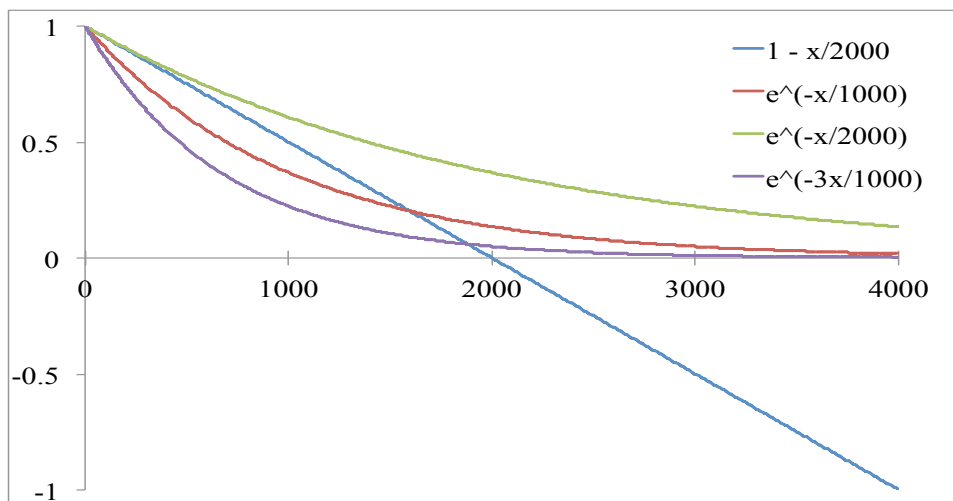


Figure 1. Effect of different parameters in Location-based scoring.

From Table I it can be seen that good empirical values for α can be obtained with the formula $\alpha = 2 / D$, to keep scoring and its derivative not too different from the linear case in $[0, D]$ and being not too high when $S_{d1} = 0$. A factor 3 (green line, Figure 1) would give too much importance to nearby events (being the derivative much smaller for small distance), while a factor 1 would behave like the linear function only for nearby events, but will be too high for events with distance D or bigger.

In the first implementations of the algorithms it was tested accurately the first scoring system on equation (1), while after some intensive testing was noticeable the difference in behavior with situations that doesn't use the awareness scoring system, but only the location awareness scoring. Thus it was implemented and chosen as more valid the second scoring system equation (2), very simple, easy to manage, monotonically decreasing, and with not appreciable changes in computational time.

Other meaningful parameters can be utilized, like using time estimate instead of distance, but in the current implementation were utilized only the above described exclusive distance functions.

3.2 Habit Awareness Scoring

While the location awareness scoring described is mainly one-dimensional (having different exclusive scoring formulas for different transportation habits), the context awareness scoring implemented is multi-dimensional, giving different meaningful scorings to measure how a person can be interested in some context more than in others.

In our case were utilized two relevance parameters, that expresses the frequency of seeing the details or sharing within social networks news or events belonging to a specific taxonomy; in our case it was utilized a flat categorization, but can easily be extended to a generic taxonomy provided with a good metric [30].

More in general, assuming to have N different non-negative context-based relevances, $s_c = \{s_{c1}, s_{c2}, \dots, s_{cN}\}$ it's important to keep in consideration the possible correlation between them, and remap the values of every relevance in the interval $[0, 1]$, similarly to what was done in the location scoring. The correlation between the relevance can be dealt with appropriate weights in a following phase, when a total scoring has to be defined through a data-fusion algorithm.

To re-normalize the values were considered the functions s_{c_j} as functions on a discrete set of information $J = \{j_1, j_2, \dots, j_M\}$ thus with always limited values, and the remapping a simple linear mapping show on equation (3).

$$\begin{cases} s'_{c_j}(0) = 0 \\ s'_{c_j}(\max\{s_{c_j}(I), c_{c_j}\}) = 1 \end{cases} \quad (3)$$

The values c_{cj} are empirically defined minimum values that depends on the context based relevance, and represent the minimum scorings that can be considered valuable (for example, if $s_{c1}(k)$ represents the number of times that the user shared information of the category k via a social network, c_{c1} can be set to a value around 15-20 units); in our tests this lower limit helped to obtain a more precise global relevance in those cases where the specific scoring method was under-utilized.

3.3 Comparison of habit-based and location Scoring

Comparing habit-based and location-based relevance, it is immediately noticeable a difference: the maximum value 1 is often present in the image of every non trivial element of s_c , if the set I is non-empty and c_{cj} properly set, while it is almost always absent in the image of s_d . Even if a simple linear remapping can be used to correct this difference in behaviour, it was seen empirically that this difference could be positive for the global relevance. The underlying reason is that if there are no nearby informations, it's in general more important the habit-based scoring.

In the current analysis were utilized only different exclusive scoring parameters for location-based scoring (only one scoring for a specific situation), while could easily be found several habit-based scoring parameters. Avoiding complex implementations, based on semantics or other web 3.0 contents (in a wider interpretation of Conrad Worlfram [6]) nowadays difficult to implement in runtime on mobile devices not always connected in Internet, other parameters could be considered, for example:

- frequency of views of information's
 - of the same category inside a fixed taxonomy with a metric, and all other categories, weighted depending on the distance from the chosen category;

- that contain specific keywords in the text/title, with an appropriate process of stop-words removal and stemming;
- from the same information-provider; frequency of “sharing” of the information on a social network, divided by social network;
- frequency of “sharing” of the information to a targeted friends (can be thought as independent from the social network sharing, as a user can forward the information not because it's interested, but because the specific target is interested in the topic);
- frequency of “like” or any feedback system, as the percentage of the details seen, if the content is presented in scrolling views or tree views, or some statistics on clicks to external links;
- specific user search terms/queries.

The relevance parameters should also become more complex when a bigger set of informations flooding the user will make this a necessity; for example, time or day dependent parameters can give better results (the preferences of a user should change between working hours and in non-working hours, between a week-day or weekends), media-content analysis can give new ranges of context awareness scoring, and semantic web-services can be used to provide online deep-analysis, giving scope to the user to define it's own areas of interest, that will reflect similar structure of his/her “todo lists”, the email inbox, the documents organization, as well as the informations scoring.

3.4 Combining context and location scorings

In order to produce a single global relevance, out of a set of N parameters is usually regarded as “data-fusion”. Several algorithms were proposed in data fusion research area, most of the more complex outperforming the more simple ones just in very specific conditions. Not seeing any advantage for the current work in utilizing more

complex and processor intensive algorithms, the current work focused in four main intuitive algorithms, as described in the classical work of Fox and Shaw [10]:

- CombSUM
- Weighted CombSUM
- CombMNZ
- Weighted CombMNZ.

Both these methods are utilizing relevance, and not just their induced ordering (rankings), and are defined as follows. For an event/news, or generically a document d , and a set $S=\{s_1, \dots, s_N\}$ of different relevance parameters, let n_d be the number of systems that returned positive relevance for document d , and $W=\{w_1, \dots, w_N\}$ a set of weights that expresses not only user preferences but also the independence of the parameters, it's commonly defined:

$$CombSUM_s(d) = \sum_i s_i(d) \quad (4)$$

$$CombMNZ_s(d) = n_d \sum_i s_i(d) \quad (5)$$

$$wCombSUM_s(d) = \sum_i w_i s_i(d) \quad (6)$$

$$wCombMNZ_s(d) = n_d \sum_i w_i s_i(d) \quad (7)$$

From Lee's works it was shown that data fusion techniques could be applied to combine different relevance, but only when the relevance are appropriately re-normalized (and the process of re-normalization can influence the results of the data fusion itself). In his work CombMNZ on equation (5) works better than CombSUM equation (4), but in our case it was noticed that the two are very similar and one does not outperform the other in all the situations, being easy to produce common cases where CombSUM equation (4) or CombMNZ equation (5) are one better than the other.

CombSUM, equation (5) it is an algebraic mean, except a re-normalization factor $1/N$, and thus represent a stable fusion technique, quite intuitive in the results, and well behaving in our tests.

CombMNZ, equation (4) it is like a class-algebraic mean, where the number of non-zero parameters defines classes and their relative weights. For example, in our specific implementation were grouped all the documents with 1, 2, or 3 non-zero parameters (it is not possible to have 0 positive parameters for the way location relevance is defined, but more generically these documents have no impact), were calculated the algebraic mean of the class, then were joined the algebraic means weighting them with their cardinality multiplied by the number of the non-zero parameters of the class.

Weighted fuses, equation (6, 7) are interesting and can have a big impact in mobile recommendation systems, because can give personalized results, depending on parameters that the user can define in real-time, and perceive the feedback of this change (while statistical measures changes have usually a more stable behavior). The user can decide that these choices have to be defined more by location (in days/hours where he sees that there is more traffic), while can be defined more by interests and habits in other days/hours. Asking feedback to users it was noticed that using weights in the range $[0.33, 1]$ gives best empirical results for users that provide significant relevance in all the 3 implemented parameters, probably because will keep some balance between the extremes of having values in a neighborhood of zero and others in a neighborhood of 1.

4. CityEvents Demonstration and Validation

CityEvents is a simple mobile application for viewing events or news. The CityEvents system includes a user-friendly layout using the user-interaction capabilities of the

iPhone. The user- interface is shown along the CityEvents system demonstration presented in this section. Figure 2 shows the Home window of the application. This window displays several informations (e.g. title, image, and a brief summary) about the week event, which is the most important category for the user. By clicking on the event image, the application leads the user to the detail page of the event. This feature allows users to know which event is considered the main event of the week, without the need to search for it.



Figure 2. Home Window.

On the right top is a button for the user access to their preferences, called User Preferences. Figure 3 displays all preferences for the user and some changes for the user to make. In the preferences menu, the user can choose his means of transportation and he can change some other criteria. Those changes will affect the scoring of the events. Depending on his choices and preferences the results are shown on a map and a list of events. On the map shows a display of the events. The more important events are in icons with colour, the less important have a black icon. Respectively the icon for each category of the event. This list of events is shown from the most important events to less important ones.

On the next tab bar, called Events, a list of events is shown to the user as presented on Figure 4. Displaying a list of events sorted by the user's preferences. Events are sorted from the most visualized category to the less visualized one. At the bottom of this tab, the user can see the number of events available on the list. In the specific case shown in Figure 4, the user may choose from a range of 139 events.



Figure 3. User Preferences.

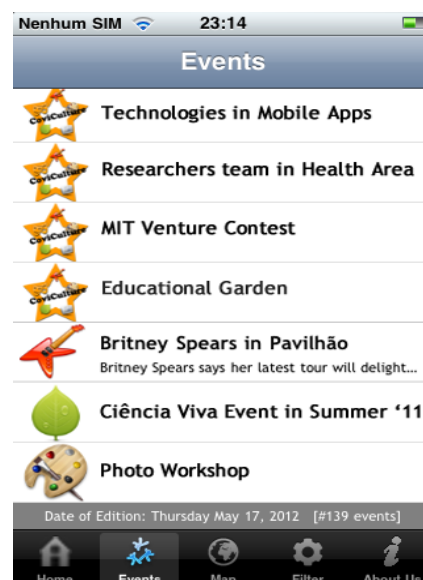


Figure 4. List of all available events.

When an event of the list is selected, the system will get the corresponding information about it and show the details to the user. Figure 5 present the Event Details window. As may be seen in Figure 5 a), the details include the event title (at the top), a brief summary, an image with the corresponding caption, the event date, the publication date, and the author of the post. At the end of the view the user is able to see the description of the event (Figure 5 b). When the description field is bigger than the available window area, the user is allowed to scroll the text in order to read it.

At the Filter tab Figure 6 a), the user may choose to see a specific category of events. This is made using a filter available at this tab bar. Figure 6 a) also presents the list of the available categories to the user. Figure 6 b) shows the result when the user chooses a category. The application will fetch only the user's choice and the information of these events. With this feature, CityEvents implements a cognitively distinct group of users.

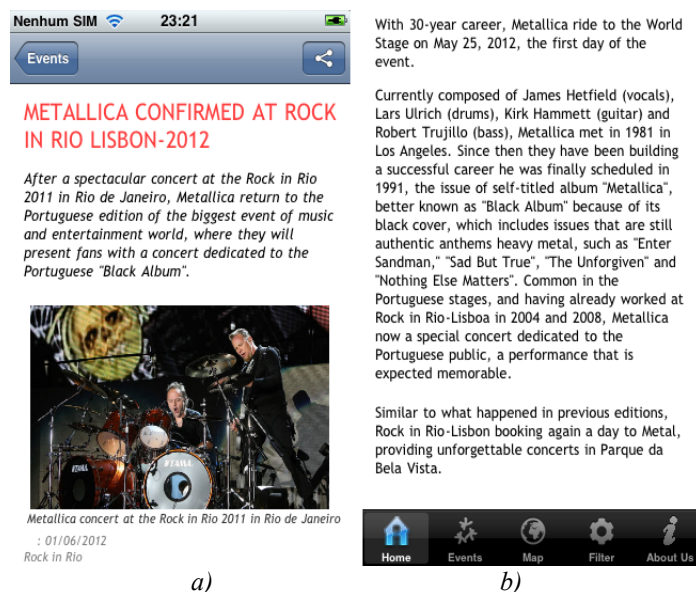


Figure 5. Example of an Event detail.

At the Event Detail window the user has the option to share an event with friends, by tapping the share button. The user has three options: share an event in their facebook page, send an email and send a text message to a friend or family member. Figure 7 shows the options to share an event in CityEvents.

Figure 8 shows an event the user liked has been shared. In Figure 8 on the left side the user shared the event on Facebook. Figure 8 on the right side the user will send the event by email to her friends. On the lower portion of Figure 8 the user can send a SMS with the event he wants to spread. (With these features of sharing a event will give a most score to the event category on the user's profile.)

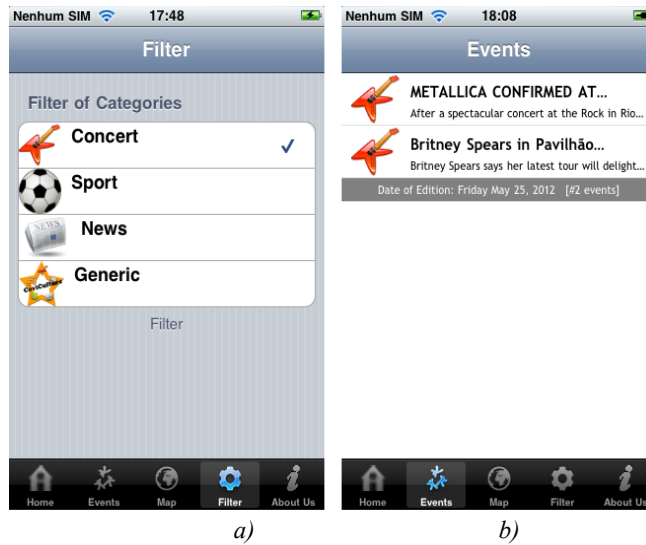


Figure 6. List of categories and corresponding events.



Figure 7. Options to share events.

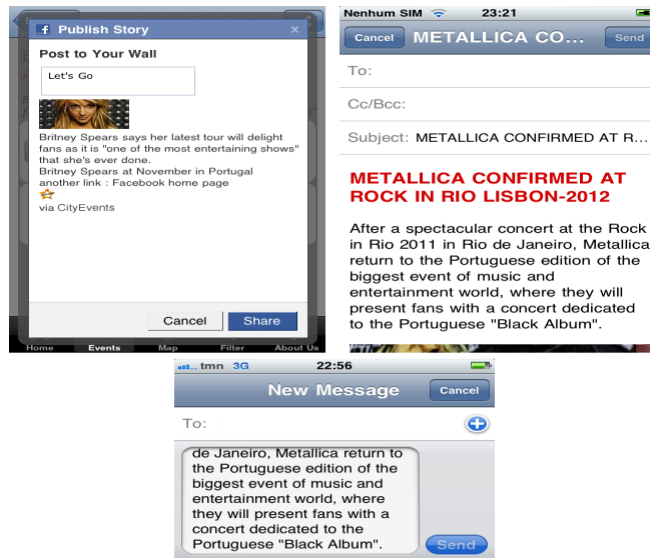


Figure 8. Sharing Events.

Figure 9 shows the Map tab presenting a map with the localization of a specific event. In this tab it is also shown all the available events, using pinpoints that represent the event geolocation. The nearby event is represented by the respective icon of the category. The user location is also shown on the map. When the category is clicked, the user can read the title and a brief description of the event. Figure 9 a) shows an alert to the user of the event more important to him, catching their attention for an event of her preferred category. Figure 9 b) presents to the user a map with events of their interests, based on her preferences and categories most important to him.

Each score for each news / event will be used by the application CityEvents. Based on this score the application will show all news / events more relevant to the user, catching their attention to events of interest.

The CityEvents system was evaluated and performed very well, as expected. The application was deployed in a real device and it is ready for use. The CityEvents system was evaluated and performed very well, as expected. The application was deployed in a real device and it is ready for use.



Figure 9. Maps with alert of event and scoring events.

5. Performance Evaluation and Results

The proposed re-normalization techniques and data-fusion formulas are not intensive in terms of resources, processor or memory, and are by far less problematic than the resorting algorithms to be utilized in the content-adaptation layer of the application, or the display of the chosen news/events as points in a map on the mobile device.

Being the application to be evaluated by user-feedback, a survey was proposed. CityEvents was installed, deployed, configured and was accessible through the iPhone. A total of 114 users from the University of Beira Interior, Portugal have answered the survey. The users have used the system for some time to become familiar with it in order to test. After some tests and experiments, they have completed the CityEvents survey. The questions of the respective survey are available in Table II. Figure 10 and Figure 11 it can be seen that the majority of the users agree that the application CityEvents has an attractive design, the application is user friendly and intuitive, as good navigation, the options are clear and easy to use. The event detail is consistent and text is written in good way to understand, fonts and all the event detail are easy to read

on the screen. A large percentage of users also think that the application is very easy to use and helpful to bring the best events to him. Most part of the users agrees that the application storing the users preferences and sort the events based on their preferences is good. Some users also agree that on a map see all the points of interests and events based on their preferences is useful and attractive. Mostly users agree that the events scored based on their preferences and location is useful.

Table II. Questions in CityEvents Survey.

Question	Description
Q1	Is the application design attractive?
Q2	Is the application easy to use?
Q3	Is the application environment user friendly and intuitive?
Q4	Are the navigation options clear and consistent?
Q5	Are fonts easy to read on the screen?
Q6	Is the feedback and response time of the application fast enough?
Q7	Is the application store with users' preference useful?
Q8	Is the events/news sorted in function of users' preferences useful?
Q9	Is the map with all the points of interest and events based on users' preferences useful and attractive?
Q10	Is the events/news scoring based on users' preferences and location useful?

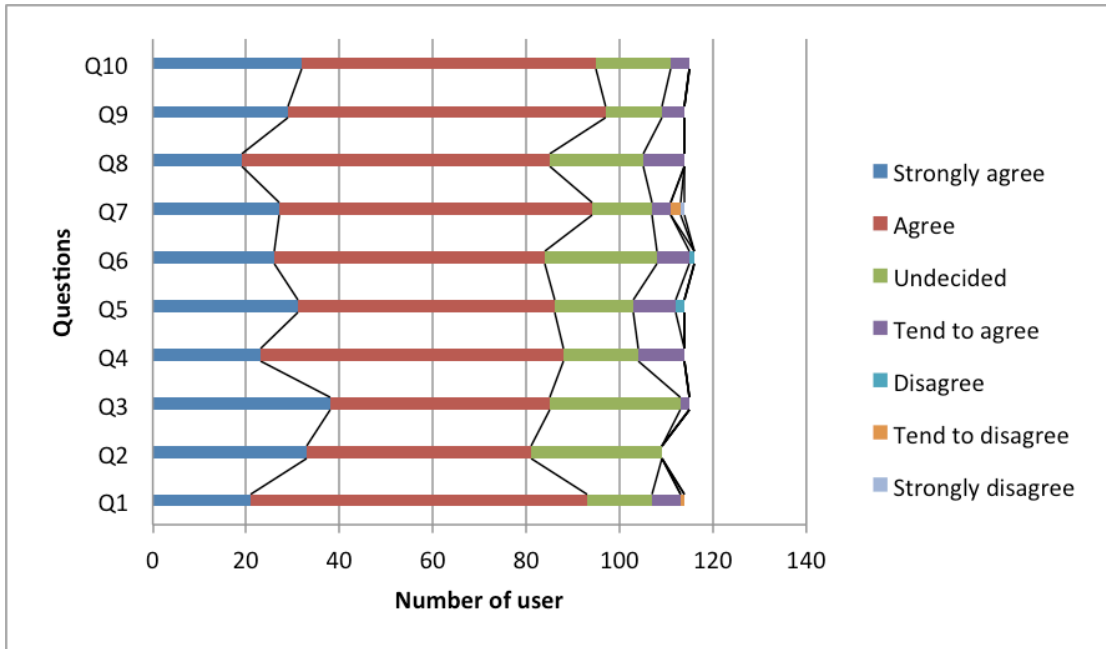


Figure 10. Results of CityEvents users survey.

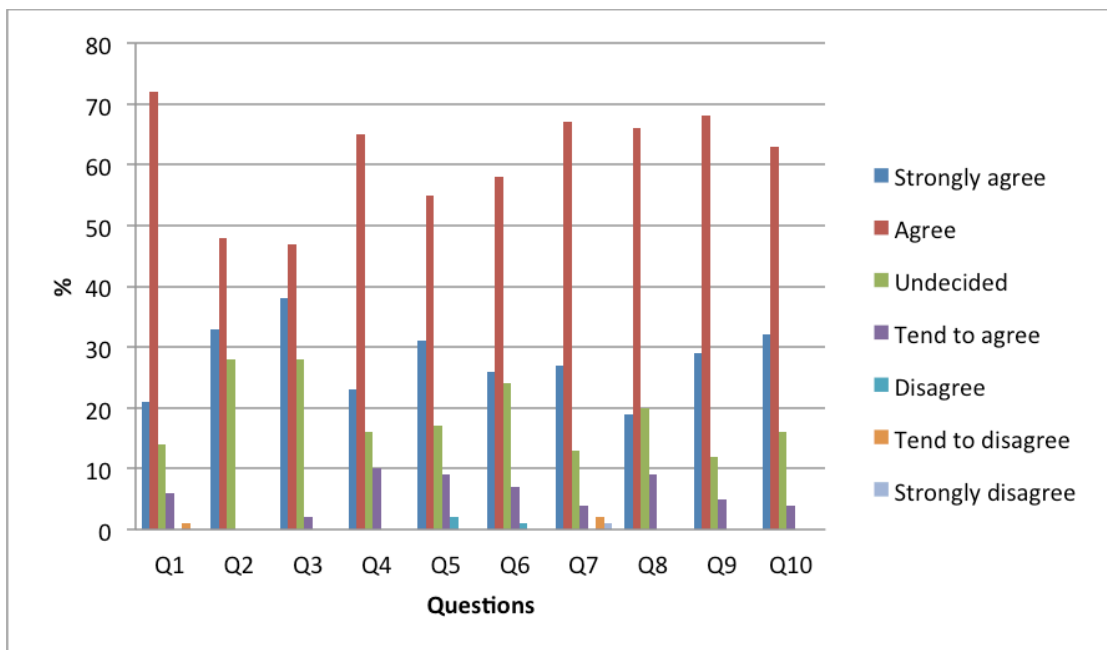


Figure 11. Results of the users survey (percentages).

Another issue considered is the distribution of the location-based scoring; considering that the news are usually distributed relative to one area of interest, for example a country or a smaller area, high oscillations in the number of documents per relevance could give rise to further optimizations. Thus it was analyzed the distribution of 9 sets of documents, categorized as: Accommodation, Leisure, Attractions, Community, Car,

Food, Shopping, Supermarket, Travel and it was calculated the number of documents per relevance windows. In Figure 12 are shown the results of the 3 categories with more documents, and the Average over all the 9 categories, with a windowing width of 0.05, leading to a resolution of 20 intervals in the range $[0,1]$.

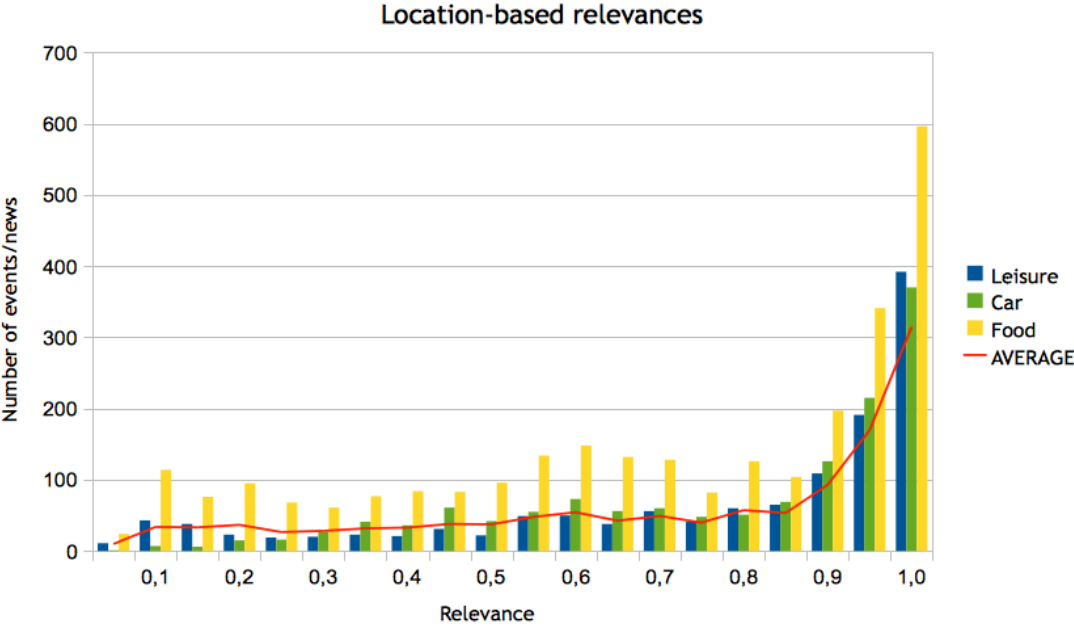


Figure 12. Location-based relevance average.

The results clearly showed that the results are clustered around the chosen point of reference (the center of the bigger city in the area of interest) and the distribution curve is rather smooth, maintaining almost a slowly monotonically increasing value between 0.10 and 0.85; also at higher resolutions (window width 0.1, with 100 intervals in the range), there are not high oscillations, as we hypothesized. Thus the investigation in this direction was stopped.

6. Conclusion and Future Work

This paper proposes a ubiquitous location, context-aware mobile recommendation system composed of a client-side application called CityEvents, and a Internet-based service providing well ordered multimedia Geolocated cultural events to display on

mobile devices. The user is provided with the best information, filtered and ordered keeping in consideration habits, context, location and potentially other parameters useful to achieve sharper results, in a personalized and interactive way. Different formulas for re-normalization and data-fusion were tested, compared and implemented in a complete demonstrative mobile application to analyse user feedback and possible pitfalls or improvements. Some directions of investigation were stopped when results from experimental data were available contradicting one hypothesis, while the majority of improvements and ideas developed during this work are suitable to future research.

As the future work, some improvements and directions of investigation are:

- testing the effect of using more advanced data-fusion techniques,
- testing the effect of more complex taxonomies endowed with proper metrics,
- testing the effect of rank-based scoring instead of relevance-based scoring,
- considering documents as structured entities, to identify some interesting relevance parameters,
- investigating possibilities to use generic browsing history to generate some interesting relevance parameters,
- implementing the demonstrative client in more mobile platforms like Android or Windows Mobile to get platform dependent user feedback.

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Chapter 4

Conclusions and Future Work

4.1 Main Conclusions

This Chapter presents a synthesis of the main achievements and points to several directions for future work. The main objective of this dissertation was the design, construction, and deployment of a weight-aware algorithm for mobile events agenda. This system is based on geo-located events in a database. The mobile system obtains the entire context and all the information needed to display events on the mobile device. The system includes a weighted algorithm to give an event score based on user preferences and historic habits. It shows an ordered list by user preferences and most important events displayed on a map, for better visualization. A performance study of a mobile system solution for iPhone was already conducted.

The study to create a ubiquitous computing approach for mobile devices led to the construction of a mobile application for delivering geolocated events. It follows an approach based on an agenda providing the needed information to the user in an easy and intuitive way. It reworks the user's habits, interests, and tries to suggest other nearby located events and presents them in a map, offering detailed information about it. List of events and map views are also available.

A client-server solution to answer the objective of managing a list of events (server-side) and presenting them to the user based on his preferences and location using a mixed-weighted awareness algorithm was created. This application (client-side) was deployed on iPhone. It can easily be ported to other mobile operating systems.

Based on an ubiquitous approach, the amount of data transferred between clients and server is reduced because the information is automatically filtered by location and user interests. The proposed solution was demonstrated and validated, and it is ready for use. Therefore, all the proposed objectives were successfully achieved.

After introducing and presenting the topic of this dissertation and define its objectives, Chapter 2 described a ubiquitous mobile events agenda called CityEvents. The chapter describes the system requirements, specifications, design, system architecture and CityEvents demonstration, and validation.

Chapter 3 presented a weight-aware recommendation algorithm for mobile multimedia system. It described the weight mathematical overview, a weighted scoring algorithm for mobile applications, and CityEvents demonstration and validation. The weighted scoring algorithm for mobile applications describes the location and habit awareness scoring, comparing with habit-based and location scoring. The system performance evaluation and results analysis was also presented.

4.2 Directions for Future Work

For future work, several improvements are suggested. A list of favourite events for the user may be created. Using more equipment information, default settings, and wireless network may increase ubiquitous computing experience. Contents may be improved with more multimedia elements, such as, video, photo slideshow and audio. For instance, providing weather data for the user allows him to see if he can go to an event or not, such as going to a concert. The mobile application can also be deployed in other mobile platforms, such as Android or Windows mobile.