SunPet – Real-time Sun Exposure Monitorization using Smartphones

Fernando Xavier Rocha Correia
Mestrado integrado em Engenharia de Redes e Sistemas Informáticos
Departamento de Ciência de Computadores
2014

Orientador
Engº. Luís Rosado – Fraunhofer AICOS

Coorientador
Prof. Dr. Luís Torgo – DCC-FCUP

Todas as correções determinadas pelo júri, e só essas, foram efetuadas.

O Presidente do Júri,

Porto, ______/______/_________

Agradecimentos

Gostaria de agradecer a todos aqueles que me acompanharam e ajudaram durante este projeto, e a todos os que contribuiram de diversas formas para a conclusão desta etapa da minha vida.

Ao meu orientador, Eng. Luís Rosado por me ter dado a oportunidade de integrar este projeto, pela sua orientação, pelo apoio profissional e pessoal.

Ao meu coorientador, Professor Doutor Luís Torgo, pelo seu profissionalismo e orientação durante todas as etapas do projeto.

Ao Filipe Silva e Nuno Ribeiro do IPATIMUP, por toda a motivação, disponibilidade e contributos essenciais no desenho do conceito do projecto.

Aos meus pais, que são um exemplo de dedicação e trabalho, por me terem ajudado a crescer como pessoa e Homem, e me proporcionarem todas as condições para a conclusão desta etapa.

À minha irmã, por me apoiar e aconselhar em todas as minhas decisões.

À minha namorada, Joana, que sempre me incentivou e disse "Tu és capaz!", pois sem ela, seguramente que nada disto teria acontecido.

E claro, ao meu grupo de amigos que durante todos estes anos estiveram sempre presentes. Todas as situações inesquecíveis que vivemos, por todos os dias e noites de estudo, por todos aqueles momentos que acabaram à gargalhada.

A todos, o meu muito Obrigado.

Resumo

A evolução do conceito de telemóvel, para um *Smartphone*, foi o início de um novo capítulo nesta era tecnológica. Continuando com os princípios base do telemóvel, os *smartphones* adquiriram funcionalidades e capacidades dos computadores pessoais, dando origem a um pequeno e poderoso dispositivo.

A possibilidade de explorar e aliar as potencialidades de um *smartphone* às necessidades da população é uma característica presente no desenvolvimento de novas aplicações. De um modo particular, a criação de aplicações que envolvem problemas de saúde publica, têm capacidade para se tornarem num dos maiores avanços na vida dos utilizadores.

Este relatório descreve o trabalho desenvolvido na empresa Fraunhofer AICOS no projeto "SunPet - Real-time Sun Exposure Monitorization using Smartphones", correspondente ao estágio curricular no âmbito da conclusão do curso de Mestrado integrado em Engenharia de Redes e Sistemas Informáticos na Faculdade de Ciências da Universidade do Porto.

Existe uma evidente necessidade de conscientização da sociedade para os perigos da exposição solar. Assim sendo, este projeto tem como objetivo o desenvolvimento de uma aplicação móvel para servir como assistente pessoal na prevenção da excessiva exposição ao sol, e consequente prevenção de doenças de pele relacionadas com queimaduras solares.

Ao longo do documento será feita uma revisão do estado da arte, observando os aspetos básicos relacionados com o âmbito do projeto, serão também analisadas algumas aplicações móveis com um semelhante objetivo. Serão apresentados os

objetivos do projeto, detalhes de implementação e as características inovadoras. Por último serão descritos alguns dos diferentes caminhos que este projeto poderá seguir no futuro.

Abstract

The evolution of a Mobile phone concept, to a Smartphone, was a new chapter in the technological age. Continuing with the main principles of the mobile phone, the smartphones added the functionalities of the personal computers, leading to a powerful gadget.

The possibility of exploring and allying the potential of a smartphone with the populations needs is a present characteristic in the development of newest applications. Particulary, the creation of applications involving global health issues has the potential to be a major breakthrough to the user's life.

This report describes the work developed at Fraunhofer AICOS under the project "SunPet - Real-time Sun Exposure Monitorization using Smartphones", corresponding to the curricular internship under the scope of the course Master's Degree in Network and Information Systems Engineering at the Faculty of Sciences of University of Porto.

There is an evident need to increase the community's awareness regarding the danger of sun exposure. Therefore, this project aims to developed a mobile application to serve as a personal assistant in the prevention of sun overexposure, and consequently in the prevention of skin diseases related with sunburns.

In the course of this document, a state of the art review is firstly made, taking into account the basic aspects related with the scope of this project, as well as an analysis of the existing similar applications on the market. There will be also presented the project objectives, the implementation details and some innovative features. To finalize, will be approached different paths to the future of this project.

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Acronyms

UV - Ultraviolet

App - Application

ISP - Internet Service Provider

GPS - Global Positioning System

SPF - Sunscreen Protector Factor

UML - Unified Modeling Language

API - Application Programming Interface

IDE - Integrated Development Environment

ADT - Android Developer Tools

SDK - Software Development Kit

URL - Uniform resource locator

JSON - JavaScript Object Notation

HTTP - Hypertext Transfer Protocol

CPU - Central Processesing Unit

Chapter 1

Introduction

Throughout the years, we have been witnessing a technological revolution, which has been evolving onto a situation in which the use of a smartphone simplifies the life of the population. Smarphones have become more convenient to use, due to his size, efficiency and adaptability to the population's needs, in detriment of the normal personal computers. In this way, the use of a smartphone is gaining importance in the everyday life, helping on determinant tasks for the user's health and well-being.

Over the past decades, new habits and new behavioral traits are being ingrained in the actual society. In some of these habits, the adoption of certain cares on behalf of individual's safety is becoming a relevant need. The excessive sun exposure without the necessary precautions, is a serious worldwide problem, since the rise in the incidence of skin cancers over the past decades is strongly related to increasingly popular outdoor activities and history of sunburn.

Considered these facts, there is an urgent need to create a tool that could be used as an aid to the population in this particular matter. Therefore, this project emerges with the aim of detecting in real time risk behaviors regarding sun exposure, working on the prevention of future skin related diseases.

1.1 Project

1.1.1 Motivation

Skin diseases caused by solar overexposure are a real threat present in our society. The excess of solar radiation can be responsible for several changes on the human body, such as skin aging, sunburn, changes in skin pigmentation and even skin cancer.

With the arrival of the sunny days, the tendency to practice some outdoor activities increases, and, as consequence, the amount of solar radiation received by the human body considerably increases. Unfortunately, in several cases the necessary prevention measures are not taken, increasing the risk of develop skin diseases.

The continued growth of malignant melanoma worldwide is seen as a serious problem, and can be justified with the failure to follow the necessary safety precautions.

The globalization of the mobile technologies and continued evolution in favor of the society makes the smartphone a powerful gadget to explore for this particular purpose. With the main goal of facing risky behaviours regarding sun exposure, this project aims to develop a mobile-based tool which will serve as a personal ally on the prevention of overexposure to UV radiation.

1.1.2 Objectives

This project consisted on the development of a smartphone application running Android operating system, to monitor in real time the sun exposure of a user. Merging different factors and technologies, we developed a tool which helps on the detection of risk behaviors regarding sun exposure.

The use of the GPS technology allows us to achieve precise values for the UV radiation levels on the sun exposure location. Combining environmental and geographical characteristics with genetic and personal aspects, we are capable of determining the personal safety exposure time, and, through a warning system, monitor the user's behavior.

Adopting an attractive and intuitive design, with a user-friendly interface, this application emerges to play an active role in the society regarding the prevention of skin diseases caused by excessive sun exposure.

1.1.3 Partners

This project is based on a curricular internship of the Faculty of Sciences at the University of Porto, developed at Fraunhofer, counting with the participation of the Institute of Molecular Pathology and Immunology of the University of Porto - IPATIMUP.

The Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions, is a research center of Fraunhofer Portugal, resulting from a partnership with the University of Porto. Fraunhofer Portugal focuses its activity in the area of assistive information and communication solutions, with the intention of creating technological solutions to the market success of its clients products and services.

The IPATIMUP is a private non-profit association of public utility, under the aegis of the University of Porto. It is an associated Laboratory of the Ministry of Science, focused on carrying out research and innovation on oncobiology, with a strong emphasis on pathology, aiming to improve cancer prevention and management of cancer patients.

1.1.4 Structure of the report

The presented internship report is organized as follows: chapter 2, is dedicated to the state of the art, making a study of several aspects approached in the course of the project, and analyzing the existing applications with similar concepts as well. Chapter 3 provides the application description with a global overview of the main functionalities. The chapter 4 describes the application architecture using a UML diagram to represent a standard utilization of the application, explaining, as well, the cases where server requests are needed. Chapter 5, presents the technologies and tools used during the project, and discusses the implementation stages, describing the principal classes, problems and solutions occurred during the entire project. The chapter 6 is dedicated to the demonstration and discussion of results, obtained by a simulation of a normal use of the application.Finally, chapter 7 addresses the different possibilities of future work for this application.

Chapter 2

State of the Art

The evolution of the smartphone devices allows gathering different information collected from several services, which combined, can modify and improve the pattern of the prevention of skin diseases due to solar overexposure. This state of the art review briefly describes the main principles used during this project. Understanding topics as Ultra Violet radiation and its effect on human skin, skin type classification and problems associated to the outdoor activities, are fundamental issues to serve as a basis for the project development. In this review other smartphone applications with similar objectives are presented, analysing and comparing them with the SunPet concept.

2.1 Ultra Violet Radiation

Ultra Violet (UV) radiation is a part of the electromagnetic spectrum emitted by the sun and invisible to the humans. The UV rays are usually divided in three bands, characterized by different values of wavelength and consequent different behavior: UV-A, UV-B and UV-C. The UV-C radiation (100 - 280 nm) is the most dangerous due to its high level of energy, but this kind of radiation is completly blocked by the ozone layer and the oxygen.

The UV-B radiation (280 - 315 nm), is a dangerous radiation, primarily responsible for quick sunburn. Approximately 90% of these rays are absorbed by the ozone layer, however, a small part reaches the Earth's surface.

The majority of UV rays reaching the surface are the UV-A (315 - 400 nm). The UV-A radiation is weakly absorbed by the atmosphere. Despite being the less harmful to the human, the overexposure leads to sun spots and even skin cancer [11][22].

UV radiation is also important to Earth's life. It is fundamental in the occurrence of important photochemical and photobiological effects. Particularly, to the human life, the exposure of the skin to UV is essential for the synthesis of Vitamin D [9]. Sun light is beneficial in limited amounts and with proper protection from overexposure. Too much exposure to UV rays can cause sunburn. The UV rays penetrate the outter skin layers and pass into the deeper layers, where they can damage or kill skin cells.

2.1.1 UV index

To help in the prevention of skin damage, the World Health Organization in combination with the United Nations Environment Programme, and the World Meteorological Organization created a human-friendly scale system, divided by dangerous levels of UV radiation, allied to a color system in order to alert people about the necessity of adopting protective measures. This scale system called UV Index (UVI), is calculated depending on the amount of incidence of UV radiation in a particular location [11].

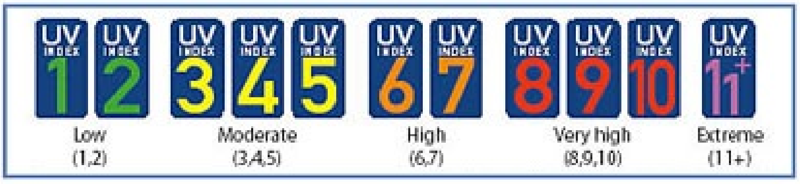

Figure 2.1: UV index scale

This scale of dangerousness is just a prevention model that needs to be allied with different measures of protection, dependent of some other factors. One of the most important factors is the skin type of each person.

2.1.2 Effects of UV on skin

The skin is the largest organ in the body. It separates the internal body parts from the external environment and plays an important protective function. It is divided in three layers: epidermis, dermis and hypodermis. Reaching our skin, UV rays penetrate deeply and trigger photochemical and biochemical reactions that result in skin damages, sunburn, allergies and later skin cancer. Skin pigmentation is a defence mechanism against UV rays. When UV radiation is abundant, specialized cells, called melanocytes, increase the production of melanin[1]. Therefore, skin color changes in sunburn, notifying people of the extreme UV exposure.

The UV-A rays penetrate into the deeper skin layers, where connective tissue and blood vessels are affected, causing genetic mutations and DNA damages. As a result, the skin gradually loses its elasticity and starts to wrinkle.

It is worth noting that UV-A rays are present in our every living in different degrees of incidence, and long-term sun exposure results in profound and permanent alterations in epidermis and dermis, being directly related with the development of skin cancers. Regarding the UV-B rays, they affect the upper layer of the skin, epidermis and are responsible of redness skin associated to sunburn after sun exposure. UV-B stimulates the production of new melanin, which leads to an increase in the dark-coloured pigment and the incidence of these rays is particularly higher in the summer. However, higher doses of UV-B can increase your likelihood of developing cancer [23][7].

2.1.3 UV index calculation

The UV index calculation involves many resources, and can be performed in two different ways. By ground observation, using UV sensors to measure the intensity of the UV radiation in specific locations at specific moments, or using computer models.

The use of computer models in order to determine the UV index, is based on forecast stratospheric ozone concentration, cloud amounts and elevation, obtained via satellite. The compute procedure begin with measurements of current total ozone amounts over

[1] Pigment that gives color to the skin.

the entire globe previously obtained. A Radiative transfer model [2], uses the ozone data and the angle of solar incidence, to calculate the strength of UV radiation at ground level for different wavelengths from 290 nm to 400 nm. These strength are weighted by McKinlay-Diffey Erythema action spectrum, to simulate the skin reaction to the different wavelengths. Using these values, and adding the effect of the elevation and cloud cover, the computer model determine with accuracy the UV index [6].

2.1.4 Outdoor activities

Atmospheric and geographical factors can considerably influence the UV radiation levels, which must be taken into account in any outdoors activities. Factors shown below, have direct impact in amount of UV rays absorved by the people [11].

- Sun heigh: the higher the sun is in the sky, higher will be the UV radiation;
- Latitude: places near to the equator have higher UV levels;
- Cloud cover: cloudy sky gives some resistance (though weak) to UV rays unlike cloudless skies that show higher UV radiation levels;
- Altitude: every 1000 metres increase in altitude, UV levels increases beetwen 10% to 12%;
- Ground reflection: UV radiation is reflected or scattered with different values depending of the surface.

These enviromnental characteristics described above, associated with the number of hours on outdoors activities, and unsuitable protection can increase the risk of skin diseases.

A study by Fears et al.[14] indicates that most of total life exposure to sun of an individual is made in the childhood and adolescent years (0-20). However, it is in adult age that the skin diseases will develop and have more incidence. This study [14] concludes that, there is a strong evidence that the risk for melanoma increases with increased time outdoors, even for those who can develop a deep tan.

[2] Model that measure the energy transfer in the form of electromagnetic radiation.

To attenuate the increasing incidence of skin diseases, it is necessary to adopt prevention measures, using mechanisms that can cover the biggest number of individuals of different age groups.

2.2 Skin Type

Skin is our first protection against UV radiation. However, several factors can influence the way UV rays affect people, such as race, ethnicity, skin color, hair, eyes, freckles and spots. The combination of genetical characteristics and skin conditions have direct influence on the protection behaviors that each person should have with the sun. Different behaviors have to be taken considering the different type of skin, and to classify it, the Fitzpatrick Skin Phototype Classification is commonly used by dermatologists [4].

The Fitzpatrick Skin Type, firstly developed in 1975 by Thomas Fitzpatrick, is a skin classification system based in one numerical schema for color skin [16]. The test, as shown in table 2.1 is a standardised questionnaire divided in two groups, Genetic Disposition and Reaction to Extended Sun Exposure, used to collect information about eyes, hair and skin colour, quantity of freckles and sun exposure habits. The result determines the skin type of the person.

Fitzpatrick Skin types Quiz	
Genetic Disposition	Reaction to Extended Sun Exposure
Your eye color is: Light blue, light gray or light green=0 Blue, gray or green = 1 Hazel or light brown = 2 Dark brown = 3 Brownish black = 4	**How does your skin respond to the sun?** Always burns, blisters and peels = 0 Often burns, blisters and peels = 1 Burns moderately = 2 Burns rarely, if at all = 3 Never burns = 4
Your natural hair color is: Red or light blonde = 0 Blonde = 1 Dark blonde or light brown = 2 Dark brown = 3 Black = 4	**Does your skin tan?** Never – I always burn = 0 Seldom = 1 Sometimes = 2 Often = 3 Always = 4
Your natural skin color (before sun exposure) is: Ivory white = 0 Fair or pale = 1 Fair to beige, with golden undertone = 2 Olive or light brown = 3 Dark brown or black = 4	**How deeply do you tan?** Not at all or very little = 0 Lightly = 1 Moderately = 2 Deeply = 3 My skin is naturally dark = 4
How many freckles do you have on unexposed areas of your skin? Many = 0 Several = 1 A few = 2 Very few = 3 None = 4	**How sensitive is your face to the sun?** Very sensitive = 0 Sensitive = 1 Normal = 2 Resistant = 3 Very resistant/Never had a problem = 4

Table 2.1: Fitzpatrick Skin Type Quiz.

Skin type results [4][16][20]:

- Type I (0 - 6 points)- White, Very fair-skinned, red or blond hair, blue eyes and freckles:

  Always burns, never tans

- Type II (7 - 12 points)- White, fair-skinned, red or blond hair; blue, hazel, or green eyes:

  Usually burns, sometimes tans

- Type III (13 - 18 points)- Beige or Light Brown:

  Sometimes burns and always tans

- Type IV (19 - 24 points)- Medium Brown, typical mediterranean skin

  Rarely burns, always tans

- Type V (25 - 30 points)- Dark brown:

  Very rarely burns and tans very easily

- Type VI (31+ points)- Black:

  Never burns and tans very easily

The way of protection against sun exposure in an outdoor activity can greatly vary according the UV index and skin type, therefore, different measures need to be taken depending on these factors. According to the World Health Organization, if sun protection is required, this should include all protective means, i.e. clothing and sunglasses, shade and sunscreen.

Many studies showed positive associations between the risk of skin diasese and a history of sunburn, but a solid interpretation of this association is complicated [17][19]. Melanoma is the most fatal skin cancer, and is incidence is increasing. The progressive growth of malignant melanoma have higher incidence in fair skinned people than those with dark skin, suggesting, as already know that color skin can increase the protection against UV radiation. Geographical factors, with areas closer to the equator and higher in altitude generally having higher rates indicating that UV radiation plays an important role in the development of the disease [21].

2.2.1 Sun exposure time

Knowing what is our skin type is crucial to avoid overexposure to the sun, particularly when practicing some outdoor activities, which normally keep us susceptible to different values of UV radiation for longer periods of time in mixed environments. The analysis of the maximum of sun exposure period is a delicate task, due to the need to take into account several variables, such as UV index, latitude, longitude, altitude and the surrounding environment. The level of UV radiation can be increased in accordance to the factors previously referred in sector 2.1.4, having direct influence on the equation for determining the safe period of sun exposure. Altitude can increase 12% of UV incidence in each 1000 meters, reflective surfaces, such as snow, water and sand can increase respectively 80%, 10% and 15% of the UV radiation.

The way to calculate the maximum exposure time, without sunscreen, and avoid the sun burn is given by the next table [23]:

Skin type	Color	Maximum exposure time
I	Very white	67 min / UVI
II and III	White and light brown	100 min / UVI
IV and V	Medium and dark brown	200 min / UVI
VI	Black	300 min / UVI

Table 2.2: Maximum exposure time whithout protection.

To better understand this calculation, a person with skin type 3 and exposed to UV radiation of index 8, will be taken as reference.

In this scenario, the maximum exposure time, until the skin start to burn is 10 minutes [100 (min) / 10 (UVindex)]. However, associating environments aspects, like altitude, will drastically decrease the recommended exposure time of these individual. At an altitude of 2000 meters, the UV intensity will be 24% higher, thus, the UV index is adjusted to 12.4 [10 * 1.24 = 12.4], this gives a maximum exposure time of 8 minutes [100 (min) / 12.4 (UV index) = 8 min].

If, in the same conditions we add snow activities, the UV intensity will drastically increase in 80% due to reflexion. In this conditions, the UV index rises from 12.4 to 22.3 [12.4 * 1.80= 22.3] and so, there is only almost 4 and half minutes until sunburn begins.

Regarding protection, the use of sunscreen is essential to help prevent the sun's UV radiation from reaching the skin. The sunscreen lotion, are designed to absorb or reflect the sun's UV rays, acting as skin protector. These protection effect is measure by the Sun Protection Factor (SPF) value, which indicate how much longer an individual can stay in the sun compared with his exposure time without any protection. In other words, the SPF value is directly related with the safe exposure time, which increases as much as the SPF value.

Using the same conditions as before, being in the snow at 2000 meters of altitude, but using sunscreen of 45 SPF, the maximum exposure time increase to more than 201 minutes (more than 3 hours) [4,48 (min) * 45 (SPF) = 201,6 (min)].

2.2.2 Skin cancer incidence

The skin cancer can be divided in three main types. Basal cell carcinoma, Squamous cell carcinoma (these two form the non-melanoma skin cancer group) and Melanoma.

Non-melanoma skin cancer is the most common type, with 95% of the global value of skin cancers. However, it is highly treatable making the rate of deaths very low.

On the other hand, Malignant Melanoma is the most serious type of skin cancer, accounting for only 5% of all skin cancers[13], and according with GLOBALCAN [15], is the 19th most common cancer in the world, responsible for almost 200 000 new cases in 2008.

Malignant melanoma, has shown the fastest increase in recent decades, being significantly higher among fair skinned population. The rates of incidence are highest in Australia and New Zealand and lowest in South-central Asia, as showed in figure 2.2.

Concerning to the lowest rate of incidence, these values may be underestimated since many of the case reports in the underdeveloped countries are not properly recorded, limiting appropriate conclusions [8].

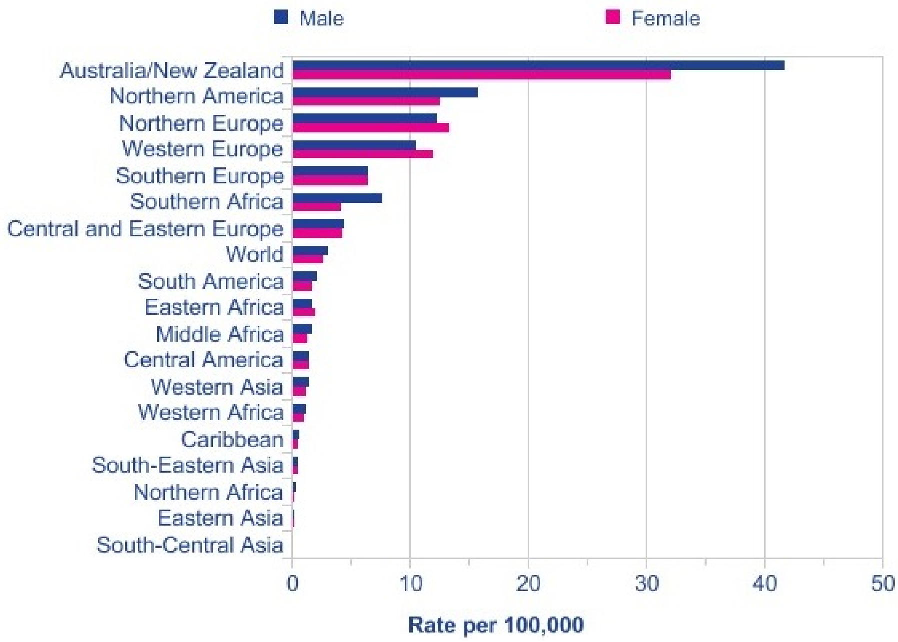

Figure 2.2: Malignant Melanoma- World Regions [8]

Looking at the figure 2.2 distinct situations emerge, between Australia/New Zealand and Northern Europe. Australia/New Zealand, experiences some of the highest levels of UV radiation in the world, due to some geographical conditions. They are located closest to the equator where the UV incidence is high, and the ozone layer over Australia is thinner, leading to more UV radiation reaching the earth. These factors can be the reason to the higher incidence of Malignant Melanoma in those countries [1].

The Northern Europe situation is totally different. Geographical conditions are not applied to increasing the UV radiation. Quite the contrary, it is in Northern Europe that the UV radiation is lower. However, notwithstanding of geographical, environmental and genetic factors, a new factor needs to be added to explain these results: the socioeconomic status.

To better understand this new factor, let us review the situation of the incidence of malignant melanoma in Europe.

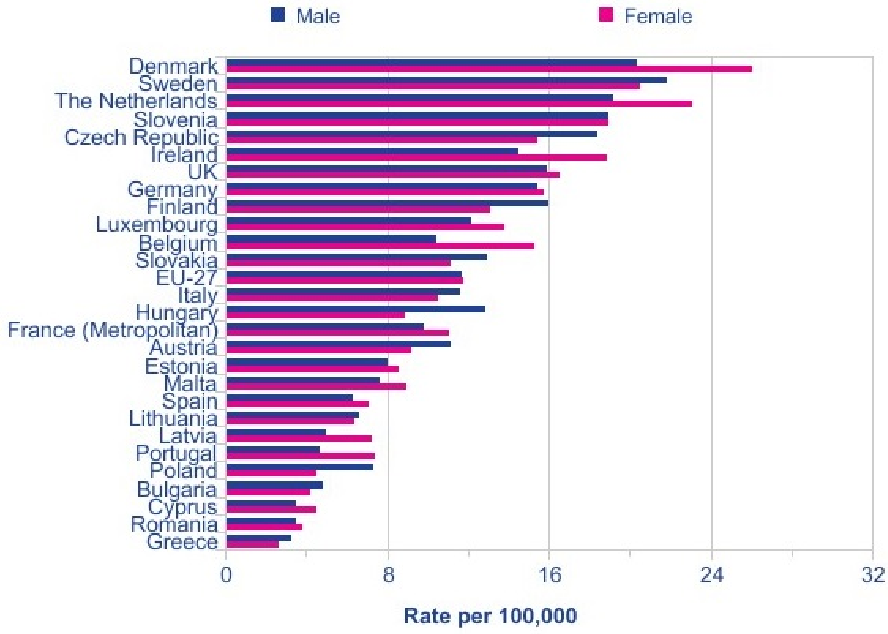

Figure 2.3: Malignant Melanoma- Europe [8]

Among European countries, the highest melanoma incidence rate is estimated to be in two Northern European countries: Denmark for females (around 26 cases per 100 000) and Sweden for males (around 22 cases per 100 000). In the bottom of the list, Greece has the lowest rate for both sexes.

Framing these results with the socioeconomic factor, we can find a relation between the economic power and the melanoma incidence on the population. It should be noted that on top there are countries whose population has higher socioeconomic status such as Denmark, Sweden and The Netherlands. At the opposite side, with less population with higher socioeconomic status we find Cyprus, Romania and Greece.

Some investigators have concluded from similar data, that there is a genuine effect of socioeconomic status on melanoma incidence [18]. The social and economic changes are associated to the increase of malignant melanoma, as result of changes in lifestyle involving increases in intermittent intense exposure to UV radiation. People of higher socioeconomic groups, may travel more frequently to high altitude or to sunny destinations in which the UV radiation are higher, adopting a behavior involving increased risks. However behavioral changes of the people with lower socioeconomic status can approach them to the habits of higher status groups.

The incidence of skin diseases has been rising during the last decades of the last century, as a result of several changes in destinations of vacations, sunbathing attitudes and styles of clothing. The bad habits in childhood and adolescence of sun exposure, are associated with the risk of developing melanoma in adult age [12].

2.3 Sun exposure monitorization applications

With the appearance and advance of mobile technologies, the development of mobile applications became easier and capable of providing any kind of information and service. The behavior change is often marked by technological changes, and smartphones have brought social changes in the way to think, act and socialize.

This subsection, describes the specific functionalities of each mobile application, with the purpose of analysing and comparing with the SunPet concept. The three examples that will be presented below are free apps available for download at *Google Play Store*. All of them have the same main objective preventing skin damage however they present different functionalities.

2.3.1 Sun Shield

The Sun Shield application (App), was created by the North American company, Spot On Solution, a company dedicated to business consulting and software development for mobile devices applications.

The Sun Shield app is available for Android devices, iPhone and iPad, being paid for iOS devices. The App provides the UV index in a specified location introduced by the user or based on the location given by the Internet Service Provider (ISP). The lack of use of the GPS to determine the user location is a weakness of this App. A location based on ISP has lower accuracy, because the network connection can be made to a Base Station located up to 20 kilometers. This application will determinate the skin type of each person through one quiz (Fitzpatrick skin type quiz), and the result of the quiz will provide information about the individual skin type. According to skin protection, Sun Shield gives two different ways to recommend safety actions. In the first option the user determines how much time will be in the sun, and conjugated with the individual skin type and the current UV index, the App recommends the SPF. Alternatively, the user can choose a SPF level to determinate the recommended safety exposure time that he can stay in the sun. The main problem in this feature is the non-inclusion of different scenarios where the UV index can be affected, and consequently decreasing the safety exposure time.

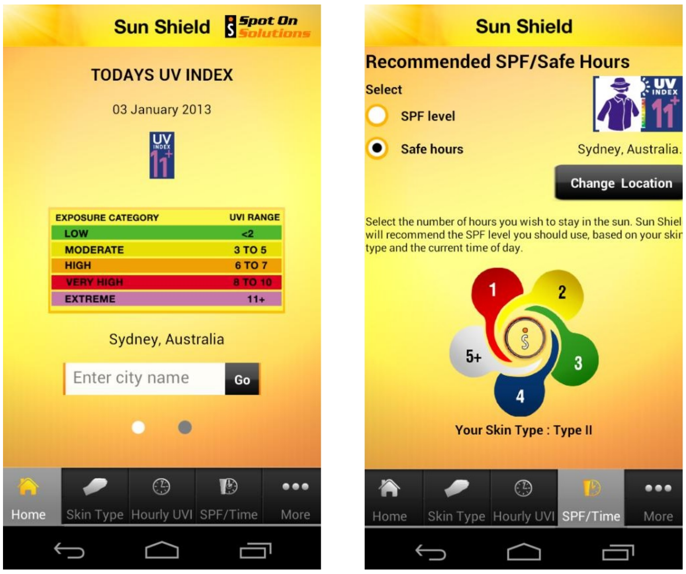

Figure 2.4: Sun Shield App

The left side of the figure 2.4 presents the Home screen that is presented to the user moments after the beginning of the App. In this image a UV index scale is highlighted informing the user of the dangerousness scale, the user location and the corresponding UV index. The right side of Figure 4 shows the screen where two options according to skin protection are presented, in that example the number of hours is given by the user and the App returns a recommended SPF level.

2.3.2 SunSmart

SunSmart application was created by Cancer Council Victoria, an Australian not-for-profit organization that works in cancer research, prevention and support.

SunSmart is available for free to iPhone, iPad and Android devices. This application is only available for Australian locations that the user can chose according to an app database. After this first step, the UV index and a period of sun protection is shown to the user. The SunSmart App can be divided in three different features for protection. Sun protection alerts, Sunscreen reminder and Sunscreen calculator. For sun protection alerts the user has two options, activate a daily reminder when the UV radiation reaches a level where sun protection is required or set customized daily alert time. Enabling a sunscreen reminder, activates a pre-defined reminder of two hours for reapplying sunscreen. Unfortunately this reminder has a fixed time and does not give the possibility to change it. The sunscreen calculator, advises the user of how much sunscreen he needs to apply. Based on a human body, the user can add or remove clothes, and depending on the amount and type of clothes the sunscreen calculator advises a quantity of sunscreen. This calculation doesn't seem much scientific, because the only variable that can change the final result are the clothes, the more clothes the prototype has, the smaller the quantity of sunscreen is advised.

Figure 2.5: SunSmart App

Figure 2.5, shows the main screen after defining the current location, the local UV index and the period of sun protection required is emphasized. The right image represents the sunscreen calculator, where the amount of sunscreen is advised depending on the quantity of body exposed.

2.3.3 UV Canada

UV Canada application, was developed by MetaOptima Technology Inc, a Canadian company that works with the aim of raising awareness about sun safety and skin cancer prevention.

The UV Canada application is available to all Android and iOs devices. This application only works with Canadian location selected from an internal database. MetaOptima also developed another app, named UV US, with exactly the same functionalities and layouts, but the location database only has North American locations. UV Canada doesn't use the GPS technology to input the user location, instead, provides a large list of cities and villages. This App works as a weather application, providing values of wind velocity, humidity, actual temperature as well as for the following days. Current UV index is shown in two different ways, as actual value and using a graph to demonstrate the UV index evolution throughout the day. Regarding skin protection features, the UV Canada application uses a highly intuitive layout, asking to the user to define all the variables (UV index, environment, skin type, SPF level) to estimate a limit time of sun exposure. This App does not assume the current UV index to carry out the calculations, and does not present coherent values when SPF level is increased.

Figure 2.6: UV Canada App

The figure 2.6 shows in the left the main view with the daily UV progression and the current UV index. The right image represents the view where the maximum time of sun exposure is determined.

2.3.4 Sunpet concept

Sunpet application emerges with the aim to detect in real time risky behaviours. The app provides a personal assistant service to monitor the UV radiation in a specific location and control the time spent in the sun. With the main objective of prevention, a funny and animated layout will capture the user attention, standing out immediately of others applications. Contrarily to other apps, Sunpet have two options to determine the user location, based on GPS location or introduced by the user. In order to determine the user skin type an accredited system (Fitzpatrick skin type) is used to handle this important factor. Due to environmental factors, the safety sun exposure time is highly affected. For this reason, different scenarios are presented to the user in order to adapt the safety sun exposure to the surrounding environment. The warning system produce visual and sound effects in some specific conditions, to alert the user of a possible risk behaviour. A new feature is the creation of a personal history. Allowing the user to save the sun exposure history, give the possibility to the user see if there were risk behaviours. The history keep information of location, UV index, and indicates if there was risky behaviours. Sunpet inovates and gathers features that are only partially offered by different apps, mitigating the shortcomings of the existing apps on the market.

Chapter 3

Application description

In this chapter, it will be firstly described the main functionalities of the developed application. Moreover, the system requirements are equally approached.

3.1 Application Functionalities

The most innovative aspect of this project was to merge distinct and determinant components in order to create a reliable metric for risk assessment of sun exposure. In this subsection, are shown these aspects and functionalities present on this application.

- Location based on GPS;
- Real-time UV information;
- Skin type classification test;
- Type of outdoor activity;
- Safe exposure time;
- Warning system;
- Risk behavior classification
- Sun exposure history

A brief description of each functionality:

Location based on GPS The GPS location is obtained using the internal GPS receiver, present on the smartphone.

Real-time UV information The UV index value, is the central variable for the calculation of the safe exposure time. Due to the UV index oscillation, the frequent actualization of this data is crucial, maintaining the user's situation updated. To have access to this data a meteorological service is used which provides a weather API to request the UV index. This service will be detailed described in the Chapter 4 - Application Architecture.

Skin type classification test The Skin type classification test, allow us to grouping the users according to his tolerance of sunlight, and subsequently apply different rules. The classification is based on the Fitzpatrick Skin Type that was previously described in section 2.2. Once made it, the result of the test is permanent, avoiding the inconvenience of going through this stage again.

Outdoor activity types The selection of the user's current activity, is used to select which variables will be applied on future calculations. Different environments have different characteristics, having direct influence on the final result. According with the World Health Organization, the UV index suffers alterations depending on the surrounding environment. The UV index at the beach is increased in 10% by the water reflexion and 15% by the sand reflexion. In activities at the mountain, the UV is increased by the altitude in 12% for each 1000 meters and by the grass/ trees reflexion in 10%. In the snow environment, additionally to the altitude factor, the snow increases 80% of the UV index value [11].

Safe exposure time Calculate the safe exposure time, is the main goal of this application. After the user passes through the previous stages, the personal safe exposure time is provided. Gathering the information on the local UV index, the user altitude and his skin type, surrounding environment and the SPF value, the application is ready to calculate the personal safe exposure time.[23] As demonstrated in section 2.2.1, the application uses the following equation:

$$SaftyTime = \frac{User\ Maximum\ exposure\ time\ (table)}{UV *\ environment\ variables\ (Altitude, reflection)} * SPF$$

Figure 3.1: Personal safe exposure time equation. Source [23]

Warning system The warning system is called when a potential risk behavior is occurring. The warning is sent to the user through a screen pop up, sound, vibration and led notification. There is four types of warnings activated in regular periods of time:

- *Look for shade* - Every two hours the user is advised to look for shade;
- *Swimming* - Every three hours the user is asked if he went to the water, and is advised to reapply the sunscreen;
- *UV change* - The UV index is verified every one and a half hours. If the UV value increases, the safe time is recalculated and the user is warned;
- *Time overtaken* - Is classified as the most dangerous situation. It is only visible if the user exceeds the safe time.

Risk behavior classification The user's behavior is classified at the end of each sun exposure. The behavior can be classified by *Low*, *Moderate* or *High* risk, depending on some risk factors. The risk classification is based in compliance of the received warnings, which, once fulfilled are classified as *Low*. If at least, one of the two warnings *Look for shade* and *Swimming* are not respected, the risk behavior is classified as *Moderate*. The most serious risk, *High*, is applied when the *Time overtaken* warning was not respected, independent of the other warning results.

Sun exposure history The Sun exposure history allows the user save and consult previously tracked sun exposure activites. Moreover, allows the users supervise and keep track his exposure risks, creating a global view of his/her behavior.

3.2 Application Interface

With the final purpose of developing a mobile application that can be used as a personal assistant, which allows to control and warning in real time the risk behavior regarding sun exposure, we had to create a substantially different solution from the ones already available on the market for similar purpose. This application also intends to cover an broader age range, so we designed an animated layout, where being funny is the key to captivate the user. Using the *keep it simple* principle, we have tried to reduce the number of necessary clicks to get the final result, avoiding the user's annoyance. This way, is possible to capture the user's attention, thus motivating him to reuse the application.

3.3 Operating System requirements

As was referred earlier, in this first stage of the project, and as company policy, the SunPet application was developed for Android Operating System.

According with the Android market tendency, the rate of devices running lower versions than 4.0 (i.e. version 2.x and 3.x), is less than 15%, and exhibiting a strong decreasing tendency. Having in mind this fact, SunPet was developed for Android devices running 4.x version, thus, ensuring the correct operation of all functionalities, avoiding compatibility problems.

As is shown in the Table 3.1, at this moment, SunPet application is covering approximately 85,8% of global number of Android devices.[1]

[1] Data collected during a 7-day period ending on July 7, 2014. Any versions with less than 0.1% distribution are not shown

Version	CodeName	Value
2.2	Froyo	0.7%
2.3.x	Gingerbread	13.5%
4.0.x	Ice Cream Sandwich	11.4%
4.1.x	Jelly Bean	27.8%
4.2.x		19,7%
4.3.x		9.0%
4.4	KitKat	17.9%

Table 3.1: Relative number of devices per Android version.

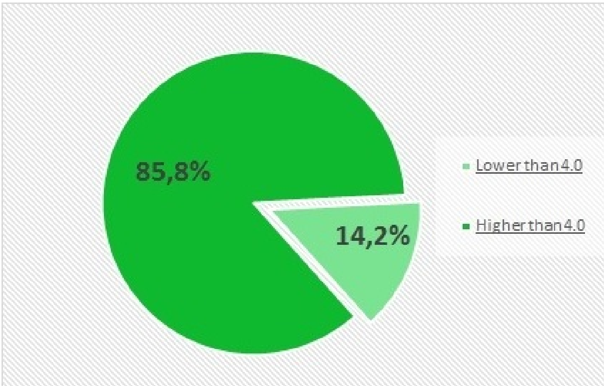

Figure 3.2: Rate of devices running Android versions higher and lower than 4.0. July 7, 2014 [2]

Chapter 4

Application Architecture

In this section, will be described and schematize the application architecture in a global context, as well as its logical implementation. It should be noted that the presented architecture, shown by the UML Activity Diagram, reveals the structure of the user's interface, showing the application flow in a standard usage. Furthermore, the external APIs that are used to collect data, which are especially important for the function of the application, will be described.

4.1 UML diagram

The represented UML diagram describes the global concept of the application on a normal use. Particularly, all the application activities with which the user can interact are depicted, covering all the user interaction from the launch of the application to the end an exposure tracking and visualization of the respective analysis report.

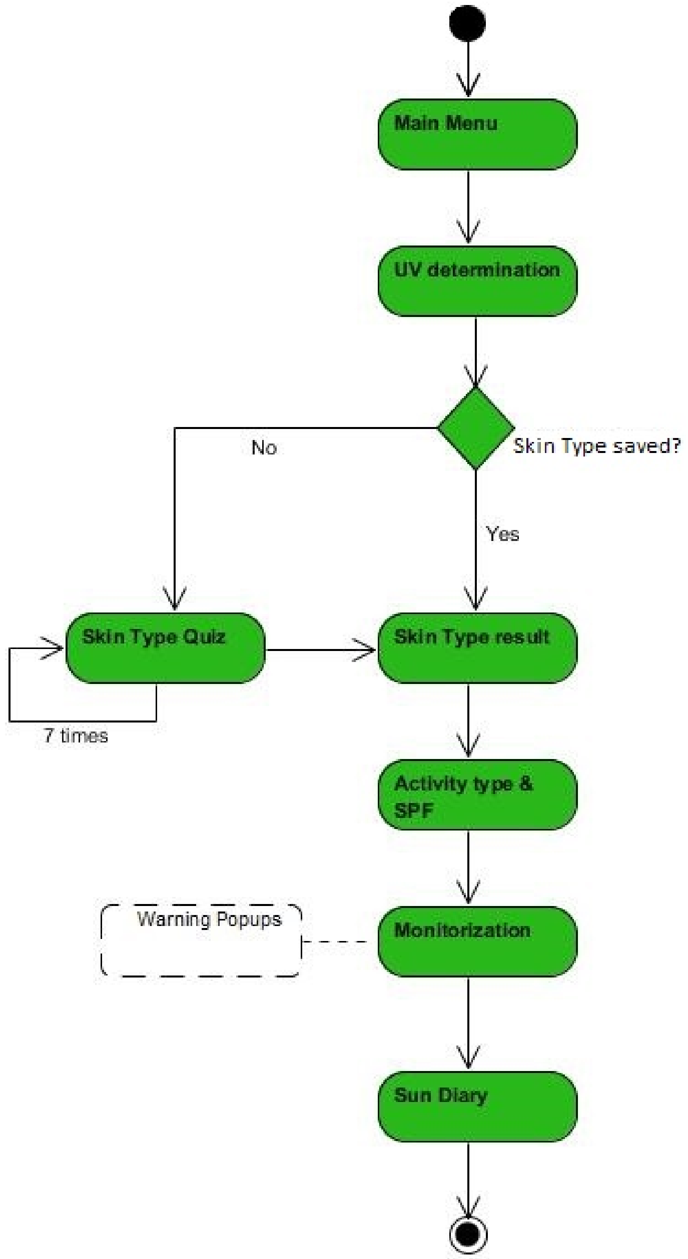

Figure 4.1: SunPet's Activity diagram

4.2 UV request

The Ultraviolet value is the key element on this project. The need of acquire an accurate value was extremely important, therefore, our option was two well-known and credited weather service, *The Weather Channel* and *Weather Underground*, that together provide an API for users interaction.

Allowing accesses in real time, we use this API to collect some values, which include the UV index, user locations name and altitude.

Initially, to use the API, it was necessary to create of a key to identify the company requests. A *Developer* key, was created free of fees, but with limited number of requests, which can be a significant problem for the scalability of this solution.

With this free key, the number of request per day is limited to 500 calls, and just 10 per minute. It should be noted that other types of plans exist, allowing for higher numbers of requests, but this type of keys must be monthly paid. At this initial point of the project, the number of requests do not justify the acquisition of an paid key. However, we do not exclude this fact depending on the application scalability [10].

4.3 Geocoding

Geocoding, is the process of converting geographical addresses into geographical coordinates, i.e. Latitude and Longitude. The same principle but with exchanged arguments, from entered coordinates converting to name address, is called of Reverse Geocoding.

As we do not have any background Geocode server, we opted for use the potential of the Google Geocoding API from Google Maps API Web services, to convert the inputted location of an user into geographical coordinates.

This service uses the same principle as previously referred, providing a developer key, with limited amount of requests per day. In the Geocoding case, we are allowed to use 2500 request per day and 10 per second. Which is perfectly acceptable in this initial stage [5].

Chapter 5

Implementation

During the project, we faced different challenges, solving them in partitular ways. In this chapter, will be described the technologies and tools used during SunPet application development. Furthermore, this section deals with the implementation details, analysing the structural classes, and presenting relevant choises made in the course of project implementation.

5.1 Technology and used tools

5.1.1 Eclipse

Eclipse is a Integrated Development Environment (IDE), used in large scale by Java developers, however, may also be used in several others programming languages, due to his open source characteristic, allowing the development of newest plugins, attending the developers needs.

This project was developed in Java language, as Android characteristic, using the Android Developer Tools (ADT) plugin for Eclipse, and the Android SDK package, to extend Eclipse resources, having access to different functionalities and offer better support for android development.

5.1.2 Android SDK

The Android SDK provides the API libraries and developer tools necessary to debug, build and test Android applications. According the test mode, the SDK incorporates an Emulator Terminal, providing to the user the opportunity to test in different screen sizes.

5.2 MainActivity Class

The *MainActivity* class is responsible for the Menu view, wich corresponds to the user's first contact with the application.

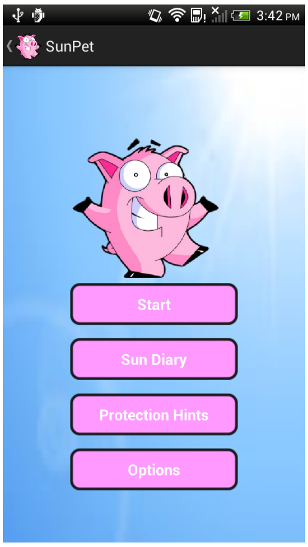

Figure 5.1: Main menu screen

In this first version, we decided to include four possible options,

- Start: Begin the application's sequency;
- Sun Diary: History of previous exposures;
- Protection Hints: Educational curiosities about sun protection;
- Options: Application options.

Whenever the application is started, an *getReadedConditions* method is executed. This method is responsible for verifying if this is the first time that the user uses the application, in order to show the "Terms & Conditions" advisement. At the moment that the user accept the terms, a flag is set as *true* an the value saved on a private file accessible only for the application. Thus, we can ensure that, the "Terms & Conditions" advisement, only appear once and in the user's first utilization.

5.3 DetermineUV class

The collection and manipulation of data in order to receive the local UV index, is the main objective of this class.

First of all, it is necessary verify the required connections for the application's full operationality, and for that, is invoked the *checkConnection* method. The internet connection is essential for the data requests, on the other hand, the GPS connection is not essential, but is advisable in order of obtain more precise data.

The user's location can be inputted into the application in two distinct ways, being necessary treat the data separately.

If the GPS is enabled, the *LocationManager* class from Android API, will be used to obtain the geographical coordinates. With the collected Latitude and Longitude, we are now capable of making a server request to get some necessary data, including the UV value.

On the other hand, if the user introduces manually his location, it will be necessary to translate the name location in to latitude and longitude. For this, we used the Google Geocoding API, which responds with geographical coordinates to an request with some name location.

To deal with all the comunnication to the server, a new class was created, the *Connection* class. The data sent by the *DetermineUV* class, will be interpreted, calling the convenient methods, separating the requests from the Geocode of the UV index. Both of the requests receive a JSON file as response, which is delivered again to the *DetermineUV* class, to proceed with the parser and collect the necessary data. The discribed communication process it is represented in Figure 5.2.

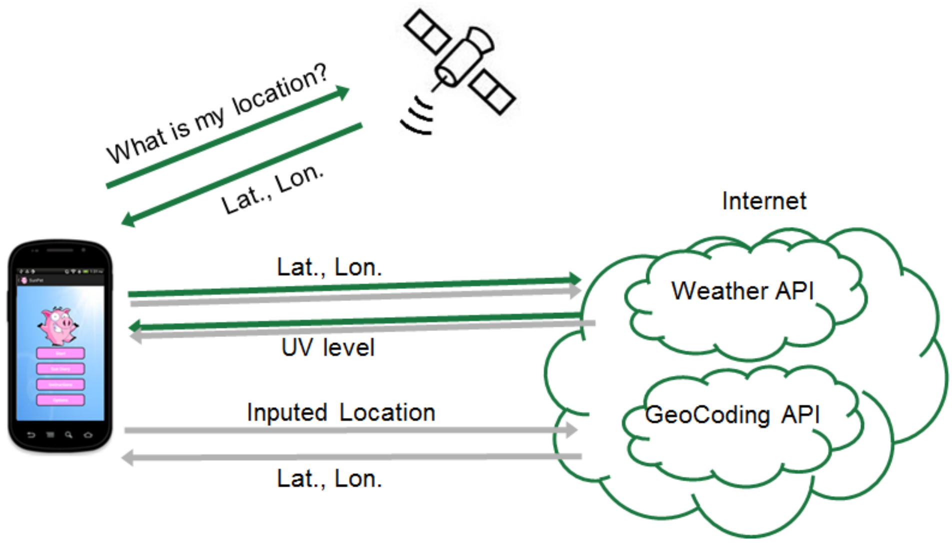

Figure 5.2: Architecture for server requests

If the received JSON file was fetched from the Geocode server, its content is the latitude and longitude of the name address inputted by the user. As consequence these values will be sent to the Weather server.

From the JSON file received from the Weather server, we save the values of the UV index, complete name location, altitude of the users and observation station. The altitude of the observation station is saved in order to calculate the difference between the station and the user, using that result as altitude value in the equation of the safe exposure time.

As we can see in the Figure 5.3, the user is notifyed of his current location and the UV index.

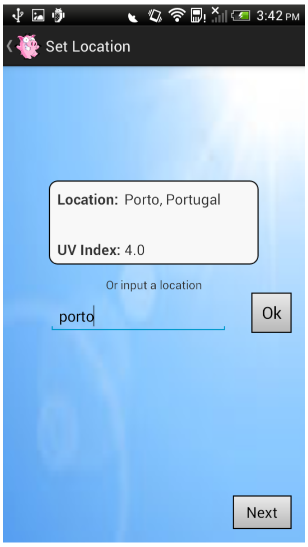

Figure 5.3: UV index screen

5.4 Questionnaire class

The *Questionnaire* class is responsible to handle and classify the user's skin type, using, as reffered before, the Fitzpatrick test. According with the test, eight question are made to the user, having each response a predefined value. To deal with the questionnaire, we opted to reserve some space of the users interface, creating fragments to fill the space. Each fragment consists on a question and its possible options. When an option is selected, the next fragment, containing the next question is automatically loaded and shown to the user, as is shown in Figure 5.4. This autoload system avoids the unnecessary clicks to get the next question.

As result of the test, the personal skin type, is returned and saved into a private file, avoiding the needed to remake the test.The Figure 5.5 represents the skin type test result.

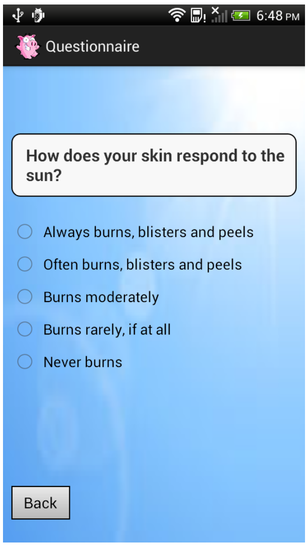

Figure 5.4: Screen of an question

Figure 5.5: Screen of the questionnaire result.

5.5 Monitorization

All the environmental and geographical data, as well as the user personal information that has been collected so far, is gather in the *Monitorization* class. This class is responsible to carry out the process of all needed calculations, as well as monitor the user's sun exposure. All the variables previously collected will be now used in order to obtain the user's safe exposure time. To monitor the elapsed time, we opt to create a timer in ascending order, therefore, ensuring that the user will have a better idea of how much time he began the sun exposure.

It is important to ensure that the timer will run without any stops caused by the different states in the activity lifecycle. For this reason, the timer method is running on a background thread, which guarantees that the UI will always be updated, and as a consequence, the warning system will always be ready to be activated under proper conditions.

The timer update is achieved using the predefined android class *SystemClock*, that provides different methods to different types of clocks. As we needed a continue timer actualization, we used the *elapsedRealtime* method, which return the time since the system was booted, including deep sleep. The time actualization processes is based on setting a *startime* variable with the time returned by the *elapsedRealtime* method at the precise instant that the user starts the exposure. The time increment is made by successful subtractions of the elapsed time and the *startime*, thereby ensuring correctly the time updating.

The warning system is activated in regular periods of time. According advices of the skin cancer associations, every two hours and after the bath reapplication of sunscreen is recommended [3]. Thus, every two hours the application sends a warning to the user to reapply his sunscreen. As the act of bathing is not regular, we decided to set the warning to be active every three hours. The UV index is also verified in specific periods of time during the user's exposure, controlling the possible UV index increase, in order to update the user's safe exposure time. Every one and a half hours the application sends a request through the weather API, to be updated on the UV index. If the UV level has increased, the safe exposure time is recalculated, and the user receives a warning, containing the UV updated, his new safe time and a recommendation to reapply the sunscreen.

In the Figure 5.6, is presented the screen during the user sun exposure.

Figure 5.6: Monitorization screen

5.6 SunDiary class

The screen presented in the Figure 5.7, is created by the *SunDiary* class, which is responsible to handle the personal sun exposure history.

When an exposure is finished, some information about it, such as location, date, risk and some behavioral aspects, are sent to a local database on the user smartphone. The saved information in the database is organized by an auto-increment ID of the exposure. This *ID* field, is also used as reference in read access. To create and handle the database, we use the Android SQLite database. The *android.database.sqlite* package, contains all the classes needed to manage our private database.

The history is displayed using an android ListView, which is a view group of scrollable items, that are automatically inserted by an Adapter, using a database query to access and pull the content. Selecting some cell of the ListView, the user can see more detailed information about that exposure and his behavior, as is shown in the Figure 5.8.

Figure 5.7: Screen of the personal history.

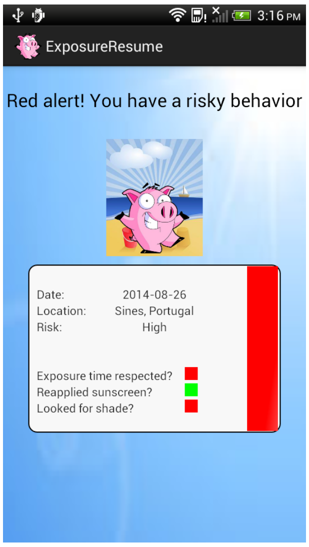

Figure 5.8: Resume of an exposure.

Chapter 6

Results

This chapter serves to clarify the purpose of this application, showing real situations where the environmental and geographical aspects have direct influence on the personal safe exposure time.

Let's first define some test elements which are directly involved in this study. To understand and test this application in different environments, we simulate the normal use of the app and analyze the impact of the different variables in the personal safe exposure time. Therefore, the test will be made under the following circumstances:

- Three scenarios - Beach, Mountain and Snow;
- Two users:
    - User A: Skin type II- White skin;
    - User B: Skin type V - Dark brown skin;
- Different UV indexes;
- Sunscreen Protection Factor: 20;
- Different altitudes.

In the table 6.1, it is represented the the safe exposure time of each of the user in the different conditions.

	UV index	Altitude	Reflexion	Safe sun exposure time			
				Without sunscreen		With sunscreen	
				USER A	USER B	USER A	USER B
Beach	UV: 4	_	Sand, Water	0:19 hours	0:39 hours	6:35 hours	13:10 hours
	UV: 10	_	Sand, Water	0:07 hours	0:15 hours	2:38 hours	5:14 hours
Mountain	UV: 7	400 m	Grass, Trees	0:12 hours	0:24 hours	4:07 hours	8:15 hours
		1000 m		0:11 hours	0:23 hours	3:51 hours	7:43 hours
Snow	UV: 7	2000 m	Snow	0:06 hours	0:12 hours	2:08 hours	4:16 hours

Figure 6.1: Use case table

This test was made to compare, in the same conditions, the time disparity between two users with distinct skin types, and better understand the influence of the different variables in the personal safe exposure time.

Regarding an outdoor activity at the Beach, two situations are presented, one with lower rate of UV radiation, representing a low UV exposure (e.g. during the morning), and other with high rate of UV incidence of an afternoon exposure. As mentioned before in chapter 3, at the beach scenario, the UV index suffers a growth due to the sand and water reflexion, increasing 15% and 10% the real UV index. Therefore, in this particular situation, the UV value received by the users, will be of 5.06. As at the sea level the altitude is 0, this variable has no effect in the equation. Combining the UV value, with the users skin type, without sunscreen, we can verify that the User A, has 19 minutes of safe time, and the User B, has 39 minutes. If the users A and B applys the sunscreen, the protection will increase as many times as the SPF value of the sunscreen. In this case, user A will have 6:35 hours and user B 13:10 hours.

In the second case, at the Beach activity, representing a high UV exposure (e.g. during the afternoon) the UV level as increased to 10, and the other variables are maintained. With this values, the safe exposure time of each of the users has decreased drasticaly to 7 minutes for user A and 15 minutes to the user B. The same time decrease occurs when the sunscreen is applied, to 2:38 hours for user A and to 5:14 hours for user B.

It is notorious that the variance of the UV level greatly influences the safe exposure time. Moreover, it is notorious that the obtained safe exposure time significantly varies between the users in the same circunstances, which is influenced by the users skin type and it's genetic disposition to be more or less sensible to UV radiation.

In accordance with the Mountain scenario, the simulation was based in one activity which include a variance of altitude. The altitude is also a factor which can make the the UV level vary. As mentioned before, for each 1000 meters of altitude, the UV radiation can increase 12%. In this test, the safe exposure time was measured at different altitudes, 400 meters and 1000 meters. In the first case, the UV radiation of index 7 will increase 4.8%, due to the altitude, and 10% due to the grass and trees reflexion. This factors are reflected in 12 minutes of safe sun exposure time to the user A and 24 minutes to the user B. In the same way as before, the sunscreen level will increase the users protection in 20 times, corresponding for user A to 4:07 hours and for user B to 8:15 hours.

The higher the altitude of the user, the higher the rate of UV multiplication will be, so, in the second case, the UV radiation will suffer a growth of 12% due to the 1000 meters of altitude, corresponding to a decrease on the safe exposure time of each user.

Finally, in the Snow scenario, the users are exposed to a UV level of 7 at an altitude of 2000 meters, which corresponds to increasing the UV value in 24%. But in this scenario the snow reflexion is a determinant variable, because its white color reflects 80% of the UV radiation. Therefore, in these conditions, the UV index of 7 will increased to 15,6 , and user A and user B, without sunscreen, only have 6 minutes and 12 minutes of safe exposure, respectivelly. The benefits the use of sunscreen are obvious, increasing the safe time to 2:08 hours for user A and 4:16 hours for user B.

It is evident that not only the UV index is determinant to measure the personal safe exposure time, but also the surrounding factors and the users skin type.

Chapter 7

Conclusions and Future Work

The ubiquity of mobile technologies allows us to satisfy the needs for a global tool, accessessible by everyone, in everyhere. This dimension reached high levels, becoming almost necessary and indespensable part in the society lifes. The new dynamics of the new technologies, mandates a policy adaptation in the educational scope, introducing new learning methodologies.

In the prevention field a new strategy was necessary to get some changes in the population habits. Adopting the smartphone's potentialities, following their constant technological evolution and globalization, the creation of an application to control risk behaviors was the step to introduce a new strategy in the prevention of skin diseases. Merging technological concepts with user aspects to create a metric in order of advise in real time the user of potential risk behaviors was a challenge and a huge motivation.

In a first stage of the project a set of core functionalities were defined, to be dedicated to each person and to each exposure, such as the user skin type, define the main characteristics which have direct influence in the UV value and creates a sun diary allowing the user to monitorize his behavior. However, according a wide range of business strategic orientation, the aggregation of new functionalities depending on the future investor remains open. All the objectives initially proposed were gradually acomplished, and the application has evolved over time, always with the stakeholders positive feedback.

This project was seen as a intelectual challenge, allowing me a first contact with a empresarial enviroment. At this point, I can afirm that this project enriched me not only in terms of knowledge, but also in the capacity of face new challenges with confidence and peacefulness.

7.1 Future Work

After achieving all the initial objectives and having completed this phase of the project, it was time to look forward and define approaches to framing this project in the market. In the prevention field of skin diseases, this application has a great potential, with a wide range of applicability. The introduction of new functionalities will depend on the business orientation of the future investor.

Below, we describe two potential alternatives to the continuity of this project, each one with distinct features.

- **UV Bracelet**

  Creating a UV bracelet wirelessly connected to the user's smartphone, make us face new functionalities and a greater control of the UV radiation level. With the creation of this bracelet, we're able to eliminate our biggest limitation, the number of server requests.

  With a personal UV detector, there is no need for internet connection in order to receive UV information, since these are collected by the UV sensor present on the bracelet. With this breakthrough, the information about the UV radiation received by the user can be even more precise. Moreover, the possibility of applying the sunscreen also on the bracelet, give us more control on the real value of UV radiation which is being received by the skin, furthermore, the user can be warned when his level of sunscreen is low.

- **Sunscreen Company**

  Sunscreen companies share the same goals of the SunPet project in terms of sun exposure protection and prevention. From a comercial point of view, allying sunscreen products with this app will open doors to new functionalities dedicated for the company concerned. The advising of some sunscreen types depending on the UV index value and user's skin type is one possible new feature. Several other new features can be add to this app, depending of the company orientation.

We are maintaining a watchful eye on the smartphones advances, wich are now starting to incorporate UV sensors as part of their hardware. A possible investment of several manufactures on this hardware will allow us explore this potentality.

As consequence of the successful development for Android Operating System, and according the high rates of iPhone users, the future of this project can include the development for iOS. For the application's diffusion, the connection to social networks will also be an important step.

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