HAPPY SPEAK

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The Happy System
A system that inferences human emotion: two test cases

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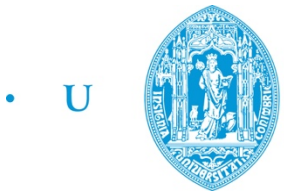

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The Happy System

A system that inferences human emotions and improves behavior: two study cases.

Dissertation submitted to the University of Coimbra to meet the necessary requirements for the degree of Master of Biomedical Engineering.

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Abstract

Day-to-day gadgets and devices are becoming increasingly more intelligent and interconnected. In fact, the “Internet of Things” (IoT) is being used to support many new types of cyber-physical systems (CPSs). The IoT and CPSs are closely related concepts which embed physical and everyday objects with intelligence, allowing them to be sensed and controlled within their network connectivity, enabling the collection and exchange of large amounts of data. This creates opportunities for more direct integration between the physical world and computer-based systems, resulting in improved efficiency, accuracy and social benefits.

CPSs normally aren’t human-centric applications. Instead, CPSs consider the human to be an external element of the control loop. To better serve the human needs, future CPSs will need to reinforce their connection to the human element. These interconnected and intelligent devices use various sensors which can be used to monitor and evaluate human parameters, namely psychological states, emotions and physical actions, improving the humans’ life quality. Humans become, thereby, an integral part of CPSs and we enter now in the realm of Human-in-the-loop Cyber-Physical Systems (HiLCPS), that is, cyber physical systems that take human interaction into consideration.

In this study, we give particular focus on mobile phones, since behavioral sensing in CPSs has been maturing with these devices. In fact, they are becoming more like personal assistants helping us to be more effective in everyday tasks. Used across the globe, they are capable of processing considerable amounts of information making the smartphone a device with key characteristics and a powerful platform for creating context-aware personal systems. As such, smartphones can be used to develop systems that sense human and crowds with potentially tremendous positive social impact. These devices represent a versatile computational resource with great sensing capabilities and

they are widely present even in development countries where poverty is higher, not to mention that even the cheapest smartphone has the most crucial sensors, such as the microphone and the accelerometer.

The purpose of this thesis was to implement and study innovative HiLCPS. This is a very recent area and there are important research questions to be evaluated. As far as we know, this is one of the first attempts to implement two human-in-the-loop systems based on the IoT, using machine learning and signal processing techniques as well as an innovative beacon system. Consequently, our work resulted in four publications in international conferences - one of them where Ashley Figueira is the first author, a submission to *Foro Cyted*, three proposals for international projects and a participation in the European Social Innovation Competition 2016, currently one of the 30 semifinalists in 1095 participants.

The applications developed during this project were WeDoCare and HappySpeak - implementations of Human-in-the-Loop Cyber-Physical Systems that attempt to help solve issues in real-world scenarios and help human beings improve their state of minds and wellbeing.

These two application are based on a system arquitecture developed by Eng. David Nunes - “The Happy System”. This system tries to produce change in the user’s behavior in order to improve his emotional state. It does this by collecting data from various sensors, processing and inferring emotion through machine learning algorithms, then, depending on the emotion inferred, the system gives suggestions to the user. HappySpeak and WeDoCare are both two test cases of “The Happy System”.

HappySPEAK aims to detect if the user is isolated and give suggestions that may help him overcome it. Although the application can be used by any user migrants are the perfect candidates. This is because, generally, migrants come alone to a new country not knowing the language and with no friends – making them more susceptible to social isolation.

WeDoCare aims to detect, in an automated way, violent attacks against users through a scream detector, using the mobile phones sensors, in particular the microphone and the accelerometer. It takes advantage of this mechanism to help people by warning nearby citizens that someone is in danger, giving users a chance of collaboration and help.

Both solutions integrate affective computing, IoT and HiLCPS.

Resumo

Os aparelhos e dispositivos de uso diário estão cada vez mais inteligentes e interligados. De facto, a internet das coisas (IoT) é usada cada vez mais para apoiar novos tipos de sistemas ciber-físicos (CPS). A IoT e os CPSs são conceitos que estão intimamente relacionados e que incorporam objetos físicos e funcionais com a inteligência, permitindo assim que eles detetem e controlem estes objetos dentro da sua rede, possibilitando a recolha e troca de informação. Disto, surgem oportunidades para uma integração mais direta entre o mundo físico e os sistemas baseados em computadores, resultando numa maior eficiência, precisão e benefícios sociais.

Os CPSs, normalmente, são aplicações não centradas no ser humano. Em vez disso, os CPSs consideram o ser humano como um elemento externo do sistema. Para melhor servir as necessidades do ser humano, os CPS no futuro terão de reforçar a sua ligação com o elemento humano. Estes dispositivos interligados e inteligentes usam vários sensores que podem ser usados para monitorizar e avaliar vários parâmetros humanos, estados emocionais, como emoções, e a sua atividade física, melhorando, assim, a qualidade de vida dos seres humanos. Os seres humanos tornam-se, assim, parte integrante dos CPSs e entramos agora no reino do *Human-in-the-loop Cyber-Physical Systems* (HiLCPS), ou seja, sistemas físicos cibernéticos que têm em consideração a interação humana.

Neste estudo, destacamos os telemóveis, uma vez que a deteção de emoções nos sistemas ciber-físicos foi amadurecendo com estes dispositivos. Na verdade, os telemóveis são cada vez mais usados como assistentes pessoais, ajudado o ser humano a ser mais eficaz nas tarefas do dia-a-dia. Usados em todo o mundo, eles são capazes de processar grandes quantidades de dados fazendo com que o telemóvel seja um dispositivo com as características-chave necessárias para a criação de uma plataforma poderosa, sensível ao contexto de sistemas pessoais. Como tal, os telemóveis podem ser

usados para desenvolver sistemas ou aplicações capazes de detetar emoções humanas, podendo ter assim um tremendo impacto social positivo.

Estes dispositivos representam um recurso computacional versátil, com uma grande capacidade de deteção e inferência. Estão amplamente presentes em países em desenvolvimento onde a pobreza é mais elevada e, para alem disto, mesmo o telemóvel mais barato tem vários sensores importantes, tais como o microfone e o acelerômetro.

O objetivo desta tese foi implementar e estudar sistemas inovadores de HiLCPSs. Esta é uma área muito recente e há várias questões e investigações importantes a serem avaliadas. Tanto quanto sabemos, esta é uma das primeiras tentativas de implementar dois sistemas *human-in-the-loop* com base na Internet das Coisas, usando algoritmos de *machine learning*, processamento de sinal, bem como um sistema inovador de beacons. Consequentemente, este trabalho resultou em quatro publicações em conferências internacionais - um deles, onde o Ashley Figueira é o primeiro autor, a submissão ao Foro Cyted, três propostas de projetos internacionais e uma participação na *Euorpean Social Innovation Competition 2016*, atualmente um dos 30 semifinalistas em 1095 participantes.

As aplicações desenvolvidas durante este projeto foram o WeDoCare e o HappySpeak. Ambas as implementações, centradas no conceito de *Human-in-the-Loop,* tentam ajudar a resolver problemas em cenários do mundo real e ajudar os seres humanos a melhorar o seu estado de espírito e bem-estar.

Estas duas aplicações são baseadas numa arquitetura desenvolvida pelo Eng. David Nunes. Este sistema foi utilizado para desenvolver outras aplicações, nomeadamente, o HappyHour e o HappyWalk. Escolhemos dar o nome de *The Happy System* a este sistema. Este sistema tenta produzir uma mudança no comportamento do utilizador, a fim de melhorar o seu estado emocional. Isto é feito através da recolha de dados de vários sensores, processamento e inferência de emoções através de algoritmos de *machine-learning*, em seguida, dependendo da emoção inferida, o sistema dá

sugestões ao seu utilizador. O HappySpeak e o WeDoCare são ambos dois casos de teste do *The Happy System*.

O HappySPEAK é uma aplicação que visa detetar se o utilizador se sente isolado e dar sugestões que podem ajudá-lo a superar esse problema. Embora a aplicação possa ser usada por qualquer utilizador, os imigrantes são os candidatos perfeitos. Isto porque, em geral, os imigrantes viajam sozinhos para um país que não conhecem e geralmente sem ninguém - tornando-os mais suscetíveis ao isolamento social.

O WeDoCare, por outro lado, visa detetar, de uma forma automática, ataques violentos contra os seus utilizadores através de um detetor de gritos, utilizando os sensores do telemóvel, mais em concreto o microfone. A aplicação tira proveito desse mecanismo para ajudar as pessoas, alertando os cidadãos que estão nas redondezas de que alguém está em perigo, dando aos usuários a oportunidade de colaborar e ajudar.

Ambas as soluções estão integradas nos conceitos de computação afetiva e internet das coisas.

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List of Acronyms

AC Affective Computing

ANN Artificial Neural Networks

API Application Programming Interface

BCI Behavior Change Intervention

CPS Cyber-Physical System

DAO Data access object

HiLCPS Human-in-the-loop Cyber-Physical System

HiTL Human in the Loop

HTTP Hypertext Transfer Protocol

IoT Internet of Things

JSON JavaScript Object Notation

MVC Model-View-Controller

ORM Object-Relational Mapping

POI Point of Interest

REST Representational State Transfer

SVM Support Vector Machines

UI User Interface

UNHCR The UN Refugee Agency

UUID Universal Unique Identifier

UX User eXperience

XML eXtensible Markup Language

1 Chapter

Introduction

1.1 Context

The Internet-of-Things, IoT, embeds physical and everyday objects, allowing them to be sensed and controlled, within a network connectivity, which enables these objects to collect and exchange data [1]. The Internet-of-Things creates opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and health benefit [2].

The Cyber-Physical-System, CPS, in the other hand, is a system of elements collaborating together computationally controlling hence physical entities [3]. The IoT and CPSs are, therefore, closely related concepts. In fact, both approaches have now become inherently complementary and synonymous. These interconnected and intelligent tools use various sensors which can be used to monitor and evaluate human nature. That is, IoT systems should also integrate human nature and presence in their designs and architectures. As such, we believe that the future IoT will be supported by Human-in-the-loop Cyber-Physical Systems (HiTLCPS), systems that will take human nature into consideration. With this type of awareness technology can evolve in powerful new ways. Human presence and behavior will be no longer seen as an external and unknown factor but become a key part of the system. HiTLCPSs infer the user's intents, psychological states, emotions and actions through sensors, integrating this information into the control-loop [4].

This dissertation describes the work carried out under the student's Master Thesis in Biomedical Engineering in the area of HiTLCPS and IoT.

This project was composed of professors and researchers of the Departments of Informatics (DEI), specifically, the Laboratory of Communications and Telematics research group from the University of Coimbra. The team consists of Prof. Jorge Sá Silva (professor at DEI), David Nunes (doctoral student of Biomedical Engineering at DEI), Ricardo Barbosa (informatics engineering master student at DEI) and Ashley Figueira (biomedical engineering master student at DEI).

1.2 Objectives

This master thesis aims to expose the work developed under the HappySystem project. The main objective of this work is to place the human being and his complexity in the CPS. Within the complexity of human beings, we try to understand and detect emotions.

Initially, we intended to create a mobile system of 'people-centric sensing', called HappyStudent. We began to see how the HappyStudent could be developed, what techniques, libraries, services and sensors could be used. The aim of this application was to assist the user (student), by understanding his motivations, context and emotional state, and it would also take proactive actions. Using the information provided by the smartphones sensors, the objective was to create a service that would help the user in real time. The application would collect information from the phone's sensors such as ambient noise through the microphone, agitation through the accelerometer position via GPS and weather status via a web API. Using machine learning techniques, the aim was to understand the impact of academic workload in stress, sleep patterns, physical activity, socialization and emotional well-being of students. Although, after the arising partnership with SPEAK and its CEO (Hugo Aguiar) we started trying to figure out how we could help his company and help the refugee and immigrant crisis and their social inclusion. Hence came the HappySpeak, an app which tries to detect social isolation or depression and attempts to improve these emotions by giving suggestions to the its user's. A person usually migrates due political and economic reasons. They come to a

new country not knowing anything or anyone and often isolate themselves. This can be detrimental to their health and well-being and it is here that the HappySpeak intends to act. With this application the user can easily get to know the city, meet knew people and even attend SPEAK events making them learn the language. Along side this, the main goals were to get involved in the project and become comfortable with the various technologies used and learn the concepts and paradigms that are being researched, such as HiTL and CPS. Before starting with the development of HappySpeak we started looking for ways of how we could detect social isolation. After this, we started developing the application. Eng. David Nunes and other previous graduate students had already worked on people-centric sensing applications, so, one of the objectives in the early stages of this project was to assess the existing solutions, mainly HappyWalk, which we then planned to build upon and reuse its code.

As stated above, one the responsibilities of this thesis was the building an android application, HappySPEAK. However, in the second semester we developed another application called WeDoCare. WeDoCare is a mobile phone application that tries to detect violent attacks against its users using a scream recognition feature. It uses signal processing and machine learning techniques to do this and when a scream is detected the application warns nearby citizens that someone is in danger, pointing to that location. With this, a user who lives in dangerous areas, such as the favelas of Brazil, the user can simply scream and the application will send an alert to all nearby or surrounding users telling them that the user is in danger and needs help. WeDoCare, thus, functions as a personal surveillance system that integrates HiLCPS and IoT concepts. With the occurrence of this idea we contacted the UNHCR. We then had a meeting with them in which the requirements of this application were discussed. In this meeting we also analyze the viability of the idea and how it could help refugees.

Towards the end of the second semester, tests to the HappySPEAK and WeDoCare system were made in terms of battery life and accuracy of the system. By doing these tests

we wanted to see if the developed apps were energy efficient, an important aspect of mobile development, and if the implemented classifier was effective in correctly categorizing the different emotions of the applications.
Since HappySpeak was developed during the first semester, this allowed the student to gain experience in the Android world which was beneficial for the development of the second application. We also want to state that all the back-end of both applications were developed simultaneously.

These apps were built upon the Happy System, a Behavior Change Intervention system, which we will talk about in Chapter 3 of this report. The main objective of these apps, as we'll see throughout this thesis, is to collect relevant data that can help users with their daily lives, by giving them helpful tips at convenient periods. These applications are focused on the concept of HITL and are described in detail in chapter 4.

The final contribution of this thesis are these two case studies that advance knowledge in the area of HiTLCPS. They are concrete examples of how these ideas can be applied. We would also like to mention that the WeDoCare is the main focus of this thesis.
Various articles based on this work was written and are available in Appendix A.

1.3 Thesis Structure

The master thesis is structured in six chapters. The first chapter reports the context of the project, in order to frame the Happy System and the apps developed derived from this system in today's technology landscape. In this chapter, it is also presented the method of work, the project objectives as well as the technologies used.

The second chapter is an introduction about the areas where apps derived from the Happy System fit, this is a state of the art. Then we compare the apps developed and human emotion inference with other similar platforms. On the third chapter we talk about the Happy system, its objectives and diverse applications we've built or intend to

build. We also do a brief requirements gathering. The fourth chapter explains the development of both applications (WeDoCare and HappySpeak). In the fifth chapter we evaluate the implementation on both applications and we perform tests, either at a battery level and at the accuracy level for the inference of the emotion we want to achieve in each application. And finally, the last chapter is used to present a summary of the complete thesis plan and provide some suggestions for future work. In order to complement the material exposed in this thesis, we added several appendices. These appendices are:

- Various articles published, namely:
    - R. Barbosa, D. Nunes, A. Figueira, S. Sinche, H. Aguiar, J. Sa Silva, C. Herrera and F. Gonzalez, "An Architecture For Emotional Smartphones in Internet of Things", IEEE Ecuador Technical Chapters Meeting, ieeeXplore, Guayaquil, October 2016, Ecuador.
    - A. Figueira, D. Nunes, R. Barbosa, A. Reis, H. Aguiar, S. Sinche, A. Rodrigues, V. Pereira, H. Dias, D. Raposo, C. Herrera, J. Sá Silva, F. Boavida, "WeDoCare: A Humanitarian People-centric Cyber-Physical System for the benefit of Refugees", IEEE Global Humanitarian Technology Conference (GHTC), October 2016, Seattle (USA).
    - A. Reis, D. Nunes, R. Barbosa, A. Figueira, H. Aguiar, S. Sinche, A. Rodrigues, V. Pereira, H. Dias, D. Raposo, C. Herrera, J. Sá Silva, F. Boavida, "Tech4SocialChange: crowd-sourcing to bring migrants experiences to the academics", IEEE Global Humanitarian Technology Conference (GHTC), October 2016, Seattle (USA).

    - A. Reis, D. Nunes, R. Barbosa, A. Figueira, H. Aguiar, S. Sinche, A. Rodrigues, V. Pereira, H. Dias, D. Raposo, C. Herrera, J. Sá Silva, F. Boavida, "Tech4SocialChange - Technology for all", 16th International Conference on Innovations for Community Services (I4CS 2016), Springer, June 2016, Vienna (Austria).
- Various forms for National and International competitions. These competitions where: European Social Innovation Competition 2016, Nokia IoT Innovation Challenge 2016, EDP Solidária 2016, HeroX Social Innovation Challenge.
- Press release for the European Social Innovation Competition 2016.
- Detailed business plan for the European Social Innovation Competition 2016.

1.4 Scheduling

In this section we address the scheduling of the work stage. The scheduling of this thesis was established in the early stage in September.
In this initial plan the following tasks were planned:

- Study of state of the art, the currently existing prototype and supporting technologies to the development of the project. Estimated duration: 1 month
- Study and integration of machine learning techniques to detect sleep patterns, physical activity, socialization and emotional state of students. Estimated duration: 3 months
- Implementation of the system server and application for Android, with reporting mechanisms and tips. Estimated duration: 2 months
- Development and implementation of anonymisation techniques.

Estimated duration: 2 months

- Testing, improvement, evaluation and writing of the thesis. Estimated duration: 2 months

Although along the initial stage of this project came the chance to explore new avenues of research and development which led to the need to restructure the work plan. In this respect came partnerships with SPEAK and UNHCR for the development of HappySpeak and WeDoCare. However, we want to note that the study area is the same and that HappySpeak and WeDoCare applications follow the same standards as the HiLCPS application, HappyStudent. The new work plan, provided the following tasks:

- Study of state of the art, the currently existing prototype and supporting technologies to the development of the project. Study of the concepts of mobile phone sensing, cyber-physical systems & human-in-the-loop. Estimated duration: 2 months
- Implementation and development of the system server and the various modules on the HappySpeak application, as well as the Isolation Recognition system.
  Estimated duration: 2 months
- Implementation and development of the system server and the various modules on the WeDoCare application, as well as the Scream Recognition system.
  Estimated duration: 2 months
- Tests on the WeDoCare battery life as well as the Scream Recognition module.
  Estimated duration: 1 month
- Writing of various articles.
  Estimated duration: 1 month

- Writing of forms for various competitions. Estimated duration: 2 weeks.
- Development of a web landing page for WeDoCare. Estimated duration: 2 weeks.
- Production of various videos describing the WeDocare application. These videos where used in various forms for competitions. Estimated duration: 2 weeks.
- Writing of the thesis. Estimated duration: 1 month.

The formalization of the requirements for each application is presented in Chapter III.

1.5 Methodology

Regarding the fulfillment of the established objectives of this thesis, goals were set together with Eng. David Nunes in the first semester. Subsequently, Professor Jorge Sá Silva reviewed and approved the set of assignments and the respective duration.

In the second semester, in order to enrich this thesis and take advantage of the opportunities risen, the work plan changed. The changes were explained in the last section.

The methodology used was based on the Kanban method [5], which organizes the development of the product through stages. To do this we used Trello – a tool for task management (more details on this tool on section 1.6). These stages represent a phase in the life cycle of the task, this is, each task has a state. The tasks are arranged in a backlog according to their states, as you can see in Figure 1. In the same image it is possible to observe the states of each task during the development of WeDoCare, namely:

- **To Do** - Initially the tasks are placed in this list according to their priority in the project.

- **Doing** - As the tasks enters the development stage, the task is moved to this list. Sometimes you need more than one task in this stage, which implies a priority management. The resolution of this conflict is to first start with the most urgent tasks.
- **Done** - When a task is completed its status is updated to the list of completed tasks.
- **Testing** – When a task has been implemented but is being tested.
- **Freezer** – When a task is not urgent and left for future work.

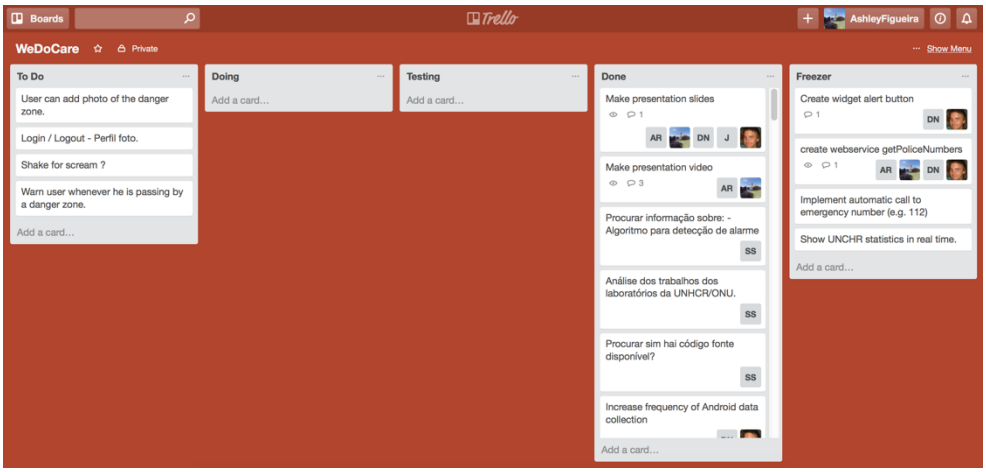

Fig 1 - Screenshot from WeDoCare's trello board.

Professor Sá Silva and Eng. David Nunes were always aware of the work and tasks done during the week. However, in certain weeks' artifacts appeared which made the work to be delayed. These artifacts were mainly:

- Writing of forms for competitions;
- Writing of articles.

During the realization of this thesis we adopted a policy of weekly meetings with the mentors. Specifically, on Monday's of every week we exposed the progress, difficulties and obstacles, but also possible solutions. The meetings had an average

duration of 15 minutes. At the end of each meeting we define objectives and strategies to achieve throughout the week. At the same time, and along the project duration, weekly meetings, on Friday's, with the whole IoT project team and meetings with advisors enabled support, project planning, organization and adjustment of objectives. Contact with Prof. Sá Silva and Eng. David Nunes was also performed asynchronously, using tools such as email and Skype [6] to communicate at a distance. This helps to facilitate decision-making and work improvement.

We held a conference with all stakeholders of this project with the UNCHR, which led us to the development of the WeDoCare application. In this event the objectives were discussed to check the reliability or possibility of an application of this kind.

The requirements and the design and development methods used along this thesis is described next.

1.5.1 Requirements

The software requirements specification, SRS, in software development, is a description of the behavior of the system to be developed [7]. SRS is written to understand the features and accurate details that each module, and the final system must comprise. The requirements describe every external functionality of each module of the system.

Each requirement has a unique identifier, a brief description and a priority associated. A second classification, related to the purpose of the requirement, is also associated with each one. We studied two types of requirements: Functional Requirements and Non-Functional Requirements. Functional Requirements are those describing the forehand behavior of the software, such as user interactions and deliverables. Non-Functional Requirements are always associated with a functional requirement; its function is to evaluate performance and reliability of the function performed by the father requirement.

Further on, for each application developed throughout this thesis we check the requirements for each.

1.5.2 Design and Development

The design of the system architecture intends to provide a blueprint for the system that is going to be developed. This arquitecture was used on the HappyWalk app and developed by all team members including Ashley Figueira. This arquitecture already developed was adapted to both applications developed in this thesis.

Concerning the arquitecture of the mobile application itself, we used a modular approach. The application was divided into various different modules depending on functionality. This approach of modularizing the system separates complexity and eventual failures, eases development and results in a more coherent and adequate final application. It also helps us to test the the modules adequately and more efficiently.

1.6 Technologies Used

Finally, in the last part of this chapter we cover the concepts addressed and technologies referred and used throughout this work. Since the smartphone was the center piece in the several projects we worked on, the main technology used throughout the development stage was, without a doubt, Android Studio.

Android

Android is a mobile operating system (OS) currently being developed by Google. This OS is based on the Linux kernel and is designed to be used with touchscreen smartphones and tablets; this is because, Android's user interface (UI) is mainly based on direct manipulation, using touch gestures such as swiping, tapping and pinching, to manipulate on-screen objects, along with a virtual keyboard for text input. Android has also been developed or extended into Android TV for televisions, Android Auto for cars

and Android Wear for smart watches. Android is the largest installed operating system with approximately 1.4 billion active users [8]. Google Play store, which is where Android apps are published, has over one million Android applications published, and over 50 billion applications downloaded [9].
Even though the base system is Linux, the OS runs on a Java Virtual Machine designed specifically for this kind of devices.

The primary programming language used to develop apps for the Android OS is Java although C++ can be used to do some low-level programming.
Even though Android is fully compatible with Java there are many quirks associated with developing for this platform. Some of them are activity and fragment management, native tools only available in Android such as parsers, file access and memory management.

Android is an open-source technology which makes it possible for anyone to develop using this OS. This is one of the majors' reasons why Android was chosen as the development platform for this thesis but also because we had previous work developed by David and other students. Previous work provides us with some resources which were used to accelerate the project development. Part of that work was the HappyWalk app, which served as a basis for the apps we talk about in throughout this thesis.

Android has a large community of active developers who develop and distribute freely their own software or libraries. Many libraries have great extended documentation and support.

Google Play Services

Google Play is an app which allows Google to roll out new features to Android users running 2.2 and up without getting a complete OS upgrade. It is a powerful tool for bringing new features to users of old operating systems.

Google Play Services gives Google a stage to launch new features that are critical to Google's presence on smartphones and tablets. This means that 98.5% of Android devices can utilize new features that are released. This effectively solves the problem of fragmentation, at least for features that roll out via Google Play Services instead of Android updates [10].

Google Play Services allows users to access an array of services, provided by Google, such a world map, geolocation in the real world, face recognition, Cloud services, among others.

We chose to use this library because it is continuously supported with new versions and functionalities, it has been extensively tested by Google and has a lot of documentation and useful tutorials.

Other Web Services

Web services are designed to promote the exchange of information between applications through the Internet. This exchange of information between applications creates integration and allows interoperability between different organizations where the information provided by various applications is widespread in a simple way and without exposing the database. External services are important in all aspects of this project. We used various external web services for different tasks. For example, Google's Geolocation API provides information about points of interest. Facebook allows users to quickly register and login to our app or it can be used to notify friends about events or emotional states.

Encog

Encog is a machine learning framework available for Java, C++ and .NET. Initially, Encog was created to support only neural networks, but with the growth in popularity later versions of Encog expanded into more general machine learning algorithms.

Having a Java implementation makes it compatible and reliable for Android development. Encog contains classes to create a wide variety of networks, as well as classes to support normalization and data processing. Encog also contains many different techniques for training the various machine learning algorithms. Multithreading is also supported in Encog, this is used to allow optimal training performance, making it an excellent framework for Android development. Encog has been in active development since 2008 and has a great open-source community [11].

TarsosDSP

TarsosDSP is an audio processing library for Java, making it compatible with Android. In fact, it has its own Android version for optimal performance. It aggregates various audio processing algorithms into practical and easy-to-use audio processing library. This library is in pure Java and doesn't rely in any other external dependencies. The library tries to hit the sweet spot between being capable enough to get real tasks done but compact and simple enough to serve as a demonstration on how DSP algorithms work [12].

JAX-RS

RESTful Web Services (JAX-RS) is a Java API that provides support in creating web services according to the Representational State Transfer (REST) architectural pattern [13]. JAX-RS uses annotations, to simplify the development and deployment of web service clients and endpoints. REST is an architecture that uses the HTTP protocol and its resources. Its main features are:

- All resources on the web are identified by a URL;
- Interactions with the service provider is done using the GET method, POST, PUT and DELETE. These methods make the

bridge with the CRUD methods in the database (Create, Read, Update and Delete);

- Interactions are stateless - the service provider knows the state of resources, but do not maintain customer sessions (scalability);
- It uses intermediate elements for caching and proxies, also contributing to scalability. The implementation time is faster, since these intermediate elements remove the developing of caching mechanisms.

Hibernate

Hibernate is a high-performance Object/Relational persistence and query framework licensed under a LGPL (Lesser General Public License). Its primary function is mapping Java classes to database tables while also providing data query and retrieval facilities [14].

PostgreSQL

PostgreSQL is one of the world's most used open source object-relational database system. As a database server, its primary function is to store data securely, and to allow for retrieval when requested by the applications developed throughout this thesis. Some of its features include MVCC, point in time recovery, tablespaces, replication and transactions. PostgreSQL runs on all major operating systems, including Linux, UNIX, and Windows. It has been active for more than 15 years and has earned a strong reputation for reliability, data integrity, and correctness [15].

Trello

Trello is an online project management tool that makes collaborating, managing and organizing projects easy. A team can divide a project in tasks, and attribute tasks to the

different team members. This tool was used throughout the development stage of this thesis to better control our tasks.

Version Control System - Git

Version control systems are a category of software tools that help a software team manage changes to source code over time. Version control software keeps track of every modification to the code in a special kind of database. If a mistake is made, developers can turn back the clock and compare earlier versions of the code to help fix the mistake while minimizing disruption to all team members [16].

Git is a common version control system and is used widely across the globe. It is an actively maintained open source project originally developed in 2005 by Linus Torvalds, the famous creator of the Linux operating system kernel. A staggering number of software projects rely on Git for version control, including commercial projects as well as open source. Developers who have worked with Git are well represented in the pool of available software development talent and it works well on a wide range of operating systems and IDEs (Integrated Development Environments). In addition to being distributed, Git has been designed with performance, security and flexibility in mind [17]. The benefits of using a version control system for this thesis are:

- A complete long-term change history of every file. This means every change made by many individuals over time. Changes include the creation and deletion of files as well as edits to their contents. Having the complete history enables going back to previous versions to help in root cause analysis for bugs and it is crucial when needing to fix problems in older versions of software.
- Branching and merging. Having team members work concurrently is a no-brainer, but even individuals working on their own can benefit from the ability to work on independent streams of changes.

Creating a “branch” in VCS tools keeps multiple streams of work independent from each other while also providing the facility to merge that work back together, enabling developers to verify that the changes on each branch do not conflict.

- Traceability. Being able to trace each change made to the software and being able to annotate each change with a message describing the purpose and intent of the change can help not only with root cause analysis and other forensics.

In the next chapter we address the theoretical concepts of which both applications are based. We also disclose a comparative study between HappySpeak and WeDoCare with applications already available on the market which resembles the ones we developed in this thesis.

2 Chapter
State of the Art

In this chapter we analyze concepts and paradigms and we take a look into similar applications.

In the first part of this chapter we cover the concepts addressed and some paradigms used throughout this work which allows us to infer and detect some kind of user's emotional state. Any emotion is inferred from information using sensors and external services.

In the second section we review applications that have similar designs or goals towards the two applications developed throughout this thesis (HappySpeak and WeDoCare) as well as similar applications towards HappyStudent, with the intention of checking features and qualities present in these competing applications.

2.1 Concepts and Paradigms

In this section we introduce some concepts used in the development of the system or applications.

2.1.1 Internet-of-Things

Proposed by Kevin Ashton in 1999, the Internet of Things (IoT) refers to identifiable objects and their virtual representation in an Internet-like structure.
IoT was previously known as "control networks," a concept Reza Raji described as "moving small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories."

Today, IoT extends Internet connectivity beyond traditional devices like desktop and laptop computers, smartphones and tablets to a diverse range of devices and

everyday things that utilize embedded technology to communicate and interact with the external environment, all via the Internet. The term IoT is commonly used to signify advanced connectivity devices, systems and services that go beyond machine-to-machine communications, and covers a variety of protocols, domains and applications.

As far as the reach of the IoT, there are more than 12 billion devices that can currently connect to the Internet, and researchers at IDC estimate that by 2020 there will be 26 times more connected things than people.

According to Gartner, consumer applications will drive the number of connected things, while enterprise will account for most of the revenue. IoT adoption is growing, with manufacturing and utilities estimated to have the largest installed base of Things by 2020 [18].

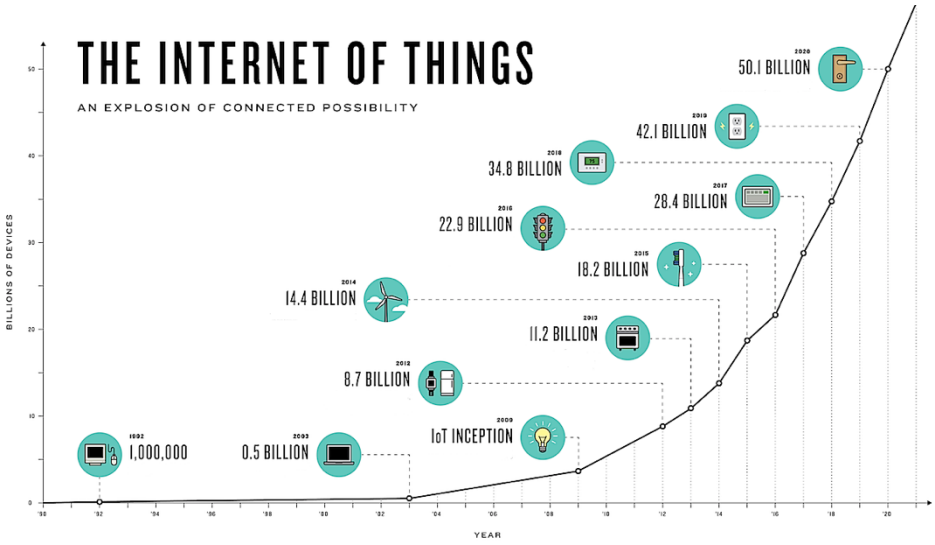

Fig 2 - The evoluiton of the Internet-of-Things.

Computational elements that monitor and control specific physical phenomena are the early precursors of true IoT deployments, where the sensing and controlling of physical entities are completely pervasive, ubiquitous and even natural. The technology

is already among us and its dissemination is exponential: several studies indicate that the next big advancement in human technology will happen in the coming years, marked by the huge number of new devices that will be connected to the Internet. There will be not just computers and mobile phones, but the millions of "things" that we use in our daily tasks, from fridges to microwaves. In fact, Gartner says the “Internet of Things will have 26 billion connected devices by 2020". However, today’s IoT is still focused mainly on isolated embedded systems with a specific engineering application in mind. This approach is only valid for target scenarios, presenting a constrained applicability and narrow approach. Most IoT technology is still directed only towards restricted and privileged users who already know how to harvest the capabilities of the network.

This state of things is merely the initial step towards a future where the vast majority of the IoT will be in reach of ordinary people. However, in order for this to happen, machines cannot remain simple machines. The applicability of these concepts must go beyond the simple sensing and automated communication between IoT elements, allowing us to know and control our environments in a powerful and intuitive way. That is, IoT systems should also integrate human nature and presence in their designs and architectures.

2.1.2 Cyber-Physical Systems

As discussed in the first chapter, Cyber-Physical-System, CPS, is a system of elements collaborating together to control physical entities [3], Making the IoT and CPS closely related concepts. Although, the IoT tends to focus more on openness and networking of intelligent devices, with CPSs being more concerned with applicability, modelling of physical processes and problem solving often through closed-looped systems [19].

These interconnected and intelligent devices use all of these sensors which can be used to monitor and evaluate human nature. Humans become, thereby, an integral part of CPSs and we enter now in the realm of Human-in-the-loop Cyber-Physical Systems

(HiLCPS), that is, cyber physical systems that take human interaction into consideration [4].

We believe that the future IoT will be supported by Human-in-the-loop Cyber-Physical Systems (HiTLCPS). With this type of awareness technology can evolve in powerful new ways. Human presence and behavior will be no longer seen as an external and unknown factor but become a key part of the system. HiTLCPSs infer the user's intents, psychological states, emotions and actions through sensors, integrating this information into the control-loop [20].

2.1.3 Smartphones and HiTLCPS

Mobile phones have become personal computers that serve as personal assistants helping us to be more effective in everyday tasks. These devices represent a versatile computational resource with great sensing capabilities. Nowadays mobile phones are present in every pocket even in underdeveloped countries where poverty is higher. Even the cheapest mobile phones have flexible sensors, such as the microphone. Used across the globe, they are capable of processing considerable amounts of information making the mobile phone a device with key characteristics and a powerful platform for creating context-aware personal systems that can be leveraged to develop applications with positive social impact. Their advanced capabilities also reduce the need for extra accessories and other devices. By only using smartphones our solution becomes more effective in a population living in a more debilitated economic situation since they do not have sufficient means to possess extra hardware besides the ones they already have.

For these reasons it is not surprising that many hours have been devoted to the research and development of mobile phone sensing applications [21].

Strictly speaking, sensing data which is then processed by machine learning or signal processing algorithms is attainable and can be used to attain some sort of information

about the user [22]. As a matter of a fact, we are now witnessing a wide increase in smartphone-based systems as part of a larger group of human-aware systems.

Nowadays, smartphones are equipped with various sensors which have a great processing capability that make them scientifically attractive. Due to its mobility and processing power the smartphone is used in technologies such as CPS. These CPSs monitor, control and adapt to the environment or the user in the HiTLCPS case and can be applied in various scenarios [21], such as in health and wellness, to monitor physical activity and encourage users to perform exercise and improve their health [23].

2.1.4 Affective Computing

Sensors were first applied to identify emotion, a work done by Rosalind Picard (1995), which originated the area Affective Computing [24]. This is an area where systems can recognize, process and simulate the human emotion. There are several emotion recognition implementations which use facial expressions, voice, speech, body temperature, and, unexpectedly, the pace of key pressing on a computer [25]. The recognition itself is carried out with the use of machine learning algorithms. In the case of recognizing emotions, such as, agitation and calm using only the humans voice and speech, Paeschke obtained a 77% accuracy, in a call center, using neural networks. Physiological signs were also used to recognize emotions. In [26] it was possible to identify positive / negative feelings with a rate of 87% accuracy. In another study conducted by Samsung, they tried to identify the user's emotion analyzing the behavior to touch on the smartphone screen, which used attributes generated through 3 sensors, and with a certain rate of 82% [27]. With this study, it was possible to associate touch patterns to emotions.

The humans emotional state affects their performance, in learning, in human relations, as well as their mental health and well being, and these situations are studied in the scientific context of the Affective Computing area. It is believed that applications

that determine the user's emotion will have a direct impact on area of CPS in order to make these systems more aware of human presence.

2.1.5 Behavior Change Interventions

BCI systems seek to alter human behavior using interventions. These interventions consist of advice and availability of information on harmful behaviors (smoking, binge eating, sedentary lifestyle). This is then used to motivate the individual to correct his behavior.

Interventions were initially carried out through on-site consultations with therapists, but now they are also made through the Internet and through the use of smartphone applications [28]. Applications of such system can improve the health and well being of a human being. BCI applications try to explore the use of sensors of mobile phones to monitor the behavior of the human being and provide targeted motivation or suggestions in order to enhance and correct his behavior.

2.1.6 Human-in-the-Loop

Applications that follow the paradigm of Human-in-the-loop Cyber-Physical Systems [20] are divided into three components:

- the human being;
- the system;
- the environment.

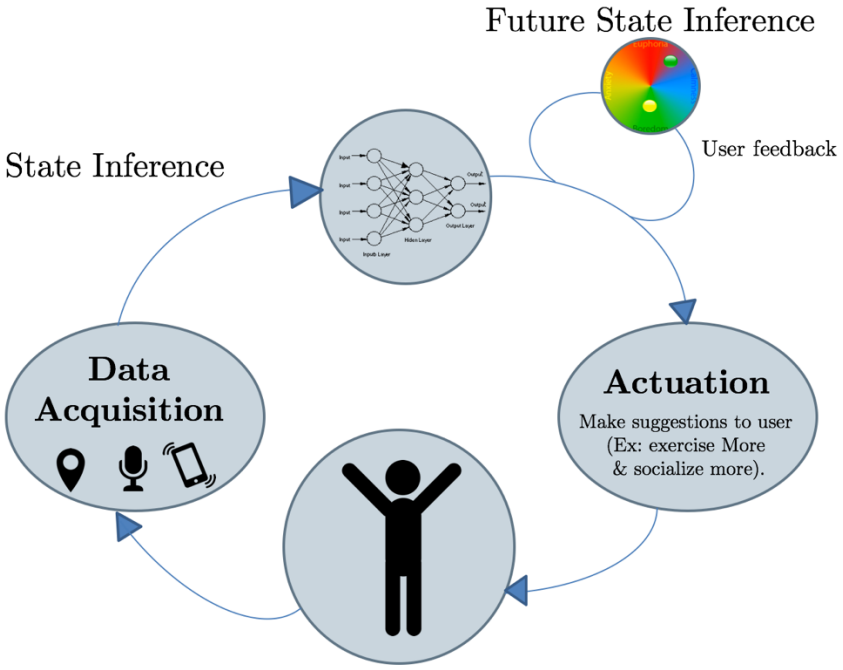

Fig 3 - The process control of Human-in-the-Loop.

As said before, this approach considers the human to be a part of the control loop, influencing the systems output. In other words, it influences the systems performance based on the environment, as shown in figure 3. There are some studies in this area, namely:

- a wheelchair with assisted driving, which avoids obstacles and also has an emergency system to avoid cliffs and stairs [29];
- a HiLCPSs project that uses relatively inexpensive sensors (About 25 dollars) to determine whether the user is at home. If the user is not at home the air conditioner is automatically turned off. The comfort level the user experiences is also taken into account, defining the temperature limits if the user is at home [30];

- a closed loop system made for the medical area in order to reduce human error. For example, as a drug is injected the system obtains information on the heart rate and the amount of oxygen, and, through an algorithm, it calculates the rate of medicine injected into the patient in each iteration of the loop. If a problem is detected through the use of physiological sensors the system shuts down the injection process. This system seeks to improve the safety of the procedure and its effect on the user [31].

This model proposed by Eng. David Nunes tries to follow the HiLCPS methodology, applied to network connections of cyber-physical systems. This approach also applies concepts of BCI to intervene when the user is in a negative emotional state, taking into account that environmental change and exercise improve mental health and the welfare of human beings [32][33][34].

It has been proven that physical exercise benefits cognitive abilities, memory and mood [32] and so we look to improve the user's mood by applying motivational and suggestive measures that induce the user to go walk, sightseeing or other activity in order to improve his emotional state.

2.2 Similar applications

Throughout this section we expose a comparative study between the developed applications (WeDoCare & HappySpeak) to some other few applications that are compassed in our discipline.

2.2.1 StudentLife

Developed by a research team from Dartmouth College for the Android system, the StudentLife application assesses the day-to-day and week-by-week impact of workload

on stress, sleep, activity, mood, sociability, mental well-being on academic performance of students. Briefly speaking, they discuss and correlate objective sensor data from smartphones to mental well-being and academic performance.

The activity and sociability emotional states of HappySpeak is inspired by the system architecture of StudentLife. The StudentLife app automatically infers activity, sleep duration, and sociability which represent important heath well-being indicators. In comparison, the two tools can monitor the user's emotion. However, in the case of HappySpeak, this detection is performed with the goal of following the theory of HiTL. Thus, emotion is detected which then allows us to introduce a variation in the system. Depending on the detected emotion, settings which are responsible for the automatic adjustment of various parameters are set to on or off. While StudentLife searches only to detect the user's emotion, HappySpeak takes a proactive attitude. In other words, the HappySpeak pursuits, simultaneously, improvement in the user's emotion, giving them some suggestions, such as tell the user to take a walk call a friend or attend a SPEAK event, since these type of activity's help the user to feel more sociable [35].

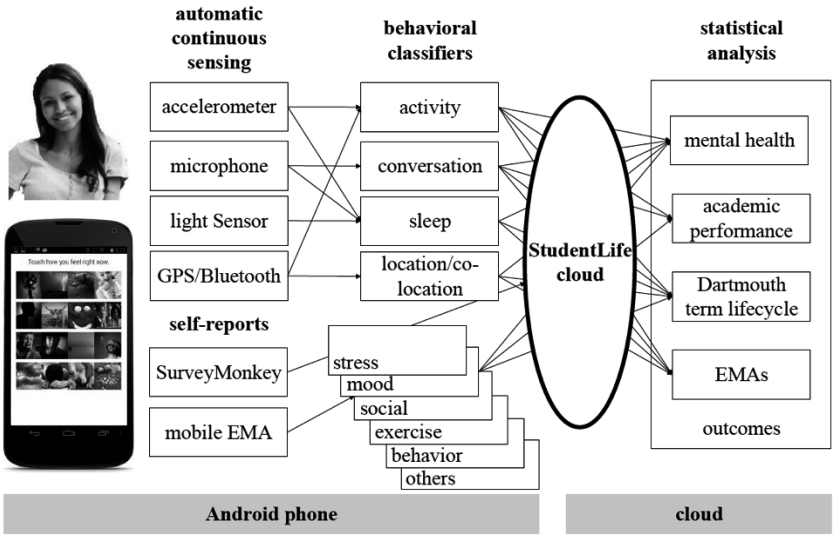

Fig 4 - Component interaction in the Studentlife application.

2.2.2 EmotionSense

Developed by a research team from the University of Cambridge for the Android system, the EmotionSense application aims to monitor the user's emotion. Given that smartphones are present in the day-to-day of users, continuous monitoring and sensing is possible. The technique used is to collect information through sensors (such as GPS, accelerometer and microphone), patterns in call, sms logs and finally through questionnaires about user's emotional state [36].

The emotional component of HappySpeak is composed of a feedback system inspired by EmotionSense. As the name implies, this feedback system allows the user to correct the detected emotion in the application, helping the neural network to improve its accuracy.

As said before the HappySpeak app aims towards a HiTL approach, unlike the EmotionSense app which only seeks to detect the user's emotion. In fact, HappySpeak takes a proactive approach.

2.2.3 Safelet

Safelet is a bracelet that lets you warn others that you are in danger r[37]. This special piece of hardware contains a button that once triggered emits an alarm to the user's friends and family. The user's smartphone also begins recording. This is useful and at the same time interesting since it gives the ability to check later on what really happened in an emergency situation. This solution has a limitation which is the extra hardware the user has to acquire. The bracelet is only accessible for the most economically advantaged and it will hardly be acquired by people undergoing economic difficulties as in the case of refugees.

2.2.4 Athena

This solution is based on a round button that clips onto a persons belt and is dedicated to prevent physical assaults by emitting loud alarms whenever the button is clicked. In addition to this feature it also sends out text messages with the user's location to their designated emergency contacts [38]. Although this solution is similar to the previous one, it has the advantage that can be used anywhere; that is, it can be hidden from the persecutor unlike Safelet, which is placed on the user's wrist and can be easily removed. However, much like the previous solution, its necessary to buy extra hardware which greatly limits the target audience. We want to provide technology-based solutions within most people's reach, therefore, we attempted to solve this issue using only the smartphone as it will be explained later.

3 Chapter
The Happy System

In this chapter we present the happy system, its arquitecture as well as how it is organized. In the first section, we present a general overview of the arquitecture used in either in HappySpeak or WeDoCare. Then, we uncover the high level architecture to characterize the system, including the mobile application, the server central and the database. Both applications, mentioned earlier, are based on the Happy System.

3.1 Overall System Arquitecture

The Happy System is a system that tries to produce change in any individual's emotion or state of mind through the collection of data from the mobile phone's sensors and warning or giving the user suggestions on how to better those emotions. With the development of the HiTL model by Eng. David Nunes, we sought to, in this work, use the WeDoCare and HappySpeak case studies to implement a control mechanism in which the human being is an integral part and influences the systems reaction. These application are described in more detail in sections 3.2 and 3.3.

As stated earlier for a system of this kind to work appropriately, we need to collect data that characterizes the human-being's emotions. To collect this data, we use the smartphone sensors which allows us to measure human behavior and his environment. These sensors can be, for example, accelerometers, gps, microphone, temperature, ambient light, etc. To store and process this information we need a server. We use Apache Tomcat 7 as the server which enables us to transmit and posteriorly save data so that we may perform some statistical analysis. The server works as a

management system and as a bridge between the mobile phone and the database. For database management we use Hibernate and PostgreSQL.

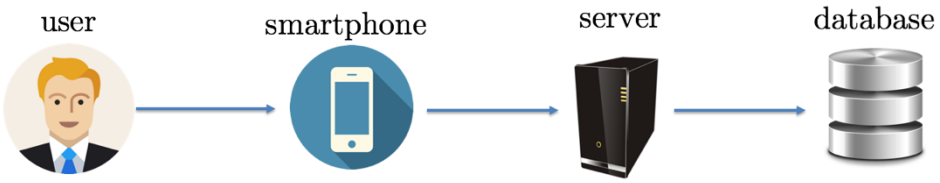

Fig 5 - Overall system arquitecture.

3.1.1 High-Level View

The existing architecture is equivalent to a common mobile platform with a backend server and a database, just as explained in the last section.

The user interacts with the "Happy System" through an Android application that has been developed for a certain purpose (in this case of WeDoCare and HappySpeak). In an addition to this, it is also possible to add external services through a single set of APIs which we can take advantage of, such as Foursquare or Facebook.

In the figures below it is possible to see the high level arquitecture for both applications developed under this master thesis.

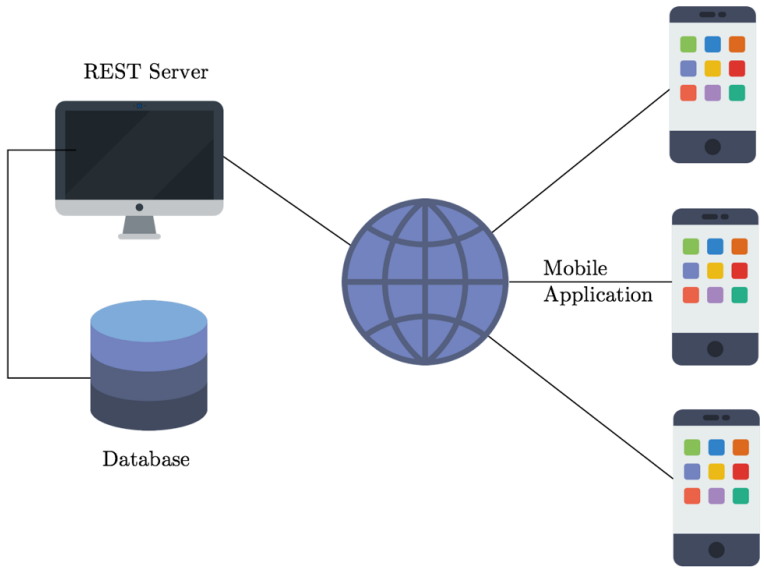

Fig 6 - High-level view of WeDoCare's system arquitecture.

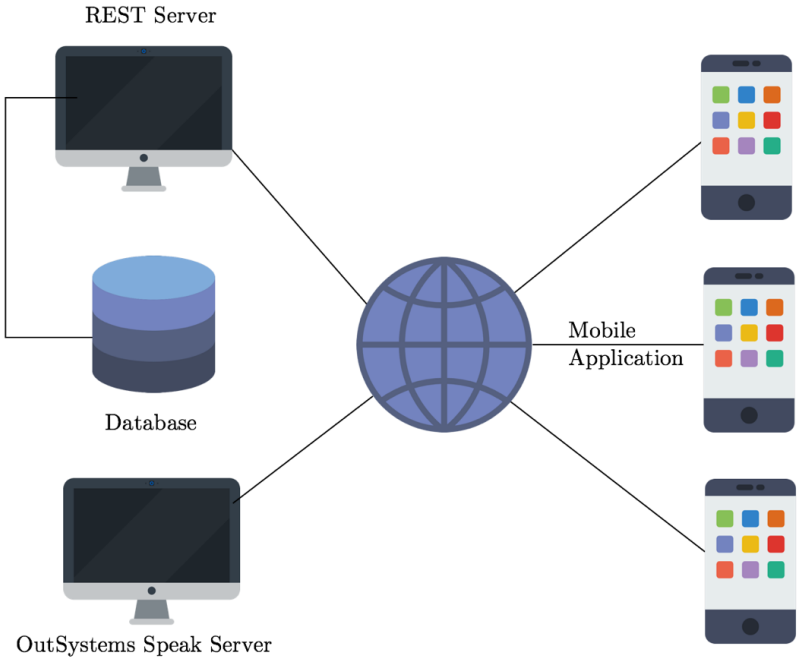

Fig 7 - High-level view of HappySpeak's system arquitecture.

The mobile application appeals to our REST server for the user's data and points of interest, this is, the REST server is specialized in sending and receiving information to the smartphone application. This information is fetched from the database.

In the WeDoCare platform the following external services were added: a location-sharing component and a login button using the Facebook social network. This social network is used in the WeDoCare mobile application to share the user's location and to add a login mechanism so the user doesn't have to create a new account in order to use the application.

The HappySpeak application appeals to the SPEAK's server, which is in OutSystems, to register the user to a speak class or event. The user can also retrieve information from SPEAK such as class attendance, speak events happening in his city, etc.

3.1.2 Mobile Application

Concerning the arquitecture of the mobile application, this contains a main thread, commonly called the UI thread, and background service. Note that this applies to any of the applications derived from the Happy System – WeDoCare or HappySpeak. The main thread or the UI thread is responsible for showing user interfaces (widgets, buttons and images), as well as to respond to the actions made by the user. The background service is a component that processes information in the background.

The UI thread in general, depending on the applications, enables us to show, in a collaborative way or not, information about the various points of interest to the user through a map. This map can show areas of high risk, areas where people feel more anxious, or events that may be happening. This interface is built with use of GoogleMaps library. Other interfaces can be built on top of this, for example, an interface for users to attend an event or for checking some type of data. This is, in

addition to the map where POI's are shown we can have other types of interfaces for dealing with other type of information.

The background service performs long-running operations in the background. They are usually used to perform operations that do not require any user interaction. Services also run in a higher priority than inactive activities so it is less likely that the OS terminates them. This component, in general, is used to determine the users' location, processes sensory information and send information to the REST server. Furthermore, it is also used to receive aggregated information from the server. Depending on the application, this service can have more functionality.

The service processes information from the sensors and, using machine learning algorithms, it combines information and infers an emotion. These emotions can be for example, isolation or fear.

All the machine learning training phases are also done in this background service. A record of this emotion is stored in the database, and these emotions are associated with a particular user.

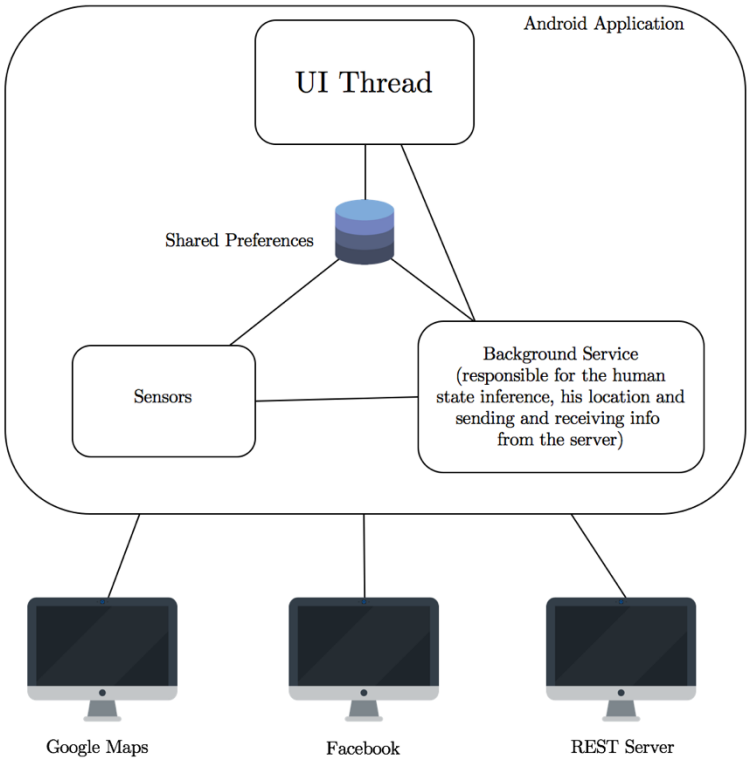

Fig 8 - Arquitecture used in both applications.

3.1.3 REST Server

The REST server is the backend of the mobile applications and it can use external services such as Foursquare to provide information on the points of interest. In this sub-section we expose this component. This component was developed in Java, deployed in an Apache Tomcat server, and can be analyzed from three distinct parts:

The data access layer: is a server component that uses Data Access Objects (DAO) to abstract the binding to each of the database tables. In this layer we also use classes generated by Hibernate, called *hibernateMaps*, which allow us to abstract instances of each table.

The Web service layer: is the segment that interacts with the mobile application. The information of the requests sent by the mobile application, to reach the service, is converted into a Data Request Object. This object is sent to the implementation layer, where the request is processed. Depending on the application, data is acquired through the DAO layer. Then, the implementation layer prepares a response. The response is converted into the response Data type object and is sent to the mobile application.

The Pooler: is a service responsible for dealing with data notifications, affluence and the deleting of information in the database. It runs in intervals of a desired time of minutes, depending on its function. It is a component that interacts only with DAO objects corresponding to the tables containing the information.

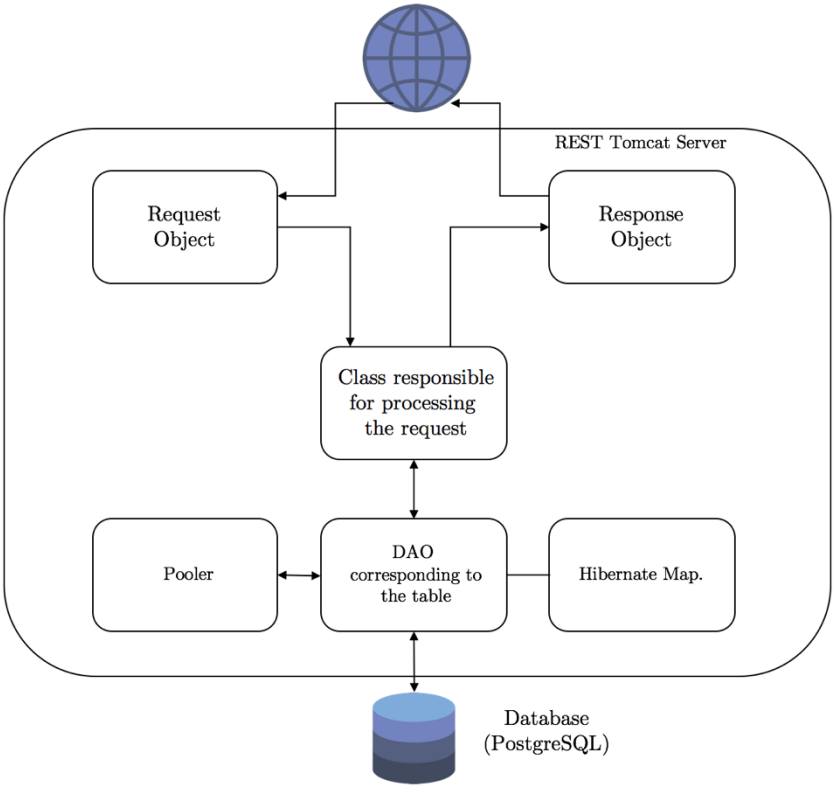

Fig 9 - Arquitecture of the REST server.

3.1.4 Database

Data received by the REST server is stored in a database. In the next chapter, the Entity-Relationship diagrams that describe the database for each application developed during this thesis are presented.

In general, the database stores information on POIs and the values used to infer the users' emotion or state. We also store some information about the user but always with anonymity in mind.

Android contains a storage option which allows us to save and retrieve persistent application data and the shared preferences. This is used to store personal data or other information necessary for the proper functioning of the application. Further information on the database of each application is detailed in the next chapter.

3.2 HappySpeak

3.2.1 Context

People have moved from their home countries for centuries, for all sorts of reasons. Some are drawn to new places by 'pull' factors, others find it difficult to remain where they are and migrate because of 'push' factors. Migrants are drawn increasingly to developed countries such as Germany, UK and France, by the following factors:

- Incomes in developed countries are higher, which draw labor from countries or areas where incomes are lower.
- International transport has never been easier and is cheaper than ever.
- People are drawn to stable democracies where human rights and religious freedoms are more likely to be respected.
- Young people move in order to get better jobs or improve their qualifications, including their language skills.

Negative factors at home add to the reasons why people feel compelled to move.

- Lack of prospects for career advancement
- Poverty and low incomes
- High unemployment rates
- Persecution and poor human rights
- Internal conflict and war
- Natural disasters, climate change and famine

The number of migrants worldwide reached 232 million in 2013 - the majority of them cross borders in search of better economic and social opportunities [39]. The problem is that, independently of their background, when they arrive in a new city they begin a new struggle: understanding the language, finding friends, getting a job, and so on. Also there are some people in their new cities that may judge them by their color, race or religion.

The process by which immigrants become accepted into society, both as individuals and as groups is what we call *integration*. This is what SPEAK tries to solve.

SPEAK [40] tries to help solving these problems by allowing people from different origins and cultures to meet and communicate. It is a project that helps integrating migrants in their new cities through a crowdsourcing language and culture exchange between them and locals, that breaks barriers, promotes multilingualism, equality and democratizes language learning (O2O model).

O2O stands for Online to Offline. An O2O website helps business owners in customer acquisition by doing a part of the business online and the rest of the part offline [41].

SPEAK tries to connect with those who have recently moved to Portugal and face adversity not only in the language barrier but also in social terms. This is, people who

struggle to meet new people or make new friends, which may lead to social isolation and depression. SPEAK helps these people by organizing dinner parties and events that bring immigrants and locals together. SPEAK also provides courses and encourages people from different cultures to share their interests and break any prejudices they may have about foreigners.

3.2.2 Description

We have talked about the work that Dartmouth College had presented. A system named StudentLife [35], which uses Android phones to continuously sense the day-to-day impact of workload on stress, sleep, activity, mood, sociability, mental well-being and academic performance of a single class of 48 students across a 10 week term.

While StudentLife provided a great example on how IoT devices (smartphones) can be very helpful in acquiring a student's context, the scope of the system was limited. The objective of the study was only to obtain a statistical dataset, containing the behavioral and mental health outcomes of the students. The system did not take measures to counteract the student's negative academic performance or undesirable lifestyles.

In this case study, we intend to use StudentLife's ideas on a different scenario (explained below) and extend it by taking a proactive approach to "close the loop". In other words, we intend to create a system that not only automatically infers the individuals' context (activity, sociability, stress, sleep, mood, mental well-being) but also feeds this information to a decision-making process, which takes measures to improve life quality.

Our scenario, as seen in the last section, is about migrants' integration in the new cities they move to.

HappySPEAK is a HiTL application which helps migrants by measuring the isolation of each participating migrant by analyzing their context. Social isolation is

related with depression [42] and refers to a complete or near-complete lack of contact with people and society from an individual. The smartphone's usage patterns (e.g. social networking data and communication patterns) and its sensors (microphone, accelerometer, location) can provide important clues that can serve a mechanism for the detection of the user's isolation level. All of this information allows us to create actuators (actions/suggestions) in order to help the user improve his quality of life and social integrity. These actuators take a proactive approach, providing the user means to keep track of their condition while delivering positive reinforcement and suggestions of activities. These suggestions can be a simple warning for the user to take a walk, go to a SPEAK class or attend any event that SPEAK is organizing.

With the sensors present on smartphones and the information available on the SPEAK platform about each participant, (refugee, migrant, local) the system collects relevant data to infer if the participant is stressed, lonely, not attending events or classes. This and other relevant information is used to act on and improve the quality of life of the participant, making sure he has friends, a positive experience in the city, and that he receives relevant information over time depending on his emotional state and needs. This will contribute towards a healthy and effective integration, maintaining a better mood, positive socialization and low stress.

3.2.3 Requirements

The following section discusses the system requirements for the developed HappySpeak application described above. We also present functional requirements and non-functional requirements.

Throughout this section, we also identify the main features that the system aims to provide to stakeholders. We intend to set out a vision for the system system where we identify:

- Stakeholders

- Actors
- Functional Requirements
- Use Case Diagram
- Non-Functional Requirements

3.2.3.1. Stakeholders

The stakeholders are the elements that interact directly or indirectly with the system. In particular, it comprises:

- The people responsible for development;
- People or entities that finance or support the product;
- People who use the product.

Stakeholder	Description	Responsibility
Team which develops the application	Professor Jorge Sá Silva, Eng. David Nunes and Ashley Figueira	Monitor the development process and application establish partnerships.
Common user	Users who have migrated recently to a new country and need to integrate more easily.	Stay safe, send sensorial information from the smartphone to the server and validate the system.
SPEAK	SPEAK organization that help migrants with social integration.	Organization that will give us the opportunity to test the app on the field and will help us define the requirements needed for this system.

Table 1 – Stakeholders of the HappySpeak application - Description and Responsibilities.

3.2.3.2. Actors

SPEAK users are the main actors of this project. By using the application, they can find out about SPEAK events. These users can also:

- Login;
- Register;
- See SPEAK social platforms;
- See SPEAK events:
- See event detail;
- Subscribe to SPEAK events;
- Unsubscribe to SPEAK events;

3.2.3.3. Functional Requirements

This section seeks to identify and classify the system's functional requirements. The user's story is a high-level definition of requirement, written in common language that can characterize the system stream as the actor interacts with the application. It contains the necessary information so that the analyst can estimate the time required to develop the desired requirement.

The requirements are built according to the parameters given in table 2.

Priority	*Must*: necessarily implemented requirements. *Should*: requirements that must be implemented, but if not implemented, the system should work. *Could*: not implemented requirements that wont affect the implementation of the important requirements. *Will not:* not implemented requirements for the project, considered as future work.
Description	Overall exposure of the requirement.
Actors	Systems that intervene with the product.
Pre-conditions	Systems state prior to the action.
Events Flow	Description of the actions that an actor needs to fulfil in order to reach the expected result.
Expected outcome	Expected result from the implementation of the requirement.

Table 2 - Parameters of the requirements.

Next we present the list of requirements for the Mobile Application:

- Login;

Priority: Must

Description: The app must allow the user to insert a valid username and password to proceed to the next menu.

Actor: Normal user

Pre-conditions: The user has to be registered to the SPEAK platform to be able to login.

Event Flow: The user clicks on the "login" button. The user inserts his username and password. The user clicks "Submit" button. If the username/password is correct, it goes to the Event List menu. If the username/password is incorrect, an error message should be shown.

Expected Result: If login is successful the user has full opening is the app's features. If the username or password do not exist on the server, the user cannot proceed to the next menu. If the username or password are not valid, a message must appear to inform the user. If there is no connection to the Internet a message must appear to inform the user.

- Register;

Priority: Must

Description: If the user is not currently registered in SPEAK, he must be able to do so from his smartphone.

Actor: Normal user

Pre-conditions: Have an e-mail address.

Event Flow: User clicks the "Registration" button. User inserts a username, password, confirmation password and e-mail. User clicks "Submit" button. If the email/username are already taken, an error message should be presented.

Expected Result: If registration is successful the user is registered to the SPEAKs platform and can start using the system. If the username or e-mail inserted is already in use the user can't be registered.

- Ability to check out SPEAK's social platform

Priority: Should

Description: Takes the user to Facebook, YouTube and Twitter pages created for SPEAK.

Actor: Normal user

Pre-conditions: Be registered to the platform and have the application installed.

Event Flow: User clicks Facebook, YouTube or Twitter icons.

Expected Result: The app opens the browser with the right link.

- See future SPEAK events or events that are happening right now

Priority: Must

Description: The ability of the user to check a list of SPEAK events that are happening or happened in the past.

Actor: Normal user

Pre-conditions: Be registered. Have the application installed and be logged in.

Event Flow: After the user logs in to the system the user is immediately presented with the list of events.

Expected Result: The user can check the list of events that can be filtered by city. If a city doesn't have any event a message is presented to the user warning hum of this situation. If no one is attending an event the "Who's Going?" text must disappear.

- Check details on a specific event

Priority: Must

Description: This feature allows the user to learn more about the event, such as where it is located, how to get there, time and date, who is going and who organized it. It also allows users to subscribe/unsubscribe to this event.

Actor: Normal user

Pre-conditions: Be registered. Have the application installed and be logged in.

Event Flow: The user has to login and click on a single event from the list. After this, the description is presented to the user.

Expected Result: The user can see various information about a specific event. The application should know the subscription status of the user so the subscription button can disappear if the user is already subscribed to that event.

- Subscribe and Unsubscribe to SPEAK events

Priority: Must

Description: A button which allows the user to subscribe to event, this is, inform SPEAK administrators or organizers that the user is attending that event.

Actor: Normal user

Pre-conditions: Be registered. Have the application installed and be logged in.

Event Flow: The user has to login and click on a single event from the list. After this, the description is presented to the user and he should then click the subscribe or unsubscribe button that is presented in the bottom of the screen.

Expected Result: The user is presented with a success/failure message. In case of success the button turns grey. In case the user clicks unsubscribe that button turn back to green.

- Isolation Recognition feature

Priority: Must

Description: The system collects data from the call/message logs and location to infer the user's isolation.

Actor: Applications System

Pre-conditions: For the collection of data to start the user must be logged in.

Event Flow: The systems collects data and sends this data to the neural network. If the neural network infers that the user is isolated the system presents the user with suggestion to improve his state.

Expected Result: Ability to infer and change the humans' isolation state.

- Send sensorial information to the server in an invisible way

Priority: Should

Description: The system must send the data it collects to our server to be saved in a database.

Actor: Applications System

Pre-conditions: Have an internet connection.

Event Flow: Whenever data is collected it should send this information to the server.

Expected Result: Information is sent and received by our server.

- Ask feedback to the user for his isolated situation

Priority: Must

Description: The system presents the user with a notification asking the user for feedback about his emotion. The feedback values are then used to train the network.

Actor: Application

Pre-conditions: Have the application running in the background.

Event Flow: A notification appears asking the user for feedback. The user responds. The network is trained and the data is sent to the server.

Expected Result: The amount of time the user is asked about his emotion must decrease along time.

- Give the user suggestions

Priority: Should
Description: If the neural network detects that the user is feeling isolated the application should present the user with a message advising the user to attend a SPEAK event.
Actor: Application
Pre-conditions: Have the application running on the background.
Event Flow: The system first detects the user is feeling lonely. The system then shows the user SPEAK events and places to visit.
Expected Result: Improve the user's social status.

3.2.3.4. Use Case Diagram

Use case diagrams are used to explain the apps features. One diagram was created to represent the use cases of the mobile application.

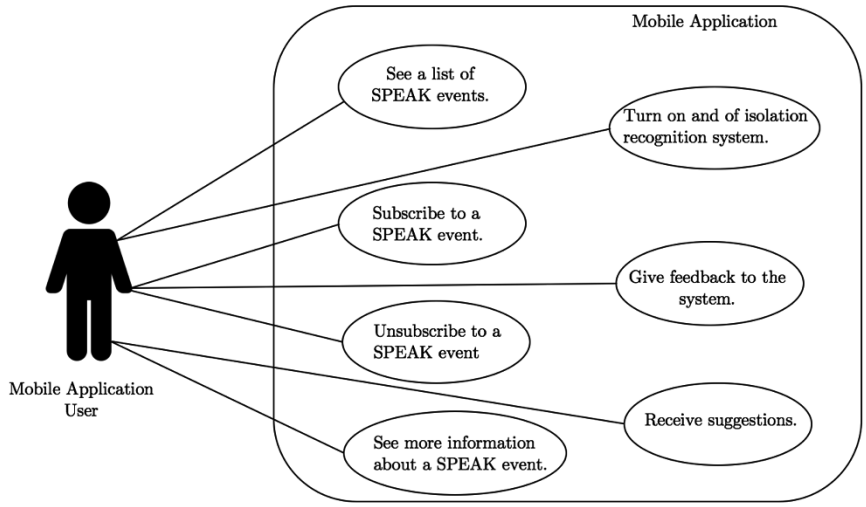

Fig 10 - HappySpeak use case diagram.

3.2.3.5. Non-Functional requirements

The Non-functional requirements for the HappySpeak application are:

- Usability - Determines the aesthetics of the UI.
- Accessibility – Determines weather all users can use this app.
- Performance – Latency and memory usage of the mobile application.
- Support - Determines features like compatibility, testability and configuration, durability and others.
- Privacy – Determines the privacy policy on the user's information.

As discussed above, performance is a serious problem in some devices, so specific performance guidelines were taken into consideration. These guidelines result in the chaining of operations such as requests sent to the server, which is done on separate threads and not on the UI Thread of the app. The event list must use the *ViewHolder* pattern to save memory. Bitmaps must be released as soon as they are not needed. All of

these points what regards to performance are also taken into consideration when developing the WeDoCare application.

As requested by Hugo Aguiar (CEO of SPEAK), the User Interface must provide a uniform look and feel between all activities. Activities must use a toolbar to display global operations available. This user interface must be as similar as possible to the SPEAK platform. Since the user base for this app is made of many cultural backgrounds and languages the system must provide multi language support and right-to-left text (for Middle Eastern people).

In the HappySPEAK server all users must be identified by a randomly generated UUID, so that no personal data is usable if the system is compromised. This UUID will be associated to a user until he wipes the app data or changes to a new smartphone. The generated UUID must be stored in the smartphone's private space so that the information is not available to other apps. This is also done on the WeDoCare application.

3.3 WeDoCare

3.3.1 Context

The European migrant crisis began in 2015, when a rising number of refugees and migrants made the journey to Europe to seek asylum and a better lifestyle.
According to the UNHCR, the number of forcibly displaced people worldwide reached 59.5 million at the end of 2014, the highest level since World War II with a 40% increase taking place since 2011 [43]. So far this year, more than 644,000 refugees and migrants have arrived in Europe by sea. Of these, just over a third – 34 per cent – are women and children who are particularly vulnerable to abuse as they transit Europe, especially in overcrowded reception sites, or in many locations where refugees and migrants gather, such as parks, train stations, bus stations and roadsides [43].

Refugee and migrant women and children travelling on their own are also at heightened risk as they move through Europe, sometimes at night, along insecure routes or staying in places that lack basic security [44]. This is a neglected problem and an effective solution has yet to be achieved.

With all this in mind, we want to take measures to ensure the protection of women and children, by providing a safe route to Europe as well as prevent sexual abuse. We also want to state that our system does not only apply to refugees, as mentioned in this section, but can also help other migrants seeking a better lifestyle in Europe. Also, a successful system to solve this issue could be adapted to solve other problems in the context of elderly healthcare or domestic violence, which show us the potential scalability of its social impact [45].

Furthermore, violence is more often in under developed countries where poverty is higher or problematic neighborhoods. People living under harsh conditions often do not have the means for acquiring items other than those they already possess. Taking this into consideration, we propose a low cost and effective solution based on HiLCPS and IoT which avoids additional hardware limiting our choice of sensors to those already provided by the smartphone. Strategies or technologies to prevent any type of violence are very few.

This application arose from an idea we had in conjunction with the UN refugee agency (UNCHR) for the protection of refugees during their trip to Europe.

3.3.2 Description

WeDoCare is a HiTL application that uses the smartphone's sensors, in particular the microphone, to detect, in an automated way and in real-time, situations of violent attacks against users through a scream detector.

The application sends out indications to nearby citizens, warning that someone is in danger, giving users a chance of collaboration by helping others – a solution that

integrates IoT. The system sends out an alarm as soon as a scream is detected. Nearby users receive a notification that pops up, warning them that someone is in danger. The app also shows the location of the user in danger, represented by a red flag in a map. To improve the effectiveness of our application we implemented an innovative beacon system so that communication with nearby or surrounding people isn't limited to an Internet connection. This way, the user can stay safe even if there isn't any mobile network, thereby increasing the effectiveness of our application.

The application also warns the user whenever he/she is passing by a zone where attacks occur more often, so that these sites can be avoided. This closes the human-in-the-loop, as the app actuates to prevent further danger.

The dominant characteristic in emergency situations or attacks is screaming (non-linguistic vocalization), therefore our application is more focused on scream recognition. This scream recognition task runs on a background service which collects the data from the microphone, extracts certain features and sends these features to a classification system. This classification system is responsible for deciding if the microphone's output is a scream or not. A detailed explanation on our scream recognition system is articulated in section 4.2.1.2.

The smartphone's GPS is also used to retrieve the location of the individual. This location, in addition to the uses described earlier, is also used to decide to which users the notification is sent. This notification is sent to the users who are in a 2km radius of the users' location. This is, when the user has an Internet connection, otherwise our beacon system comes into play. All these sensors, as stated earlier, are available straight off any mobile phone.

3.3.3 Requirements

The following section discusses the system requirements for the developed WeDoCare application described above. We also present functional requirements and non-functional requirements.

Throughout this chapter, we also identify the main features that the system aims to provide to stakeholders. We intend to set out a vision for the system where we identify:

- Stakeholders
- Actors
- Functional Requirements
- Use Case Diagram
- Non-Functional Requirements

3.3.3.1. Stakeholders

The stakeholders are the elements that interact directly or indirectly with the system, in particular, it comprises:

- The people responsible for development;
- People or entities that finance or support the product;
- People who use the product.

Stakeholder	Description	Responsibility
Team which develops the application	Professor Jorge Sá Silva, Eng. David Nunes and Ashley Figueira	Monitor the development process and application establish partnerships.
Common user	Users who were forcibly displaced or live in areas of great danger.	Stay safe, send sensorial information from the smartphone to the server and validate the system.
UNHCR	United Nations Division that deals with the security of refugees.	Organization that will give us the opportunity to test the app on the field and will help us define the requirements needed for this system.

Table 3 - Stakeholders of the WeDoCare application - Description and Responsibilities

3.3.3.2. Actors

Actors are elements that interact with the application. General users can:

- Add danger zones or helpful locales.
- Notify others nearby that you are in danger just by screaming.
- View danger zones through heatmaps and level of danger.
- Login via Facebook or our unique registration system.
- Create an account.

3.3.3.3. Functional Requirements

This section, as section 3.2.3.3, seeks to identify and classify the system's functional requirements. The requirements are built according to the parameters given in table 2. Next we present the list of requirements for the Mobile Application:

- Ability to add danger zones and helpful locales

Priority: Must
Description: The ability to add to our server or system a specific danger zone or a helpful locale with some description and a danger level or the type of location. This danger zone and helpful locale is then available to all other users to see.
Actor: Normal user
Pre-conditions: The user must be registered and logged in our application.
Event Flow: The user loges in our application. After the map appears the user must press the floating action button on the right inferior side of the screen. Choose blue or red for danger zone or helpful locale, and then long press the exact location of the zone the user wants to add. After this long press coordinates are saved and the user is presented with a screen to add additional information about that zone.
Expected Result: The danger zone or helpful locale is added to our server and system and all other users can see what zones are dangerous which they should avoid and they will also see nearby helpful locales like police stations or refugee camps.

- Be notified when passing through a danger zone and calculate other routes

Priority: Should
Description: Whenever the user passes through a danger zone the application sends out a notification warning the user to take another route.
Actor: Application

Pre-conditions: Be logged in and have the application running in the background.
Event Flow: Log in.
Expected Result: The user keeps himself safe avoiding areas where danger is greater.

- Scream recognition system

Priority: Must
Description: The application detects whenever the user is screaming.
Actor: Application
Pre-conditions: The user must be registered and logged in.
Event Flow: The systems collects data and sends this data to the neural network. If the neural network infers that the user is screaming the system sends out an alert to nearby user's warning this person is in danger.
Expected Result: Whenever the user screams the application senses or detects this scream and warns others that the user is in effective danger. These surrounding users can then help the person who is in danger making the society we live in safer and happier.

- Send sensorial information to the server in an invisible way

Priority: Should
Description: The system must send the data it collects to our server to be saved in a database.
Actor: Applications System
Pre-conditions: Have an internet connection.
Event Flow: Whenever data is collected it should send this information to the server.
Expected Result: Information is sent and received by our server.

- Ability of the server to send to all users' information/location of a nearby person in danger and the application to receive this information.

Priority: Must
Description: The server received an event which says that someone is in danger in a specific location. This event then has to be sent out to all other users that are nearby.
Actor: Application
Pre-conditions: None.
Event Flow: None.
Expected Result: All surrounding users receive a notification saying that someone nearby is in danger. Clicking this notification opens up the map with the person's (who is in danger) current location.

- View danger zones through intensity heatmaps and level of danger

Priority: Should
Description: Heatmaps make it easy for users to understand the distribution and relative intensity of danger zones. Color is used to represent the distribution of danger zones. The level of danger zone is used to represent the danger, whether it is high, medium ou low.
Actor: Normal user
Pre-conditions: Registered and logged in.
Event Flow: User logs in and click the top right button of the screen.
Expected Result: Ease of visualization of danger zones and easy identification of the most danger areas.

- Login via Facebook or other social network

Priority: Should
Description: The app must allow the user to login via Facebook.
Actor: Normal user
Pre-conditions: The user has to be registered to Facebook to be able to login.
Event Flow: The user clicks on the "login using Facebook" button.
Expected Result: If login is successful the user has full opening is the app's features. If the user does not exist on the server a new user is created. If there is no connection to the Internet a message must appear to inform the user.

- Create an account

Priority: Must
Description: If the user is not currently registered, he must be able to do so.
Actor: Normal user
Pre-conditions: Have an e-mail address.
Event Flow: User clicks the "Registration" button. User inserts a username, password, confirmation password and e-mail. User clicks "Submit" button. If the email/username are already taken, an error message should be presented.
Expected Result: If registration is successful the user is registered to the platform and can start using the system. If the username or e-mail inserted is already in use the user can't be registered.

- Avoid spamming or false additions of danger zones and helpful locales and add temporal bans to users who abuse the system.

Priority: Will not

Description: Ability of the system to detect whenever a user is abusing the system by adding to much POI's in a short amount of time.

Actor: System Server

Pre-conditions: None.

Event Flow: None.

Expected Result: The user is banned for 24h if he abuses the system.

- Avoid false positives from the scream recognition system.

Priority: Must

Description: The application asks the user if the scream detected is really a true scream. This avoids false positives that may occur since the scream recognition system isn't 100% reliable.

Actor: Application

Pre-conditions: Be logged in and have the application running in the background.

Event Flow: Data is collected from the microphone, processed and sent to the classification system. If a scream is detected a notification is presented to the user.

Expected Result: If the application detects a false scream the user can warn the system that it was a false scream and avoid warning other users that you are in danger.

- Warn Facebook friends that you are in danger.

Priority: Should

Description: When a scream is detected the application posts automatically a post to the user's Facebook wall, this way reaching more people.

Actor: Application

Pre-conditions: User has to login via Facebook.

Event Flow: Data is collected from the microphone, processed and sent to the classification system. If a scream is detected the application posts a message with the user's current location on his Facebook wall.

Expected Result: Warn more people that the user is in danger.

- Set a settings policy

Priority: Should

Description: The user has the ability to choose the applications settings for battery duration.

Actor: Normal user

Pre-conditions: Registered and logged in.

Event Flow: Log in to the application, click the settings button on the navigation drawer.

Expected Result: The smartphone adapts the location collection rate according to the user's needs.

3.3.3.4. Use Case Diagram

Use case diagrams are used to explain the apps features. One diagram was created to represent the use cases of the mobile application.

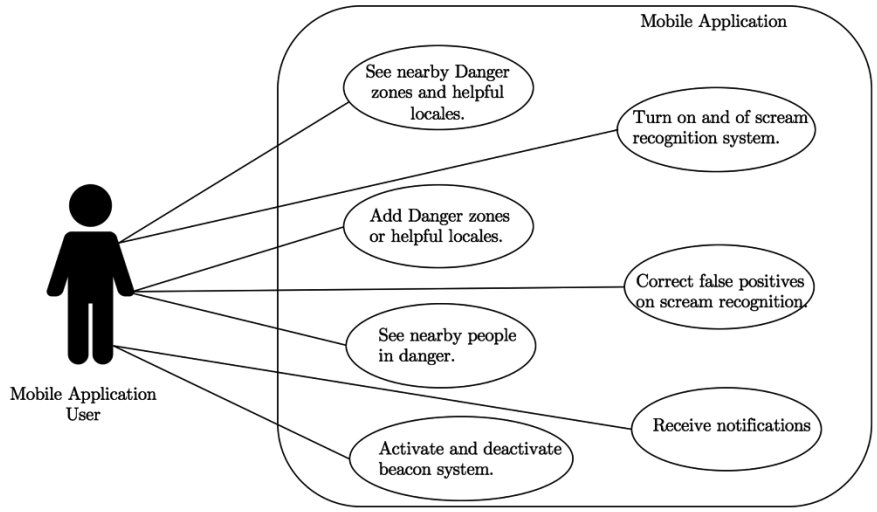

Fig 11 - Use case diagram of the WeDoCare application.

3.3.3.5. Non-Functional requirements

The Non-functional requirements for the WeDoCare application are:

- Usability - Determines the aesthetics of the UI.
- Reliability - availability of applications and fault resilience.
- Performance – Latency and memory usage of the mobile application.
- Support - Determines features like compatibility, testability and configuration, durability and others.

Since this application will be used amongst people with difficulties in using new technologies WeDoCare should be made available to the user in a practical, intuitive and easy-to-use way. Also, since many of our target users have economic difficulties and cannot acquire last generation mobile phones, the app should be compatible with the Android 4.0 and higher versions of the operating system, thus ensuring 97.4%

compatibility with Android devices. In terms of battery life, since the app activates the microphone every 30 seconds and has an expensive computational burden when processing the signal, we have to conserve battery life as much as possible. Finally, the app must be efficient and trustworthy, this is, it must detect attacks as more accurately as possible and communications with surrounding users should be reliable.

4 Chapter
Development

In this chapter we discuss the development stage of both mobile applications, and the changes made to the REST Server and Database. We also discuss the development of the WeDoCare landing page. Subsequently in the next chapter we present the tests made to both apps and their results.

4.1 HappySpeak

4.1.1 Mobile Application

The target audience of this application includes:

- People who are receptive to accept suggestions made by the HappySpeak application accordingly to the detected emotion;
- People who want to live more, get to know more people and participate on SPEAK events;

This application provides a vast amount of information about points of interest or SPEAK events, including:

- Attendance of people on that POI;
- People's emotion;

This collaborative information characterizes the points of interest. With the development of this work, the case study HappySpeak has become a tool that also monitors the emotional state of the user, and intervenes in a way which can improve their health and well-being. As a result, this new aspect of mobile application addresses the field of positive psychology, in which we concentrate our focus to the positive experiences of the human being.

4.1.1.1. User Interface

The HappySpeak application has a simple and intuitive design. It was request by SPEAKs CEO, Hugo Aguiar, that the design of the HappySpeak application was similar to the SPEAK platform. This was our main goal what refers to UI/UX in this application. The Android architecture allows developers to have a MVC UI implementation by default. MVC, Model–view–controller, is a software architectural pattern for implementing user interfaces [46]. It divides a given software application into three interconnected parts:

- The model directly manages the data, logic and rules of the application.
- A view can be any output representation of information.
- The controller, accepts input and converts it to commands for the model or view [47].

The User interface is built using a drag-and-drop tool which translates the User interface elements as XML. Pure XML can also be used for more definition when designing UIs.

Since this was the student's first experience in Android development, the application is not as intuitive as the design in the WeDoCare application. The Material Design guidelines also were not applied in this application, what is a huge downside. Furthermore, on the WeDoCare application we talk about its material design.

The opening screen that appears when the application is opened for the first time is the information screen. This screen informs the user about the application, its goals and the entities involved in the development of the application.

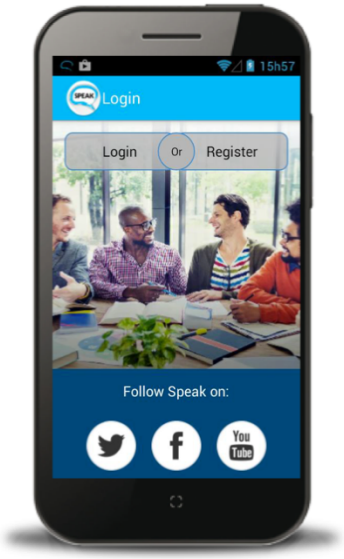

Fig 12 - HappySpeak login screen.

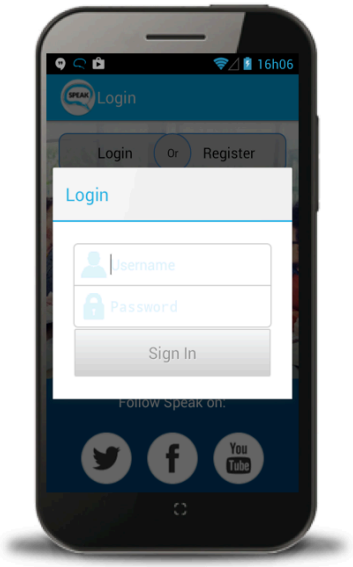

Fig 13 - HappySpeak login dialog screen.

The login screen is where the user can login and register to the SPEAK platform. The user can also see SPEAK's social media platforms such as YouTube, Facebook and

twitter accounts. This screen is very similar to the SPEAK platform and appears after passing through the information screen. Due to the limited functionality of the login and register features, it was not deemed necessary to build standalone activities for the login and register buttons when clicked. Instead we used dialog boxes (pop-up boxes). The Login Dialog allows the user access to his account and is necessary to see SPEAK events. The Register Dialog allows the user to create a new SPEAK account.

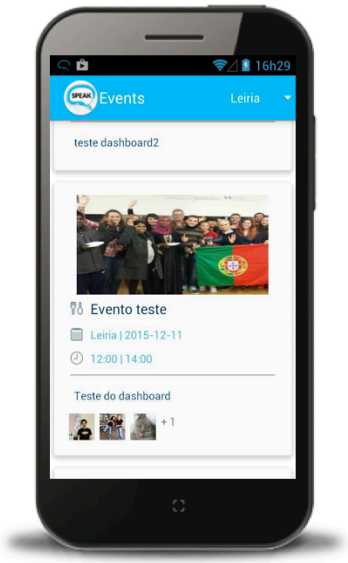

Fig 14 - HappySpeak event list screen.

The event list screen is where SPEAK events are presented to the user. It is possible for the user to see all past and future events for a specific city. If the user changes the city using the widget in the toolbar, the list will refresh and display events only for that city. To be able to display a custom list we had to create a custom ListAdapter, that are used to draw and organize list entries.

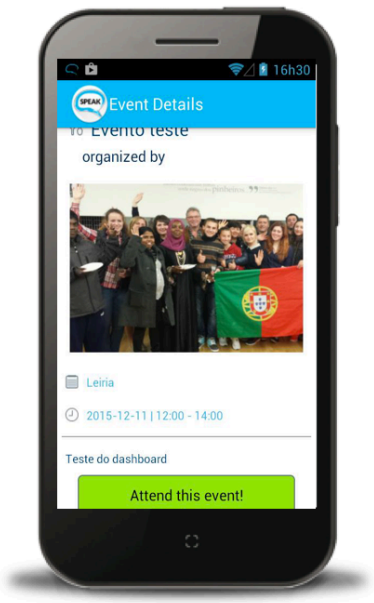

Fig 15 - Details for a specific event screen.

Each speak event has a set of information that is presented to the user in the event detail screen. In this screen, the user can see more information about a specific event, such as its location, who organized it, a more detailed description and the ability to subscribe/unsubscribe to the event. Traditionally, to display a place on a Google Map we require its latitude and longitude. Unfortunately, no such information existed in the SPEAK database for an event. By using geocoding, we were able to use the events address to get its geographical coordinates. Android already possesses the necessary mechanisms to do this, by communicating with the Google servers.

4.1.1.2. Isolation Recognition Module

There are a few key metrics that gives us the opportunity to help improve the user's well being or quality of life by making his integration easier to a new city. These key metrics are:

- The user's physical activity and time spent at home – When the user opens the application for the first time the application prompts the user to pin point his home on a map. This is used to know if the user stays too much time at home or is outgoing, by using the smartphones GPS. Over time the Neural Network learns about the user and knows how to evaluate his isolation. The neural network also takes into account the amount of time the user stays at home to sleep, lunch or dinner. Also, the GPS in conjunction with the accelerometer is used to detect physical activity. Physical activity and the time spent outside are considered important factors for a healthy life style. This is also important on the user's integration process.
- Measuring social interactions – Relating with people in the real-world (offline) is important for any person. Although, nowadays it is very common to interact with people using technology, this is online, using different social platforms. For the newcomer (migrant/refugee) it is important to create a social network that include locals. By accessing the user's text messages and phone calls it is possible to know the number of different people the user interacts with and how many times. We can also do this by accessing the users' social networks. It is also possible to have an idea about their nationality and understand if they are locals or not by checking the country code of the phone numbers the user is contacting with.

All these metrics help identify a sociability score and depending on that score actuators are triggered to help the user improve it. In this context actuators are suggestions of the application to the user that help him improve his sociability score

and, as a result, in his life quality and integration process in the new city. The application suggests events based on the interests of the user. This helps the user to be outgoing and interact with new people with the same interests. As physical activity is important, there are also suggestions on how to go out and explore the city as the individual exercises. Different actuators are triggered depending on the results of the different metrics mentioned in the previous subsection.

These are a few features that are implemented on our system that combine the new IoT and Affective Computing (AC) in order to help solve this important and neglected social issue:

- If the system identifies that the participant is lonely or sad, it suggests him to participate in events that have the probability of improving his emotional state and allow him to connect with other people.
- If the user is not attending events or not having opportunities to live his culture, the system automatically suggests him and trains him on how to create an event about his culture and language and open it to other people interested in.
- If the user is not going out for physical activity the system motivates him to do so at the same time the user explores the city.
- If the participant has just arrived to the city, the system suggests him to connect with someone of his original country that is more experienced in the city, and suggests questions and topics to discuss with that person. The system also does the same suggestion to the experienced participant to maximize the probability of a connection between the two. Moreover, the system does the same exercise with a local that has been in contact with people from the country of origin of the new comer.

As we've said before, HappySpeak aims to measure human isolation and help people who feel this way interact and strengthen their sociability, by promoting relationships between people of different backgrounds, showing them SPEAK events to which they can attend. And in resume, to measure this type of human emotion we collect data from GPS, call and sms logs. The GPS is used to check if the user spends a lot of time at home.

The simple scoring system works as follows: every time the application runs the neural network we have a list of locations the user went through during the day, this is, we have a local record of the user's whereabouts since the neural network last ran. The system then goes through all of these locations. For each of this location we give -10 points if the location is home and +10 points if the location is out of home, ending up with a sum which is then divided by the number of records we have. However, taking into account the fact that we sleep (during 8 to 10 hours), have lunch and dinner at home we do not consider the home locations during these usual times.

In conjunction with this value, we send to the neural network the ratio of incoming and outgoing calls as well as messages.

Emotion recognition tasks are performed on a background service using a simple feedfoward neural network with a sigmoid activation function. This component is also used to collect the sensor data from time to time and send it to the HappySPEAK server and to launch an Activity that asks the user for feedback on how they are feeling. In order to avoid influencing the user in giving results that don't reflect reality, we only show what the neural network inferred after the user has submitted his feedback.

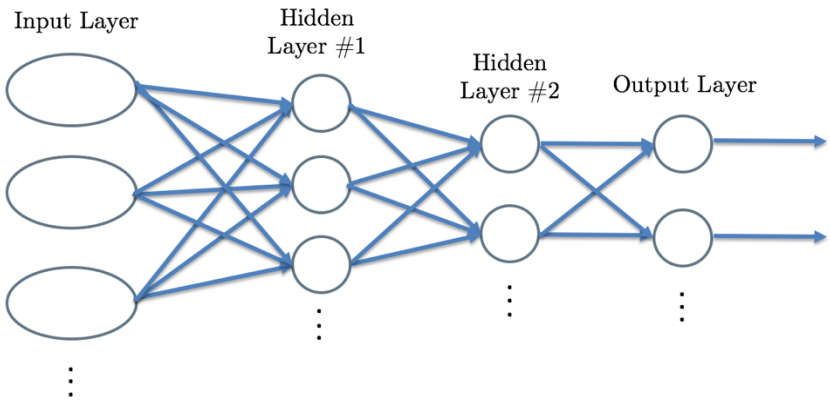

Fig 16 - HappySpeak's Neural Network Arquitecture.

If the network detects that the user feels lonely, it triggers the map activity which displays suggestions of SPEAK events occurring soon and places that can help him meet new people. These suggestions will help the users to socialize; thus, reducing his isolation. In order to train the neural network, the system occasionally queries the user on how he is feeling. By asking the user for feedback the network will require less and less training, and as accuracy grows, the number of times feedback is requested drops.

4.1.2 WebServices

As mentioned in section 3.1.3, we implemented various methods in the REST server following the structure that already existed and explained earlier. These methods are used to receive:

- information on the user;
- information on the points of interests;
- social info about the user;
- motion info about the user;
- neural network inputs;

We also implemented methods to spread this same information to various mobile devices that have the SPEAK application.

In addition to this, we also have methods that interact directly with SPEAK's servers. This is a webservice that was created using the OutSystems platform. Originally we planned on using a REST webservice but unfortunately at the time, the platform's version only supported SOAP.

Since Android does not support SOAP natively, an external third party library was used to send/receive requests from the webservice. This library was Ksoap2, a mature and much recommended library used by many Android developers. With this service we were able to retrieve/send the following information from the SPEAKs platform:

- Delegations;
- SPEAK events for a specific city;
- The organizer of a specific event;
- Attendee's for the events;
- Ability to subscribe and unsubscribe to an event;
- Ability to register the user to the SPEAKs platform;
- Get information on the attendance of the user for events;

4.1.3 Database

In the figure below we represent the entity-relationship diagram of the database for this application, what concerns our side of the server. This is, this diagram does not include the database of the SPEAKs platform.

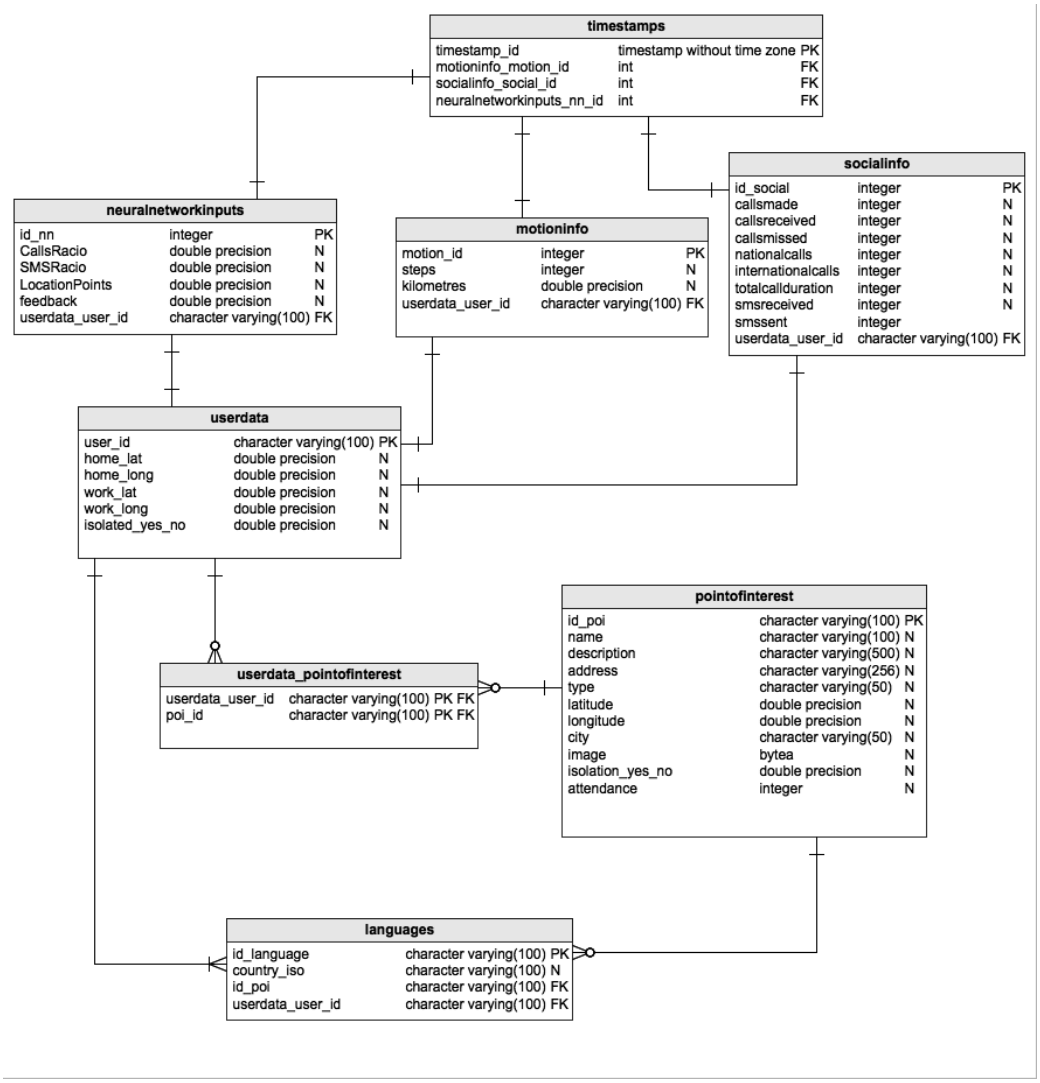

Fig 17 - HappySpeak Database Diagram.

In the above diagram we can see the fields associated with the values that are sent to the classification system, this is, the neural network input values:

- Calls ratio;
- SMS ratio;
- Location points;
- Feedback given by the user about his isolation;

In the same figure it is also possible to observe the values of the users' social info:

- Number of Calls made;
- Number of Calls received;
- Number of Calls missed;
- Number of National calls;
- Number of International calls;
- Total call duration;
- Number of SMS received;
- Number of SMS sent.

Another table represented in the diagram above is the motion's table, which has the following characteristics:

- Number of steps the user has taken;
- Kilometers the user has walked.

We also save information on the user's state and locations. This information contains:

- The users work location;
- The users home location;
- How isolated the user feels.

We also have a table that represents point of interests. This table includes the following information about a specific point of interest:

- Name;
- Description;
- Address;
- Type;

- Latitude and Longitude;
- City;
- Image;
- How isolated are the people at this location;
- Attendance.

In addition to the tables described above we also have two other tables, one that was used for the application tests.

4.2 WeDoCare

4.2.1 Mobile Application

The target audience of this mobile application includes:

- People who live in areas where crime is more accentuated and plan to stay safe with a personal vigilant system.
- People who are new in a city and want to know the area, more specifically, where the greatest danger zones are so that they can avoid those areas or where are located important places of the city like police stations.

This application provides a vast amount of information on POIs, including:

- Danger zones locations;
- Helpful locale locations;
- Level of the danger zone (minor, median, major);
- Type of the helpful locale (police station, embassy, refugee camp, hospital, etc.);
- Photos of the location;
- Quick description.

As described earlier, WeDoCare is a mobile app that detects violent attacks, through a scream detector, and warns nearby citizens that someone is in danger. It uses machine learning and signal processing algorithms to infer emergency situations by processing data from the smartphones microphone. The application can use the Internet to transmit alarms but, if no network is available, an alternative beacon system can also be used. Since the user/immigrant is new to the city the application shows on the map areas where crime is more accentuated through intensity heatmaps. Thus, migrants are able to avoid these sites and, at the same time, discover essential locales such as hospitals and police stations, establishing and locating themselves in the new city.

The scream recognition feature can help protect users from acts of great violence or even sexual abuse by xenophobic citizens or transgressors. When under attack, the victim can scream and move abruptly, which will trigger the transmission of an alarm signal to other app users nearby to ask for help. Additionally, when a person helps another, the app creates a connection, this is, the app "senses" that a possible helper is nearby and if so it asks the user if he wants to trade numbers with that person, a bond is then made with the two individuals in question.

In conclusion, we expect the application to help immigrants integrate more easily and make good friends thus decreasing their time of adaptation.

With the development of this work, as well as the case of HappySpeak, WeDoCare has become a tool that monitors the emotional state of the user, and intervening in a way which improves the users' welfare. This is possible because scream features normally represent scenarios of fear or nervousness. However, this application serves more to improve the safety of the individual and make him feel safe.

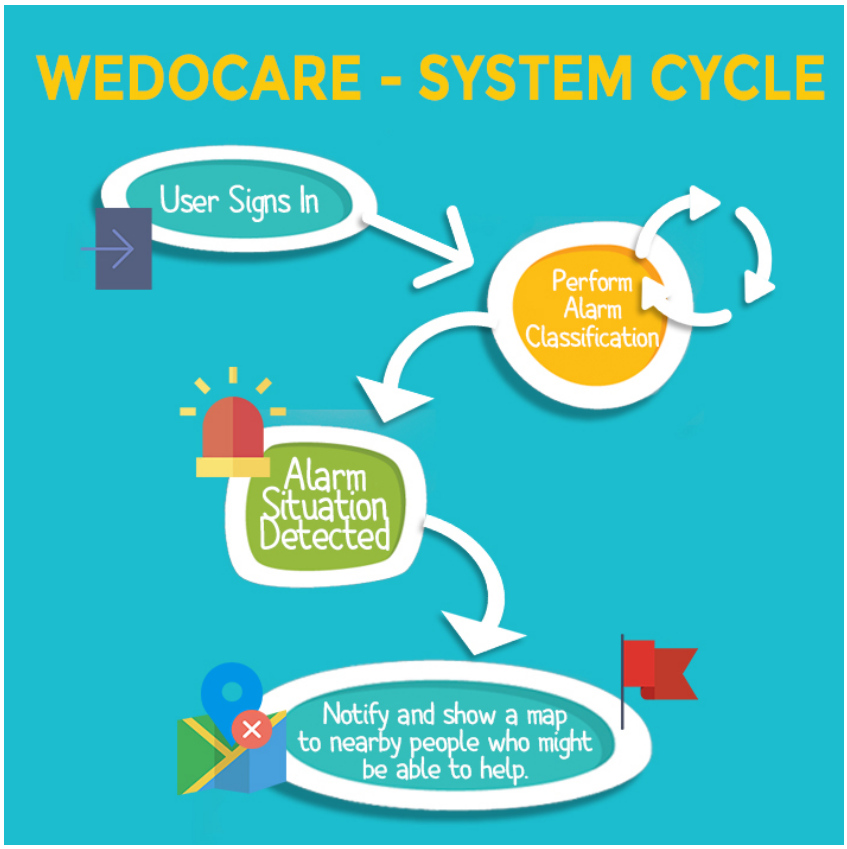

Fig 18 - WeDoCare system's cycle.

The figure above represents the loop mechanism proposed and implemented in this work. The purpose of this application is to influence the path we take when walking through a city and to recognize when we are in the presence of danger. In this mechanism, the screams of human beings are inferred periodically. Depending on the result that the scream recognition system obtain the application warns nearby users to help the user that is in danger. The goal is to stimulate mutual aid of the population.

To implement all the feature present in the app, the application uses a main thread and a service:

- In the main thread we implement activities responsible for presenting the information to the user and react to interactions;

- One of the background service collects information from sensors (microphone), infers scream and exchanges data with the server;

User interface is described in more detail in the next section and the scream recognition system is explained in section 4.2.1.2.

4.2.1.1. User Interface

Our application has a very simple interface so that the user can be easily guided. The application contains a navigation drawer, letting the user navigate throughout the app. On the map menu, the user is able to see various pins pointing to helpful locales or danger zones.

Danger zones are represented with a red marker and they have a certain transparency rate depending on the danger that location has received. In other words, danger zones with a high level of danger are more opaque while danger zones with a low level of danger are more transparent. This helps the user to identify different types of danger zones easily. The user can choose to use heatmaps for intensity representation and visual comfort. On the opposite side, we have blue markers which represent helpful locales such as hospitals or police stations, helping the users situate and establish themselves in a new city. Each map pin has a description associated with it. Any user can add a danger zone or a helpful locale, but this is restricted to three additions a day to prevent spamming or false additions to the map. If a user is abusing the system, he is automatically added to a blacklist and prevented from adding pins during a certain amount of time.

When the user enters or passes by a danger zone, the application emits a notification warning that he could be in danger. It then suggests the user to take a

different route. With these feature users can stay safe and avoid areas were crime and assaults are more common.

The user can, at any time, activate the beacon system to begin listening for other users in danger.

For the design of this application we used Material Design. Created and designed by Google, Material Design is a design language that combines the classical principles of successful projects together with innovation and technology. The goal of Google is to develop a design system that allows to unify the user experience on all of its products on any platform.

The main goal of Material Design is to create a visual language that synthesizes classic principles of good design with the innovation in technology. Material Design allows developers to design a single underlying system that allows for a unified experience across platforms and device sizes [48].

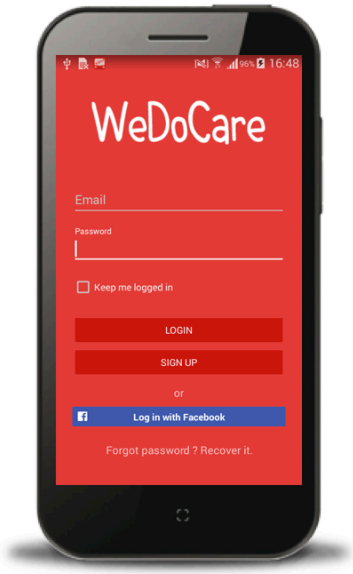

Fig 19 - WeDoCare's login screen.

The login screen includes text fields where the users can insert their e-mail and password. Touching a text field places the cursor and displays the keyboard. The type of text field determines what kind of characters are allowed inside the field. Common input types include: text, passwords, number or mixed format (emails). Password input is disguised by default. When the user engages with the text input field, the floating inline labels move to float above the field.

The login screen has three buttons. Two of them are used to login (through Facebook or through our own login system). The third button takes the user to the registration screen. These buttons, based on the Material Design guidelines, trigger an ink reaction and lifts on press. Raised buttons, such as the ones we use, add dimension to mostly flat layouts. They emphasize functions on busy or wide spaces. Raised buttons behave like a piece of material resting on another sheet – they lift and fill with color on press.

This screen also has a checkbox where the user can toggle the “keep me logged in” feature. This feature makes the user not have to go through the login process the next time he uses the application.

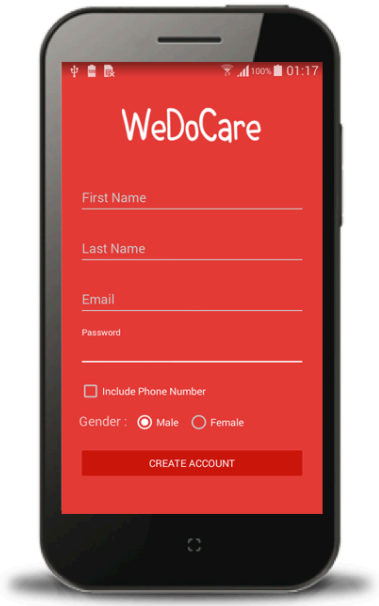

Fig 20 - WeDoCare's registration screen.

The registration screen has various text fields, a checkbox and two radio buttons for the input of information required for registration. Radio buttons allow the selection of a single option from a set. The use of radio buttons allows the user to see all available options side-by-side. The text fields are used to insert: first name, last name, email and password. The checkbox is used to optionally cause his phone number to be seen by other users if he see's fit and finally the two radio buttons are used for gender selection.

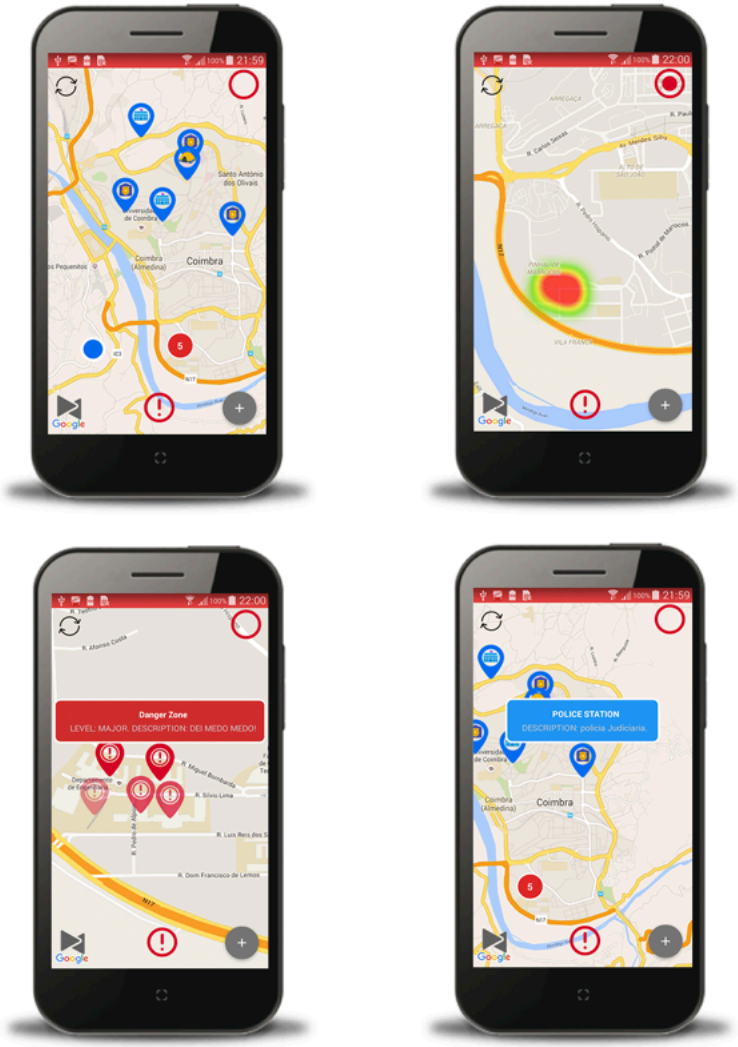

Fig 21 - Various screenshots of the WeDoCare's map screen.

The map screen is where the POIs and the user's current position are shown. A blue sphere represents the current location of the user. A red flag represents a user ongoing attacks in the vicinity. POI's are represented by all other pins drawn on the map, namely red markers which represent danger zones and blue markers which represent helpful locales. The map contains four buttons. (described from the top left to bottom right):

- Refresh button: refreshes the Points of Interest in the map.
- Toggle Danger Zones: Shows or hides danger zone heat maps.
- Activate Communications: Activates the hardware required to communicate with other devices through the beacon system.
- Emergency button: Notifies all people around the user about an attack.
- Add POI: Is used to add a point of interest to the map. This button is a Floating Action Button. A floating action button is used for a promoted action. Shaped like a circled icon floating above the UI, it has an ink wash upon focus and lifts upon selection. When pressed, it expands onto the screen and contains more related actions. These actions take the user to other menus where the user can add a danger zone or helpful locale.

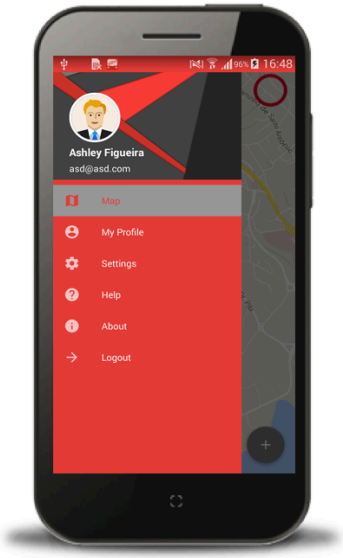

Fig 22 - WeDoCare's navigation drawer screen.

The navigation drawer slides in from the left and contains the navigation destinations for the app. This is, the navigation drawer is used to allow the user to navigate through

different screens. These screens are: the map, profile, applications settings, help and about screens. The navigation drawer spans the height of the screen, with everything behind it visible but darkened by a scrim. The navigation drawer also includes a logout button.

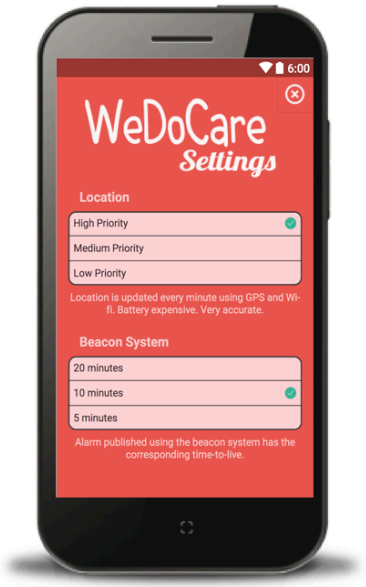

Fig 23 - WeDoCare's settings screen.

The settings screen is where the user can change the background behavior of the application. These include a section for location and section for the beacon system. The location settings allow the user to have control on the frequency at which the user's position is request, this has great impact on battery consumption as we'll see in chapter 5. The beacon section is where the user can change the time-to-live of beacon alarms.

The help screen has information about the use of the application and the about screen has general information on the development of this application.

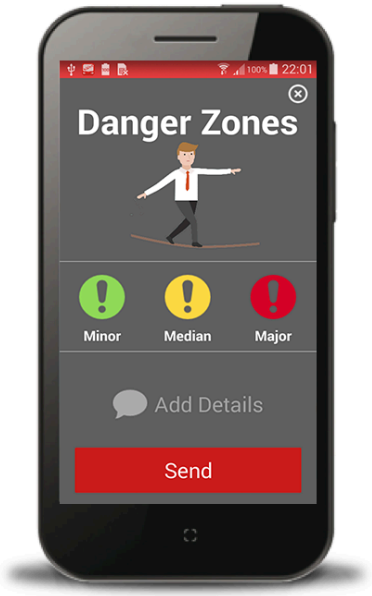

Fig 24 - WeDoCare's danger zone screen.

The Danger Zone screen is where the user can add a danger zone. This has three radio buttons where the user can choose the danger zones level of danger. This is represented as: minor, median and major. The user can add more information on the danger zone.

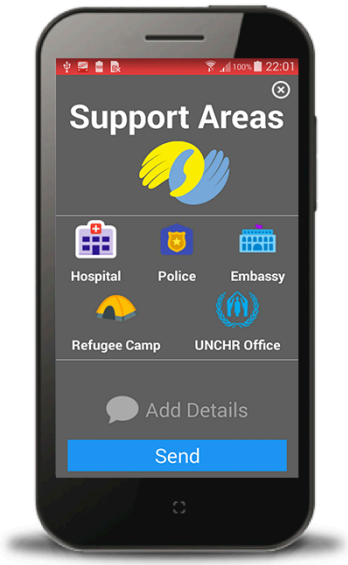

Fig 25 - WeDoCare helpful locale screen.

The Helpful locale screen is where the user can add a helpful locale. There are various types of helpful locales available right know on the application, this is: UNCHR offices, hospitals, police stations, embassies and refugee camps.

4.2.1.2. Scream Recognition Module

Nowadays, surveillance for security purposes has become increasingly significant. Traditionally, surveillance is achieved by video cameras, in many buildings corners, recording our every move. However, cameras aren't available everywhere, it is much more difficult to process video 24 hours a day than audio, and smartphones are always present making audio the leading alternative.

It is not a surprise that sound event detection like screams has attracted more attention from the research community, primarily because of the impact this may have in the security of the community. Herein we present the implementation of our scream recognition system implemented in the WeDoCare application.

The first step in our automatic scream recognition system is to extract features, i.e. identify the components of the audio signal that are of interest and filter out everything else, such as talking, crying, glass breaking or background noise. After the features are extracted these are sent to a classification system where it is decided if the audio signal streamed into our application was a scream or a non-scream. No filters were applied before feature extracting; this is because, nowadays background noise reduction is found in nearly every microphone built-in to the smartphone, which give us the ability to conduct conversations clearly.

Most of the sound energy from human speech is contained in the 5Hz-4kHz range [49]. For our purposes, we don't need elevated sampling rates and since our application processes audio in real-time we set the sample rate at 11025Hz, which is greater than

twice the highest frequency that humans can produce. This follows the Nyquist–Shannon sampling theorem [50], which says that the sampling frequency of a signal, that can subsequently be reconstituted with minimal information loss, should be greater than or equal to twice the bandwidth of the signal.

In this scream recognition system, we use an architecture that chains operations in a flexible processing pipeline, shown in Figure 24. We have only one single channel audio, streaming from the microphone, which keeps the processing pipeline straightforward and simple, contributing to the performance of the application (complicating the process pipeline could cause the application to lag). The dispatcher chops the incoming audio in blocks of 1024 samples with an overlap of 512 samples, which corresponds to 50% of the total block size, which is a common approach [51]. The dispatcher then sends the block of audio through a series of audio processing algorithms. In the processing section, sound analysis is made and features of the audio signal are extracted. Features are then exported in the output section of the processing pipeline.

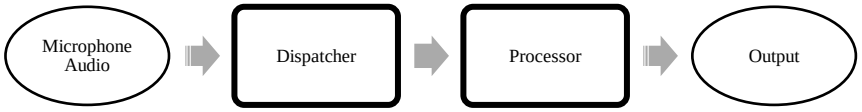

Fig 26 - A schematic representation of the processing pipeline.

As stated earlier, operations on sound were done in blocks of 1024 samples with a sample rate of 11kHz, meaning that each operation is done on a block of 1024/11kHz = 92,88ms. This block size provides a practical trade-off between computational performance, update speed and usability. In fact, a block size of 1024 is common for most standard operations, like filtering or calculating the Fast Fourier Transform (FFT) of a signal [51]. Operations on individual samples are not effective nor can they be

applied in real-world scenarios; e.g. to estimate the frequency of a signal we need at least a complete period of that signal and consequently more than one sample. Larger block sizes might add a too large delay; smaller ones might not provide enough audio-information for the wanted operation and so choosing the best block size is essential for audio and signal processing.

To represent the property of scream, 4 features that thought essential were studied. One of the features studied was the sound power level, which is a logarithmic measure of the power of a sound. The sound power level is measured in dBSWL. But, as stated in [52], extracting only this feature for any kind of audio recognition is insufficient and unreliable by itself. This is because the signal drops with the increase in distance between the source of the sound and the smartphone's microphone. Although, as stated in [45], with this feature it is possible to distinguish scream from many non-scream sounds since screams have a relative high-energy when compared to other sounds like normal speech. However, when comparing sounds with the same level of energy, this feature is less effective. The log energy of our block of audio or buffer, b, of length, n, is computed as:

$$P = 10log_{10}\frac{\sqrt{\sum_{i=0}^{n} b[i]^2}}{n}$$

Since they are very similar we also computed the sound pressure level which is a logarithmic measure of the effective pressure of a sound. It is measured in dBSPL and defined by:

$$p = 20log_{10}\frac{\sqrt{\sum_{i=0}^{n} b[i]^2}}{n}$$

Another feature extracted from our processing block is sound pitch. A pitch detection algorithm using the YIN method [53], in the frequency domain, is added to the processing chain. The YIN method is based upon autocorrelation. Usually, sound pitch is higher in a scream sound than other sounds; but screams are not all the same. There are screams with different frequencies, some are higher, and others are lower. By analyzing the scream sound, we saw that screams usually fall into the 300-2200Hz range. Girls tend to scream more acutely, between 1000Hz and 2200Hz, while boys fall more into the 300Hz-800Hz range. However, screams are generally higher than 300Hz.

Although it removes most of the background noise and other low frequency sounds, the detection of high pitch and high energy features is still not enough to detect screams accurately. Many false alarms can be reported for sounds with similar features. To increase the accuracy of our system, we need to introduce new features which better characterize the block of sound which is being processed. The Mel Frequency Cepstral Coefficients (MFCCs) are commonly used in speech recognition. In the early 2000s, the European Telecommunications Standards Institute defined a standardized MFCC algorithm to be used in mobile phones[54]. When comparing the audio streams of a non-scream to a scream, we can observe that the MFCCs vary quite differently. By default, we calculated 13 cepstrum coefficients, the amount of mel filters used in the filter bank was 26, and we applied a lower filter for the band edge of the mel filters with a frequency of 0Hz and an upper filter with half the frequency of the sample rate. These values are the default parameters for MFCC calculation and work fairly well for most cases [55]. To avoid extra computational burden on the processing pipeline we did not use the delta features.

Our application requires the features described earlier and processes it through a classifier. We opted for a SVM type classifier since this gave us better results and this classifier was used in several scream recognition studies such as in [56], [45] and [57]. Tests and results are discussed in the next chapter. Figure 25 gives an overview of the

scream recognition system. As said before, the audio coming from the microphone is sampled at 11kHz with a 1024-sample frame and an overlap of 50%.

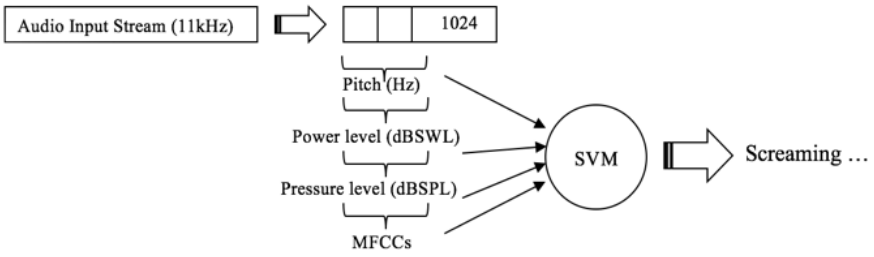

Fig 27 - Diagram of the scream classification system.

For the training phase we labelled scream and non-scream audio signals in a dataset. Figure 26 shows an example of the features labelled out.

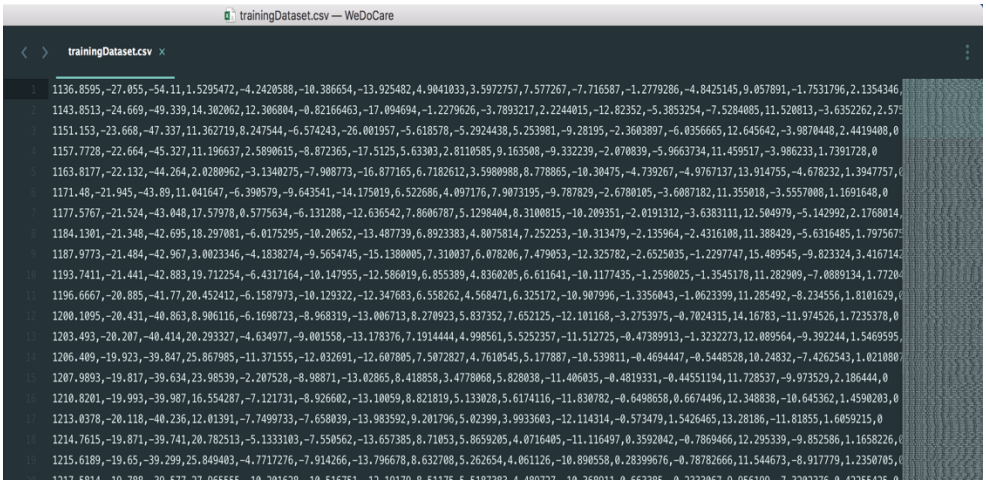

Fig 28 - Scream and non-scream dataset.

In emergency situations, people normally carry their smartphones in their pocket. We wanted to simulate this as accurate as possible; therefore, scream features were extracted by asking 40 volunteers to scream while the smartphone was recording in their pocket. Non-scream features were also recorded. This dataset was then used to train the SVM classifier.

4.2.1.3. Beacon Module

For this beacon system we use Google's Nearby API. This API relies on proximity features to create a real-time connection between nearby devices and shares information by transferring small binary payloads. It uses a combination of Bluetooth, Bluetooth Low Energy, Wi-Fi and near-ultrasonic audio to communicate between devices [58].

Google's Nearby API has two main packages: Nearby.Connections and Nearby.Messages.

Nearby.Connections allows the discovery of devices connected to be on the same Wi-Fi network using multicast packets sent over the access point. Nearby.Messages doesn't require devices to be on the same Wi-Fi network. Instead, it uses various ad hoc radio technologies to broadcast some random token others can listen to. It does, however, require both devices to have their screen awake. In this post, we'll only focus only on Nearby.Messages.

The Nearby.Messages works like a publish-subscribe pattern. The publish-subscribe pattern, in software arquitecture, is a messaging pattern where the message sender is called the publisher and the message receivers are called subscribers. However, the publishers do not send out message to specific receivers, but instead tag published messages without knowledge of which subscribers, if any, there may be. Similarly, subscribers express interest in messages with a specific tag name, without knowledge of the publishers there is.

Google recommends keeping the messages to less then 3kb. This service is not meant for exchanging larger objects such as photos and videos.

The first step on the Nearby.Messages, and for this we need internet connectivity, is to register a token to the Google Cloud. After the token is registered the user can start broadcasting a tagged message, and at the same time the other devices will get the message upon discovery. Note that both subscribers and publishers need to register a

token to the Google Cloud. In order, for the subscriber, to get the message, the Android phone has to subscribe to data tagged with the same tag as the publisher.
Here we provide more details on the "discovery" technologies that this API provides us with.

Audio – The message is broadcasted using the phone's speaker during 3 seconds interleaved by 1s of silence, and this repeatedly. Devices capture the ultrasonic sound through their microphone and process it to find out the sent message. Audio range is limited to a few meters and any wall would block sound.

Wi-Fi – The smartphone sends the list of Wi-Fi addresses around it (as Google does already in the background to improve their location services). If there is a match when reporting to the Google cloud, that is both devices are connected to the same Wi-Fi access point or see the same set of Wi-Fi, the Google cloud considers both devices to be nearby.

Bluetooth and Low Energy Bluetooth – To discover devices around, the smartphone scans for BLE peripherals.

4.2.2 WebServices

As mentioned in section 3.1.3, we implemented various methods in the REST server following the structure that already existed and explained earlier. These methods are used to receive:

- information from the scream recognition module;
- information on the user;
- information on the danger zone;
- information on the helpful locale.

In addition to this, we also implemented methods to spread this same information to various mobile devices that have the WeDoCare application. The information sent to the user includes:

- information about a user in danger;
- all danger zones available in the area;
- all helpful locales available in the area.

4.2.3 Database

In the figure below we represent the entity-relationship diagram of the database for this application.

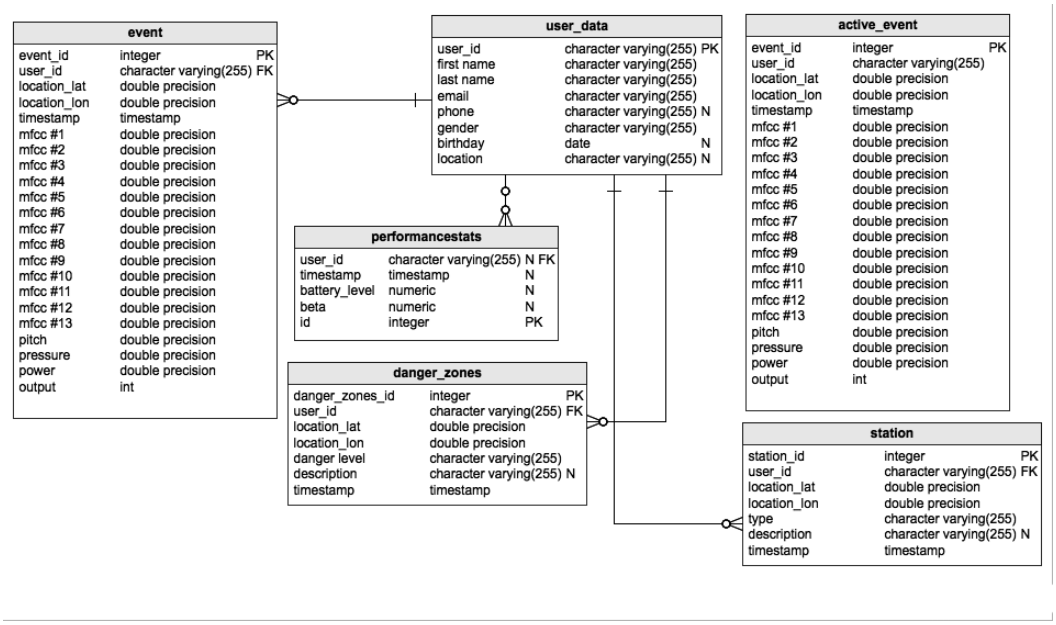

Fig 29 - WeDoCare Database Diagram.

In the above diagram we can see the fields associated with a scream. These are the values sent to the classification system, that is, the processed values from the microphone (sensor):

- 13 mel frequency cepstrum coefficients;
- sound pitch processed value from the microphone;
- sound pressure processed value from the microphone;
- sound power processed value from the microphone;
- timestamp of the scream;

- location of the user when the scream happened;
- output of the classification system.

In the same figure it is also possible to observe the values of a danger zone:

- danger level;
- description of the danger zone;
- location of the danger zone;
- time the danger zone was added;

Another table represented in the diagram above is the station's table, which has the following characteristics:

- description of the helpful locale;
- type of the helpful locale;
- location of the helpful locale;
- time the helpful locale was added;

As stated earlier, information about the user when registration is also saved in our database. This information contains:

- E-mail;
- Phone number;
- First name;
- Last name;
- Gender;
- Birthday;
- Location.

In addition to the four tables described above we also have two other tables. One was built to help us during the testing phase and the other table ("active events table") represents events but in real time, this is, screams freshly detected. This active event table is were the pooler actuates. The pooler checks if this table has any entry and if so

it sends notification to all other users that a person is currently in danger. The table used for testing was used to save important values which were analyzed later on. These values and tests are described in more detail in chapter 5.

4.2.4 Website

WeDoCare was selected from over 1,000 applicants from 36 countries as a semi-finalist in the 2016 edition of the European Social Innovation Competition. Organized since 2012 in memory of Portuguese politician and social innovator Diogo Vasconcelos, the European Social Innovation Competition gives a platform to social innovators across Europe, helping ideas to turn into impactful and sustainable projects.

The competition seeks creative approaches that help realize the potential of refugees and migrants, enabling them to contribute to the social, economic, cultural and political life of their host countries. Along with 29 other semi-finalists, WeDoCare was invited to the social innovation mentoring academy to progress their ideas with tailored support and workshop sessions.

For this competition we had to develop a website describing our application. This website contains information on the developed application, some screenshots, a contact section so anybody can e-mail the responsible for the application to ask for the code of the project for academic purposes for example. This website was developed using the traditional tools for web development, that is, HTML, CSS and JavaScript. We also used various libraries to make the development process easier. Libraries used were: Bootstrap, jQuery, wOw.js, owl carousel, animate and font-awesome.

Bootstrap is a sleek, intuitive, and powerful front-end framework for faster, responsive, mobile-first and easier web development, created by Mark Otto and Jacob Thornton, and maintained by the core team with the massive support and involvement of the community [59].

jQuery is a lightweight, "write less, do more", JavaScript library. The purpose of jQuery is to make it much easier to use JavaScript on web development by wrapping common tasks into methods that you can call with a single line of code [60].

wOw.js is a library that reveals animations when the visitor scrolls down the page. With wOw.js we can easily customize animation settings such as: style, delay, length, offset and iterations [61].

Owl Carousel is a jQuery plugin that lets us create a simple, responsive and beautiful carousel for images or text [62].

animate.css is a library which allows us to perform animations on HTML elements in a simple and easy to use way [63].

Font Awesome gives us scalable vector icons that can instantly be customized — size, color, drop shadow, and anything that can be done with the power of CSS [64].

This website resulted in a functional and appealing website with a well-defined objective. The structure of the page is based on HTML5 and is easily adaptable to include different contents (for example, text, photo, video). It has a well defined style using CSS3 and includes some dynamic and interactive elements produced through JavaScript or through external libraries. We focused on quality, organization and validity of code, visual coherence, interactivity, usability and responsiveness.

The final HTML5 code was validated in https://validator.w3.org. This validator checks the markup validity of web documents. The validator gave us some errors which were then corrected.

We concluded the development of this website with a form in PHP for sending e-mail and added email validation. We also established which fields are required.

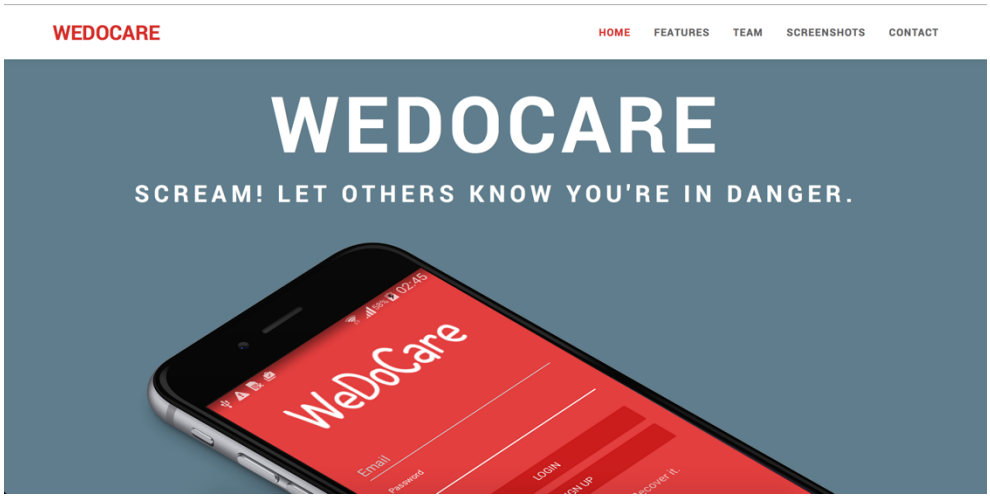

Fig 30 - WeDoCare's website screenshot.

5 Chapter
Tests and Results

5.1 Battery Life Tests

Every now and then a new smartphone is released to the market with new sensors, more powerful processing capabilities and added functionalities. But battery technology and smartphone technology are at two very different stages in their lifespans. Unlike smartphones, battery technology used in smartphones has been the same in the last two decades, and is much further down the development curve, meaning that improvements in battery technology, while steady, no longer happen at the breakneck speed of younger technology like smartphones.

Major power drain relates to increasingly complex apps, which demands elevated processing requirements. Most applications use Bluetooth, Wi-Fi and GPS and in many instances these components operate simultaneously. The GPS in particular is a notorious battery killer. As a result, it is important to manage the app's power consumption by correctly implementing background processes, such as GPS, and figuring out the best parameters to improve battery life.

Throughout all tests done to the HappySpeak app we used a Huawei ascend Y 201 Pro, which comes with a Cortex A-5 single core Processor (clocking at 800 MHz) with Android 4.0.3 [65]. Its approximate battery life is 130 hours (this value was obtained with the smartphone on standby). This value will be used as a reference throughout the analysis of our results.

For the WeDoCare app we used a mid-range smartphone, the Samsung Galaxy S4 Mini. Internally, the S4 Mini features a dual-core 1.7 GHz Snapdragon 400 processor

with 1.5 GB of RAM, 8 GB of expandable storage, and a 4.27 inch qHD (540 x 960 pixel) Super AMOLED screen with Android KitKat 4.4.2 [66]. Its approximate idle battery life is approximately 220 hours in full standby mode and as before this value will be used as a reference throughout the analysis of our performance test results.

It is important to note that for this test suite we stopped all background services and apps to ensure that the app being tested and Google Play Services were the only elements running in the smartphone.

The operational environment of the tests was also taken into account: all the performance tests were executed in the same place and using the same WI-FI access point, to avoid outliers in the results due to inconsistent Wi-Fi and GPS connections.

5.2 Neural Network Accuracy Tests

Machine learning is important because as models are exposed to new data, they are able to independently adapt. They learn from previous computations to produce reliable, repeatable decisions and results. It is a science that is not new – but one that is gaining fresh momentum.

Resurging interest in machine learning is due to the same factors that have made data mining and Bayesian analysis more popular than ever. Issues like growing volumes and varieties of available data, the fact that computational processing is cheaper and more powerful and the affordability of data storage are making machine learning more common and used in recent times.

All of these things mean it is possible to quickly and automatically produce models that can analyze bigger, more complex data and deliver faster, more accurate results. These results are predictions that can guide better decisions and smart actions in real time without human intervention. These results need to be tested, and that is what this section is about.

We analyze the accuracy of the machine learning algorithm implemented in the HappySpeak app in section 5.3.2 and the scream recognition system implemented in the WeDoCare app in section 5.4.1.

These tests allowed us to evaluate how the machine learning algorithm implemented in each app behaves and check how its accuracy progresses.

5.3 HappySpeak Results

In this section we will present all results related to the HappySPEAK system. This includes our battery and accuracy tests.

5.3.1 Battery Life Results

A feedback request consists of three steps: data collection, user feedback and network training. Data collection consists of getting the data from the sensors described in the previous chapter and inferring the user's mood. After that, a notification appears asking the user for feedback. HappySPEAK's feedback screen is a simple slider that goes from 0 to 100. We considered 0-50 as the user feeling not isolated and 51-100 the user feels isolated.

To measure battery consumption, we created two test types: one used GPS and Wi-Fi to discover the users' location, and the other only used Wi-Fi. We also considered four different time intervals to request user feedback: every one, two, three and four hours. From now on, we will refer to this time interval as β.

Instead of doing the tests manually, we added some code to automate this particular test suite: when a feedback request is received, the screen turns on, random values picked as feedback and the submit button is clicked automatically. Methods were also added to retrieve the current level of the battery before and after the feedback request and send it to a server for statistical analysis.

Some complications arose, the usage of GPS maintains a wake lock (a wake lock prevents the smartphone from entering a sleep state) on the smartphone's CPU in order to receive location updates. Wi-Fi location does not use this mechanism, and as such, the smartphone would enter a "sleep" state and never do the tasks required for power consumption analysis in the required time interval.

These complications were unknown to us at the time, and due to the nature of these tests, the debugging process was very slow. For each value of **β** we were required to wait long periods of time to check if the app would "wake up" and launch the feedback request. This debugging process continued for several weeks until the problem was identified and fixed.

This problem was solved by using a partial wake lock on the service, keeping the CPU awake so that the service could wake up when it should and collect data about the battery. A trade-off of this was a larger power consumption.

Unsatisfied with this trade-off, we decided to experiment with an Android mechanism called "Alarm Manager". This mechanism allows an app to run a block of code at a future time, even if the process that launched it is not active. This mechanism also uses a wake lock but only while it executes the registered block of code, releasing it as soon as the task is finished. This proved to be an excellent strategy, as it increased battery life by a large amount

Seen as this app does not use any sensors to detect if the user feels lonely, we only executed one test for $\beta = 1$. The results are presented in Figure 28.

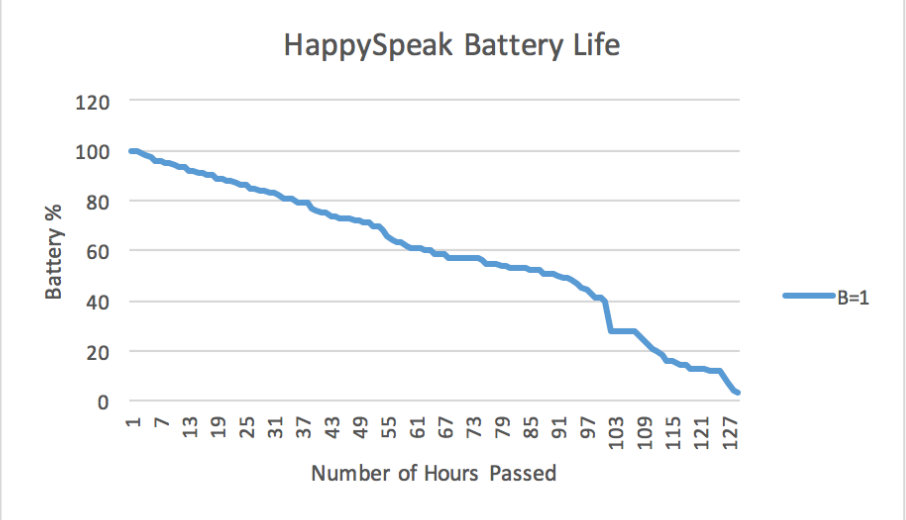

Fig 31 - HappySpeak's battery life with Alarm Manager.

The app was able to run for 127 hours, responding with automated feedback requests every hour. This is a very good result, seeing as the idle battery life of the phone is 130 hours, the battery percentage used is only 2,3%. This is a direct consequence of not using any sensors (the GPS was turned off in this test), and using only data retrieved from messaging and call logs.

5.3.2 Isolation Recognition Accuracy Results

To analyze the accuracy of the developed ANN we distributed the app by 10 people over the period of one week. Feedback requests would be launched every hour asking the user how lonely he felt. The users answered this question by using the slider in the Feedback Menu. This slider contains values between 0 and 100. We considered values between 51 and 100 to represent loneliness and any other values to represent the opposite.

It is important to note that the users did not respond to every single feedback request; many of these were ignored. Also, many of the users did not have enough

feedback responses to be considered for our results. As such we only considered users that had 10 or more feedback responses.

Accuracy was calculated using the following formula:

$$Accuracy = 1 - |O - F|$$

O represents the output of the ANN for a set of inputs and **F** represents the feedback provided by the user, for that same set. The results of these tests can be consulted in Figure 29.

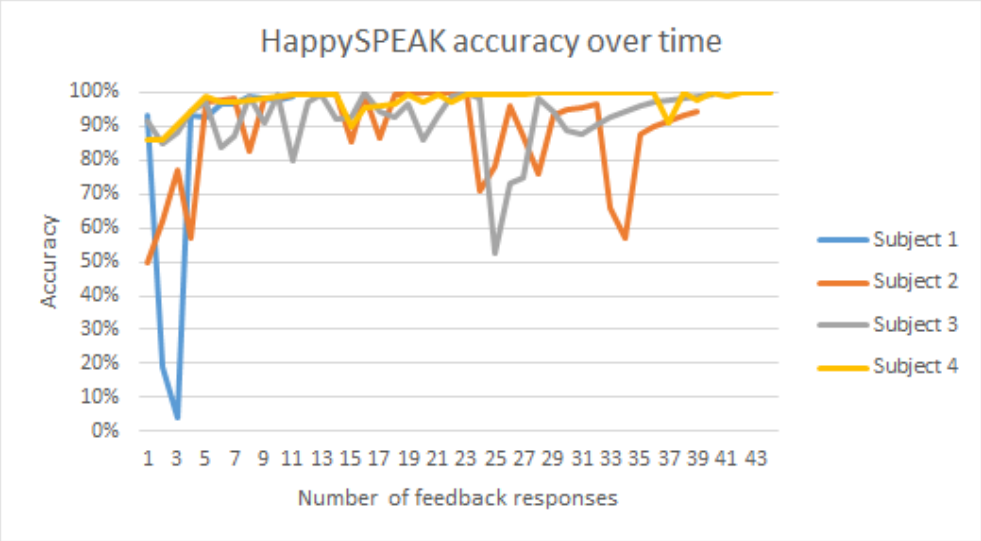

Fig 32 - HappySpeak accuracy test results.

Accuracy seems to be very high for all subjects; in the next table we can see the average accuracy for all feedback requests:

Subject	Average Accuracy
Subject 1	81%
Subject 2	92%
Subject 3	92%

Subject 4	98%

Table 4 - HappySpeaks average user accuracy.

Even though the results are very good (the ANN shows an average 90%+ accuracy for most users), the results are a bit misleading. If we observe the next figure, we can see where most of the feedback from the users was allocated:

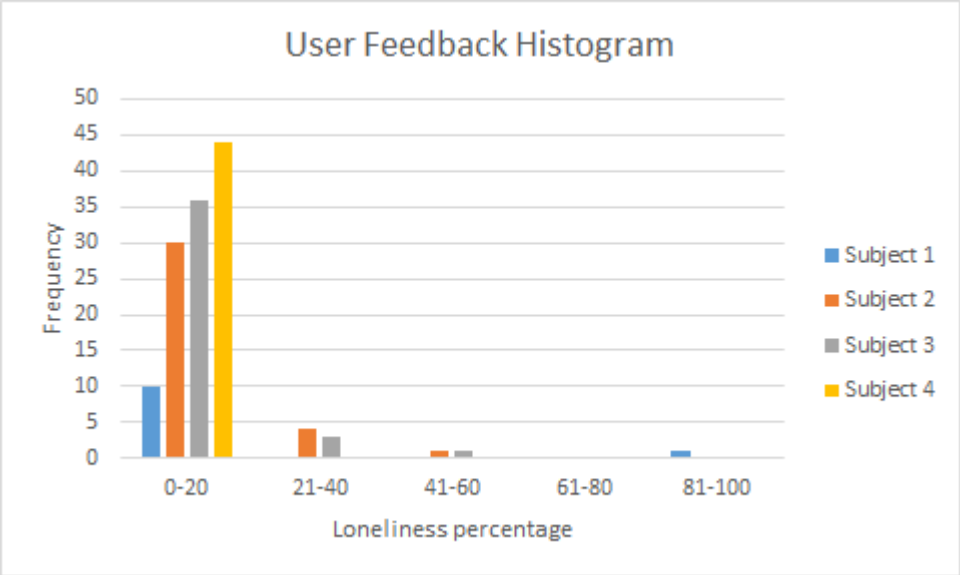

Fig 33 - HappySpeak user feedback histogram.

The histogram above shows that almost all of the feedback requests were used to describe that the user does not feel lonely (between 0 and 50%).

After analyzing these results, we come to a conclusion: the app needs users to give accurate feedback about how they are feeling in the full spectrum of our metrics. The only way for this to happen is for users to experience these emotions and give the appropriate feedback, which may take a long time.

5.4 WeDoCare Results

In this section we will present some results related to the WeDoCare system. This includes our battery and accuracy tests

5.4.1 Scream Recognition Accuracy Results

In the first phase and since we didn't know what to expect, we trained and tested our classification system with a dataset including normal day audio events such as, speech, buses and cars passing by, background noise, etc. Since these audio events are very different to scream events and the pitch of these audio events do not exceed 300Hz the classification system was always classifying (correctly) non-scream events. Therefore, and for performance purposes, the classification system (SVM) and MFCC calculations only run when the pitch detection exceeds a certain threshold. This threshold was empirically set to 300Hz which is the minimum, by analyzing the scream pitch values in the dataset. This also helps save battery since the classification system is an additional processing expense we can avoid. Regarding this, we trained and tested the classification system with sound events very similar to screams (pitch wise), such as, baby crying, sirens, whistles, glasses toasting, loud TV sounds, ringtones and dogs howling. We later saw that miss detections often occurred on single blocks of audio (92ms) which didn't make sense since screams are longer than that time. Screams usually fall in the 0.5 – 5s long range. For these reasons we only consider a scream if the classification system identifies correctly 5 consecutive audio blocks. This prevents the system from identifying a scream in a single block of audio, which is impossible. This temporal classification boosted up our accuracy results.

The performance of our classification system was measured by simply calculating the accuracy and error rate. In the testing phase we also attempted to know which approach was superior in detecting screams events. ANN and SVM are two popular

strategies for supervised machine learning and classification, although it is not often clear which method is better for a particular problem. ANNs have the benefit that their size is fixed: they are parametric models, while SVMs are non-parametric. By contrast, an SVM consists of a set of support vectors, selected from the training set, with a weight for each. SVMs are easier to use than ANNs, although ANNs can be a quite faster.

The effectiveness of a SVM depends on the selection of kernel and the penalty factor, C, and gamma, γ. As such we present and compare various results obtained by varying the kernel type of the SVM and the configuration of the ANN. For these tests we used a dataset with some of the screams used for training and we introduced two new screams. We did the same for the rest of acquired sounds, - sirens, babies crying, etc.

For the SVMs, the kernel types tested were linear, sigmoid, polynomial and radial basis function (RBF). For determining the penalty parameter of the error, C, and gamma, γ, we conducted a "grid-search" using cross-validation and exponentially growing sequences of C and γ, as suggested in [67]. For the Linear-RBF the best C and γ were 0.5 and 0.125, respectively. For the Sigmoid-SVM no optimal C and γ values were found, all of them gave similar results. For the Poly-RBF and the RBF-SVM the best γ were the same: 1.0E-4. As for the penalty factor, for the RBF-SVM the best C was 32 and for the Poly-SVM the best C was 8. Table 1 shows the accuracy and the error rate of scream event classification using the various kernel types. As we can see from Table 1, Sigmoid-RBF does badly on classifying our problem. Linear-SVM performs acceptably but is well surpassed by the Poly-SVM and RBF-SVM. Note that the Poly-SVM and the RBF-SVM give the same accuracy but the RBF-SVM gives lesser error rate.

Kernel Type	Linear	Sigmoid	Polynomial	RBF
Accuracy	89.08%	56.94%	98.41%	98.61%
Error Rate	5.84%	42.28%	6.8%	2.88%

Table 5 - Scream recognition results using various SVM kernel types.

Furthermore, and since we obtained better results with the RBF-SVM, we compared this configuration with an ANN. When designing an artificial neural network, selecting the number of hidden neurons that provides minimal error and highest accuracy is challenging. Previous research has shown that selecting a high number of hidden neurons may cause overfitting; this is, the neural network has come up with an overly complex (and possibly incorrect) hypothesis. A good practice is to select a number of hidden neurons between the number of input neurons and the number of output neurons [68]. Thus, we decided to test various configurations (always using two hidden layers with a sigmoid activation function). In order to test the training effort of each one, we registered the number of epochs necessary to successfully train the network. Table 6 shows the results obtained with the various tested configurations.

Configuration	Accuracy	Error Rate	Epochs
16-10-10-1	90.27%	5.99%	169
16-10-8-1	89.88%	5.94%	93
16-8-8-1	95.03%	5.99%	213
16-8-5-1	91.46%	5.89%	174
16-5-5-1	91.86%	5.98%	178

Table 6 - Scream recognition results using various ANN configurations

The results show that the configuration with 8 hidden neurons in the first and second layer has the best accuracy. In the other hand the configuration that has least effort training the dataset was the configuration with 10 hidden neurons on the first layer and

8 hidden neurons on the second layer. However, the number of epochs from this configuration isn't to far apart from the number of epochs from the best configuration. Comparing the artificial neural network to the RBF-SVM, table 7, we can see that the RBF-SVM offers better results.

	Accuracy	**Error Rate**	**Epochs**
RBF-SVM	98.61%	2.88%	1
ANN (16-8-8-1)	95.03%	5.99%	312

Table 7 - Comparison between SVM and ANN on scream recognition.

Although the RBF-SVM only needs one epoch to train, SVMs are more complex than the artificial neural network created here, therefore, the time it takes to train once is greater in the SVM than the ANN. We saw that the RBF-SVM took 18.169 seconds to train the dataset once while the ANN took 13.158 seconds to train the dataset 312 times, that is, each epoch done by the RBF-SVM takes longer than 300 epochs done by the ANN. We can, in advance, conclude that SVMs are in fact more expensive at the CPU level since it takes more time to process the dataset. Although, SVMs take more time training the dataset than ANNs, we can train the network previously on any machine and dump the weights on the mobile device, thus, avoiding the necessity to train the network on the mobile device. This being said SVMs can be properly used in mobile devices, since it has a greater accuracy and the time it takes to compute a new entry is milimesimal.

5.4.2 Battery Life Results

One of the things we wanted to discover, in this particular app, was the relation between the smartphones battery life and the time interval between sensor readings, β, taking into account that there must be a balance. If the interval β is high, there will be less probability of catching an attack but less battery drainage; on the other hand if β is

small, it is more likely for the app to detect alarm event, but we suspect that the battery drainage will be more substantial. To better understand this, we recorded the battery's percentage value over time for different β intervals. Note that we do not take into account the classification system and MFCC calculations for battery tests since these algorithms only run when pitch is higher than 300Hz, as stated earlier.

Location awareness is one of the features of our application, achieved through the Google Play Services Location APIs. Using this API, it is possible to set the priority of the location request of the app and the rate (interval in milliseconds) at which this request is made.

There are three possible variants for the priority: *PRIORITY_LOW_POWER*, *PRIORITY_HIGH_ACCURACY* and *PRIORITY_BALANCED_POWER_ACCURACY*.

- *PRIORITY_LOW_POWER* – This setting has an accuracy of approximately 10 kilometers. We considered this level of accuracy to be too coarse and, thus, discarded this setting.
- *PRIORITY_BALANCED_POWER_ACCURACY* – This setting has an accuracy of approximately 50 meters and is likely to consume less power. With this setting, the location services use Wi-Fi and cell tower positioning.
- *PRIORITY_HIGH_ACCURACY* – This setting has the most precise location possible, with an accuracy of about a few feet. This setting uses GPS to determine location.

Since location has a great impact on the battery's life and we need the location provider to be somewhat accurate, we created two test suits, one using the *PRIORITY_BALANCED_POWER_ACCURACY* setting and the other using the *PRIORITY_HIGH_ACCURACY* setting. We also considered three different location update intervals which we'll later talk about.

In terms of testing different time intervals (at which the sensor data is read and processed), we considered three different values: five minutes, one minute and thirty seconds. Since scream recognition tasks are in real-time (our application needs to be aware at all times), the interval at which we pull sensor values must be as minimal as possible for better results and accuracy and less miscarries on detecting screams. To automate this process, we added methods to retrieve the battery's current level at the specific rate (1 hour) and send it to a server for statistical analysis.

In this first test we set the location priority to *PRIORITY_BALANCED_POWER_ACCURACY* and the interval at which we requested the user's location was 1 minute. The results, shown in Figure 31, were quite surprising. The test shows that battery drainage pattern is very close for the various intervals, indicating the interval of sensor reading does not have considerable impact in battery drainage. In the future we'll implement a more complex algorithm which might spend more battery since it will need more computational power.

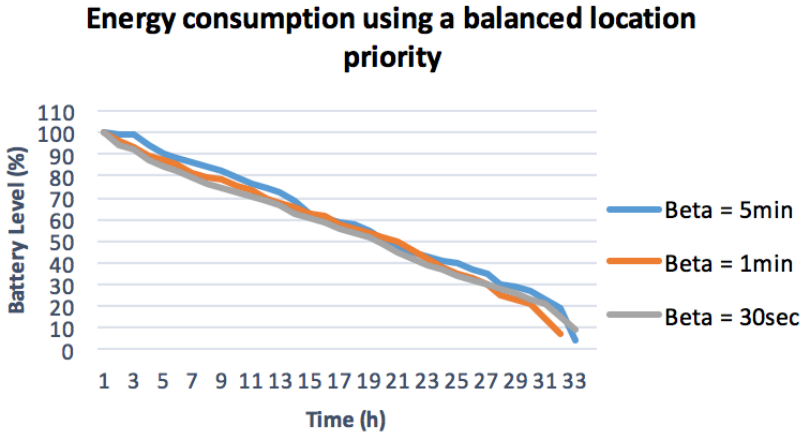

Fig 34 - Energy consumption experiments using different sensor reading intervals.

There was a shortening in battery life by 84,5% (note that this percentage is relative to the duration time when smartphone is untouched and in standby) which lets us conclude

that, in fact, there is a great amount of battery drainage when using the smartphones sensors. However, the battery drainage is not too different when comparing different sensor reading intervals.

These results tell us that the time interval for which we read sensor values is not relevant to improve the smartphone's battery life. Nevertheless, the correct usage of GPS/Wi-Fi for discovery location might be. We further validated this hypothesis in a second series of tests.

As shown in Figure 32, setting the priority to *PRIORITY_HIGH_ACCURACY* while keeping the location update interval at 1 minute, it resulted in a reduction of battery life by 93,2%, which is a difference of 8.7% compared to the previous setting. However, since our app must be as accurate as possible, this may actually be a better solution for our use-case. Furthermore, we focus on determining an interval at which location updates should be requested to improve battery life.

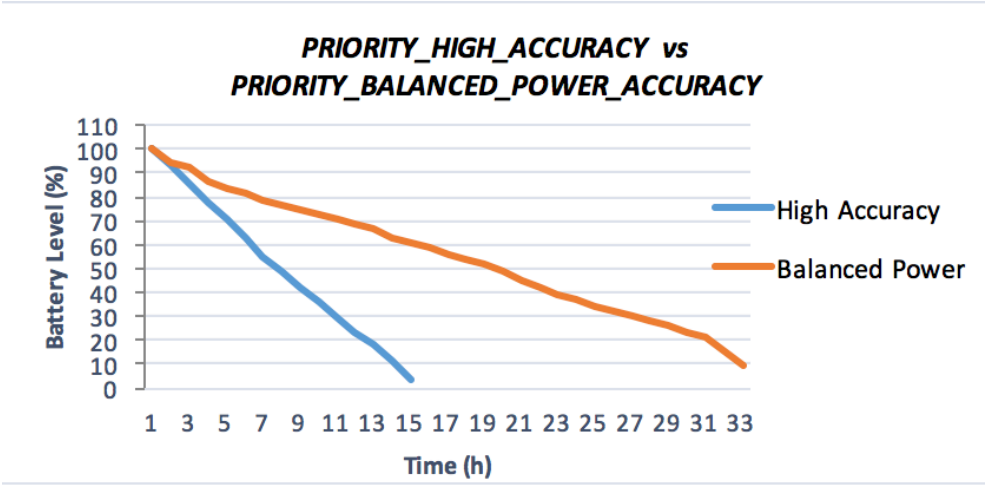

Fig 35 - Energy consumption experiments using different priorities on location.

By keeping the priority set to PRIORITY_HIGH_ACCURACY but changing the interval at which location updates are requested to five or ten minutes, we can see that

the battery drainage can be drastically improved to levels closer to the ones achieved with *PRIORITY_BALANCED_POWER_ACCURACY*. This way, we can achieve great accuracy on the user's location with a battery drainage similar to the one of a less accurate mode. With these tests, we can now find an interval for regularly updates on the users' locations that we find most convenient.

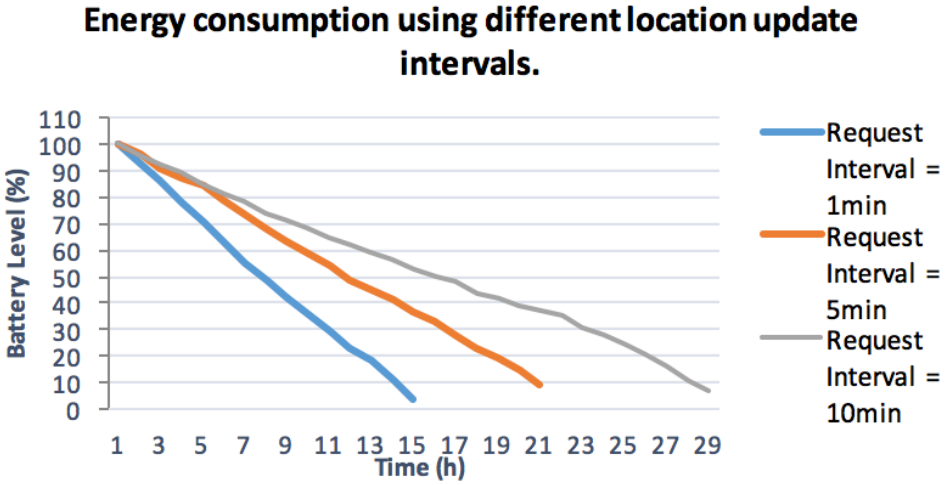

Fig 36 - Energy consumption experiments using different priorities on location.

We think that for emergency situations such as the ones considered in our application, it is important to be as accurate as possible. Therefore, a high priority for location should be used, since balanced ones may present considerable deviations in the individual's location, which may hamper the ability of other users finding the distressed person. It also is important to state that nowadays almost all smartphones have a battery life of one or two days on a normal use and so our results reveal that our approach may not impair smartphone usage significantly.

6 Chapter
Conclusions and Future Work

Throughout this work we addressed topics such as cyber-physical systems, HiLCPS, affective computing and behavior intervention mechanisms. Applications for mobile devices inspired in these themes are the result of a conjunction of values obtained through the smartphones sensors with processing mechanisms and machine learning techniques. The human being was always considered an integral part of the system.

In this work we proposed and evaluated two innovative HiTLCPS applications, HappySpeak and WeDoCare.

HappySpeak attempts to help refugees or immigrants integrate more easily in a new society/city by improving their social behavior. We performed various tests, namely neural network accuracy tests and battery life tests. These tests were done to see the classification rate of the application in detecting isolation and the battery the application spent while performing this classification. We obtained good results either for accuracy tests or for the battery tests. The results obtained by our tests also revealed that just having a lot of data of a user is not enough to accurately classify emotions; it is also necessary that the user experiences all the emotions in our spectrum in order to teach the ANN how to infer correctly an emotion, which leads us to conclude that the results obtained can not be trusted. For this application, we did not perform tests with different neural networks due to the lack of time. This resided for future work as well as the improvement of UI/UX. We also could have used more social data taken from Facebook for example, which would increase the accuracy of the system and we could have implemented a text mining feature which tries to understand how the user feels by

analyzing his sent messages. This application served much for me to enter the world of Android and the world of inference of human emotion or HiTL. I acquired knowledge about these two aspects in the first months of thesis due to the initial work done in this application which helped me developed a more concise and better second application - WeDoCare.

WeDoCare attempts to help solve issues in real-world world scenarios and in real-time through a completely described and implemented scream recognition system. We performed various tests to determine the best classification algorithm. More specifically, we studied various types of SVMs varying the type of kernel and also studied several ANNs configurations. We also made a comparison between these two machine learning techniques. We obtained good results with either techniques, however, further studies must be performed to determine which of the two take less computational resources. We also studied the impact of the frequency of the sensor readings on the smartphone's battery life. We found that the impact of the interval at which sensors were read can be disregarded in comparison to the amount of battery used by the location sensors. We also found that the distance covered by the beacon system, which uses Googles Nearby API, can cover up to 60 meters which is consistent with today's Bluetooth technology. To increase these values, we will, in the future, attach a multi-hop mechanism to this beacon system. Additional feature should also be added in future work; for example, the ability for the user to add a photo of a danger zone, a shake the mobile phone feature in case the user can't scream and implement an automatic call to emergency numbers.

This work had great importance in the student's academic and personal development. During the whole year, the student deepened his knowledge on the Android platform with the development of two applications that combines various frameworks, libraries and design patterns. Now, this is what the student wishes to pursue, a career in the Android development world. His passion for Android & UI/UX grew very fast with this project.

He also improved his knowledge in Web services by using the RESTful arquitecture in the development of the server and various theoretical concepts.

The biggest difficulty the student had during the development of this project was undoubtedly the fact of not knowing the Android frameworks. This led to time consuming moments during the development of certain tasks, since it was necessary to learn and read Google's official documentation. Another difficulty experienced in this project was the processing of raw data in Android which is more difficult than for example in MatLab. The development time for a person who knew nothing about Android was too little. I would've liked more time to improve both application, however the writing of articles, forms or the making of videos and digital content did not allow further app development. I also wished that design was a key point in the development of these applications, which never was. The applications developed have a lot of potential but without a cool design the apps don't have much success. Also, the student, would have loved to learn about automated testing tools on Android, such as Espresso, or specific development architectures such as TDD (Test-driven development) or BDD (behavior-driven development).

In the end, the main objectives for the projects were accomplished and the student believes that the extension of this project, as well as past difficulties, prepare me for the new stage of my life.

7 Chapter
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Appendices

Appendix A

Accepted Papers

WeDoCare: A Humanitarian People-centric Cyber-Physical System for the benefit of Refugees

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***Abstract*—Day-to-day gadgets, like smartphones, are becoming increasingly more intelligent and interconnected. In fact, the "Internet of Things" is being used to support many new types of cyber-physical systems (CPSs). These interconnected and intelligent devices use various sensors which can be used to monitor and evaluate human parameters, and improving the humans' life quality. In this work we present WeDoCare, an implementation of a Human-in-the-Loop Cyber-Physical System (HiTLCPS) that attempts to help solve issues in real-world scenarios. Having in mind the refugee crisis in Europe, WeDoCare aims to detect, in an automated way and in real-time, violent attacks against users through a scream detector, using the mobile phones sensors, in particular the microphone. This data is processed through a signal processing algorithm to infer emergency situations. When an emergency is detected, it warns nearby citizens that someone is in danger, allowing for crowd collaboration and altruism. The application also contains an innovative beacon system so that communication with nearby or surrounding people isn't limited by an Internet connection. Since it is necessary that our implementation lasts as much as possible, we performed some battery-level tests, to realize the involvement of some application parameters with the battery drainage. We also evaluated the range of the beacon system.**

Keywords—Human-in-the-Loop Cyber-Physical Systems; Smartphones; Monitoring; Scream recognition; Location-aware;

8 INTRODUCTION

8.1 Refuugee attack prevention and Technology

The European migrant crisis began in 2015, when a rising number of refugees and migrants made the journey to Europe to seek asylum and a better lifestyle.

According to the UNHCR, the number of forcibly displaced people worldwide reached 59.5 million at the end of 2014, the highest level since World War II with a 40% increase taking place since 2011 [1].

So far this year, more than 644,000 refugees and migrants have arrived in Europe by sea. Of these, just over a third – 34 per cent – are women and children who are particularly vulnerable to abuse as they transit Europe, especially in overcrowded reception sites, or in many locations where refugees and migrants gather, such as parks, train stations, bus stations and roadsides [1].

Refugee, migrant women and children travelling on their own are also at heightened risk as they move through Europe, sometimes at night, along insecure routes or staying in places that lack basic security [2]. This is a neglected problem and an effective solution has yet to be achieved.

Several applications have been created to solve this issue, although they have great limitations. The following paragraphs describe two interesting examples of applications in the safety area.

Safelet is a bracelet that lets you warn others that you are in danger [3]. This special piece of hardware contains a button that once triggered emits an alarm to the user's friends and family. The user's smartphone also begins recording. This is useful and at the same time interesting since it gives the ability to check later on what really happened in an emergency situation. This solution has a limitation which is the extra hardware the user has to acquire. The bracelet is only accessible for the most economically advantaged and it will hardly be acquired by people undergoing economic difficulties as in the case of refugees.

Another similar solution is **Athena** [4]. This solution is based on a round button that clips onto a persons belt and is dedicated to prevent physical assaults by emitting loud alarms whenever the button is clicked. In addition to this feature it also sends out text messages with the user's location to their designated emergency contacts. Although this solution is similar to the previous one, it has the advantage that can be used anywhere; that is, it can be hidden from the persecutor unlike Safelet, which is placed on the user's wrist and can be easily removed. However, much like the previous solution, its necessary to buy extra hardware which greatly limits the target audience. We want to provide technology-based solutions within most people's reach, therefore, we attempted to solve this issue using only the smartphone.

With the recent rise in machine learning on mobile phones, new applications that use the smartphones sensors to improve the quality of human life or to infer human activity are increasing. All mobile phones have a microphone; despite of being rarely seen as a sensor; this component permits us to obtain a lot of information. In fact, we can develop many applications using sound to obtain information about the environment (loud environments can be stressful or joyful, depending on the context) and the user. Through voice, a person can transmit moods or emotions. We can even use the microphone to detect screams or gunshots. Much research in the field of scream recognition or gunshot recognition has been made [5][6][7], however a simple and useful application has never been developed.

8.2 Smartphones and HiTLCPS

Mobile phones have become personal computers that serve as personal assistants helping us to be more effective in everyday tasks. These devices represent a versatile computational resource with great sensing capabilities. Nowadays mobile phones are present in every pocket even in underdeveloped countries where poverty is higher. Even the cheapest mobile phones have flexible sensors, such as the microphone. Used across the globe, they are capable of processing considerable amounts of information making the mobile phone a device with key characteristics and a powerful platform for creating context-aware personal systems that can be leveraged to develop applications with positive social impact. Their advanced capabilities also reduce the need for extra accessories and other devices. By only using smartphones our solution becomes more effective in a population living in a more debilitated economic situation since they do not have sufficient means to possess extra hardware besides the ones they already have.

For these reasons it is not surprising that many hours have been devoted to the research and development of mobile phone sensing applications [8].

Strictly speaking, sensing data which is then processed by machine learning or signal processing algorithms is attainable and can be used to attain some sort of information about the user [9]. As a matter of a fact, we are now witnessing a wide increase in smartphone-based systems as part of a larger group of human-aware systems. This is especially important due to the fact that the Internet-of-Things (IoT) is everywhere and increasing every day, in fact some studies estimate that human beings will have an "Internet of Things" with 26 billion connected devices by 2020 [10]. However, today's IoT is still focused mainly on isolated embedded systems with a specific engineering application in mind. This approach is only valid for target scenarios, presenting a constrained applicability and narrow approach. This state of things is merely the initial step towards a future where the vast majority of the IoT will be in reach of ordinary people. However, in order for this to happen, machines cannot remain simple machines. The applicability of these concepts must go beyond the simple sensing and automated communication between IoT elements, allowing us to know and control our environments in a powerful and intuitive way. That is, IoT systems should also integrate human nature and presence in their designs and architectures.

Humans become, thereby, an integral part of CPSs and we enter now in the realm of Human-in-the-loop Cyber-Physical Systems (HiLCPS), that is, cyber physical systems that take human interaction into consideration, making humans emotion and actions an intrinsic part of any computational system [11].

The necessary steps associated with HiTL control begin with data acquisition, this phase is where raw data is collected from the mobile phone and / or from external devices (sensing). The data is then processed in a state inference stage where human actions or emotions are identified. By using different features and sensors in conjunction or on their own it is possible to infer various states or emotions. Finally, in the actuation stage, the system may perform certain actions based on the currently identified context.

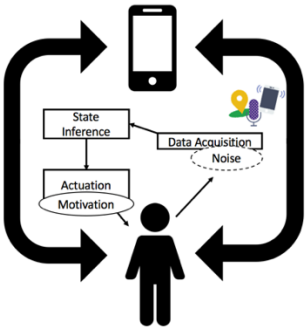

Fig 37 - HiTL Control Loop.

Any smartphone can be turned into a personal security device, allowing users to detect emergency situations around them 24 hours a day. However, there is a catch: because monitoring should be carried out continuously, the monitoring process will easily drain the smartphones battery if the detection algorithm and monitoring intervals aren't carefully designed to reduce power consumption.

It is important to acquire a slight balance between the smartphone's battery life and the application's background work. Safety-monitoring applications need to last as much as possible. Thus, within this work we intend to study the impact of sensor readings intervals with the following contributions:

- We present our own HiTL smartphone application: WeDoCare, a HiTLCPS that uses mobile sensors to detect emergency situations in real-time.
- We present studies that show how the frequency of sensor request and processing might affect the battery life, this includes studies in the location signals.

The rest of the article is organized as follows: section II presents our WeDoCare application; section III presents several studies regarding the smartphone's battery life, beacon system distance as well as some inquiries made to refugees about our app; finally, section IV discusses the results and concludes the paper.

9 WeDoCare App

With all the violence that has emerged in the world, we want to take actions and help save lives of innocent refugee, women and children, as well as provide them with a safe route to Europe. We want to prevent sexual abuse in the refugee camps, stop the violence that occurs in many country borders and increase security even in the most deprived locales. Our system doesn't not only apply to the refugee but can also prevent, for example, physical assaults in the many troubled neighbourhoods or prevent domestic violence. Our solution has great potential scalability, since it can be adapted to solve problems in other contexts, namely for elderly or dementia monitoring systems.

As such, we present WeDoCare, a HiTL application that uses the smartphone's sensors, in particular the microphone, to detect, in an automated way and in real-time, situations of violent attacks against users through a scream detector. The application sends out alarms to surrounding citizens, giving them a chance to help and collaborate by helping others stay safe – IoT being used for humanitarian purposes. The application also warns the user whenever he/she is passing within a zone where attacks occur more often, so that these sites can be avoided. This closes the human-in-the-loop, as the app actuates to prevent further danger, preserving the security of the individual.

9.1 Technical details and signal processing

As mentioned above, migrants and refugees cross remote places and often do not have the means for acquiring things other than those they already own. Taking this into consideration we are looking for a low cost but effective solution which avoids additional hardware, so limiting our choice of sensors to those already provided by the smartphone. We focused our application on scream detection (non-linguistic vocalization recognition) which is a dominant characteristic in emergency situations or attacks by processing data coming from the smartphone's microphone. Recognition tasks using information on language or discourse are well-considered by several studies for identifying human context but the automatic extraction of these related features are extremely difficult specially in real time scenarios like ours [12] [13]. We also use location information, using the smartphone's GPS. All these sensors, as stated earlier, are available straight off any cheap off-the-shelf mobile phone.

Our current prototype is currently being developed for Android smartphones, since this operating system is open sourced and one of the most used worldwide. This is important since we want to reach the maximum number of citizens as possible. However, in the future, we have plans to port our solution to other mobile operating systems. We also use Apache Tomcat 7 as a server which enables us to transmit and posteriorly save data so that we may perform some statistical analysis. The server works as a management system and as a bridge between the mobile phone and the database. For database management we use Hibernate and PostgreSQL.

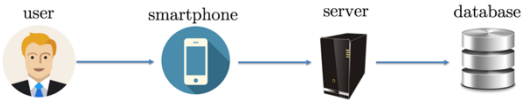

Fig 38 - Overview of the general system architecture.

The application also contains a beacon system so that communication with nearby or surrounding people isn't limited to an Internet connection. This way, the immigrant or refugee can stay safe even if there isn't any mobile network, thereby increasing the effectiveness of our application.

For the beacon system mentioned above we use Google's Nearby API. This API relies on proximity features to create a real-time connection between nearby devices and share information by transferring small binary payloads. It uses a combination of Bluetooth, Bluetooth Low Energy, Wi-Fi and near-ultrasonic audio to communicate between devices [14].

In terms of signal processing, our application runs a periodic background task to collect raw data from the sensors. Afterwards, the data is parsed and sent to a classification system. This classification system is responsible for deciding if the information collected by the sensors represents an attack or not.

The scream recognition system implemented uses an architecture that joins operations in a flexible and simple processing pipeline, shown in Figure 3. To keep the processing pipeline simple, we gave it only one channel audio. This helps and contributes to the performance of the application, since it avoids the need to have more than one running thread, which brings more computational burden.

Streamed audio is then sent to the dispatcher. This is where the incoming audio is chopped in blocks of 1024 samples with a 50% overlap. This percentage of an overlap is a common approach [15]. The dispatcher then sends the block of audio through a series of audio processing algorithms. In the processing section, sound analysis is made and features are extracted.

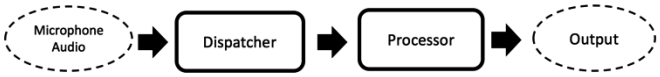

Fig 39 - A schematic representation of the processing pipeline.

Audio is extracted with a sample rate of 11kHz and from that audio we extract 4 features: sound pitch (Hz), sound pressure (dBSPL), sound power (dBSWL) and 13 mel frequency cepstrum coefficients (MFCCs). The power level and the pressure level are logarithmic measures of the sound. For the pitch estimation we use the YIN method [16], which is based on autocorrelation. By analysing the pitch values, we verified that scream sounds are usually greater than 300Hz. Therefore, sounds are only classified or sent into the classification system when this value exceeds 300Hz. This helps save battery and avoids additional computation.

The detection of high pitch and high energy values removes most of the background noise and other low frequency sounds, but these values aren't enough to detect screams accurately. There are many sounds that have similar pitch values or energy values. Take, for example, a baby's crying or an ambulance emergency sound; these sounds have very similar energy values but are completely different (noise-wise). Using only these two features may result in many false alarms being reported. Therefore, to increase the accuracy of the application, we introduced MFCCs – we used a standardized MFCC algorithm defined in the early 2000s by the European Telecommunications Standards Institute [17]. The MFCCs are commonly used in speech recognition applications and do quite a good job by characterizing the blocks of sound that is being processed. In fact, we verified that by introducing MFCCs to our system, the accuracy increased significantly. The default parameters for MFCC calculation were used; that is, 13 cepstrum coefficients were obtained using 26 mel filters in the filter bank. We also applied a lower filter (0Hz) and an upper filter (with half the frequency of the sample rate) for the band edge of the mel filters. These parameters work fairly well for most cases. Delta features were not used.

Normally, before feature extracting, filtering is done to remove any background noise that may exist. In this case we didn't apply any filter because nowadays background noise reduction filters are embedded into nearly every smartphone's microphone. This gives users the ability to conduct conversations clearly without any disturbance from, for example, cars passing by.

For the dataset construction, we labelled scream and non-scream features by asking 40 volunteers to scream and by collecting various sounds that could be similar to scream, such as baby cries, ambulance sounds or music. Since people normally carry their smartphone on their pocket, we wanted to simulate this as accurate as possible and so scream sounds were recorded with the mobile phone on the volunteer's pocket. This dataset was then used to train the SVM classifier.

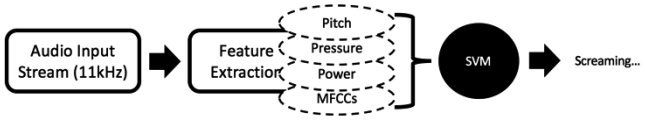

Fig 40 - Diagram of the scream classification system.

For this classification system we used a supervised learning model, a support vector machine (SVM) type classifier with a radial basis function (RBF) kernel type. The effectiveness of this classification system depends on the selection of the penalty parameter of the error, C, and gamma, γ. For determining the perfect values for which the accuracy of our system is the highest we conducted a "grid-search" using cross-validation and exponentially growing sequences of C and γ, as suggested in [18]. The best C and γ obtained were, 32 and 1.0E-4, respectively.

The performance of our classification system was measured by simply calculating the accuracy and error rate. We obtained an accuracy of 98.61% and an Error Rate of 2.88%.

Upon an attack classification, the application sends an attack event to the server. This attack event, with the user's coordinates, is then fetched by all the other users which can then be seen in the map as a flag corresponding to the location of the user in danger.

9.2 The user's perspective

Our application has a very simple interface so that the user can be easily guided. The application contains a navigation drawer, letting the user navigate throughout the app. On the map menu, the user is able to see various pins pointing to helpful locales or danger zones. Danger zones are represented with a red marker and they have a certain transparency rate depending on the danger that location has received. In other words, danger zones with a high level of danger are more

opaque while danger zones with a low level of danger are more transparent. This helps the user to identify different types of danger zones easily. The user can choose to use heatmaps for intensity representation and visual comfort. On the opposite side, we have blue markers which represent helpful locales such as hospitals or police stations, helping the users situate and establish themselves in a new city.

Each map pin has a description associated with it. Any user can add a danger zone or a helpful locale, but this is restricted to three additions a day to prevent spamming or false additions to the map. If a user is abusing the system, he is automatically added to a blacklist and prevented from adding pins during a certain amount of time.

When the user enters or passes by a danger zone, the application emits a notification warning that he could be in danger. It then suggests the user to take a different route. With this feature users can stay safe and avoid areas were crime and assaults are more common.

The user can, at any time, activate the beacon system to begin listening for other users in danger.

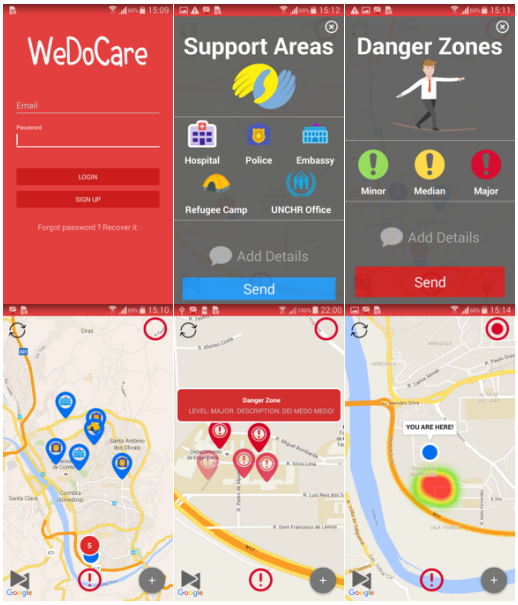

Fig 41 - Application screenshots.

10 Experiments and Evaluations

While smart technology is evolving and growing ever more advanced they are still limited by the available power. Battery technology hasn't evolved as much as the processing capabilities of the smart devices it supports. While chips and operating systems are becoming more efficient to save power, we're still only looking at a day or two of use of a smartphone before having to recharge it. Complex apps also have something to say in this matter, since major power drains can be a direct consequence of bad programming techniques or the use of unnecessary features like Wi-Fi, Bluetooth and GPS. In fact, it is known that the GPS is a notorious battery killer [19]. This is why it is important to manage the smartphone battery consumption by perfecting the application and figuring out the best approaches and best parameters to improve battery life.

Taking the fact that battery life is very important to our application, we wanted to investigate which time interval between sequences of sensor readings and data processing, β, was the best to extend the smartphone's battery time. If the interval β is high, there will be less probability of catching an attack but less battery drainage; on the other hand if β is small, it is more likely for the app to detect alarm events, but we suspect that the battery drainage will be more substantial. To better understand this, we recorded the battery's percentage value over time for different β intervals.

Throughout all tests we used a mid-range smartphone, the Samsung Galaxy S4 Mini. Internally, the S4 Mini features a dual-core 1.7 GHz Snapdragon 400 processor with 1.5 GB of RAM, 8 GB of expandable storage, and a 4.27 inch qHD (540 x 960 pixel) Super AMOLED screen with Android KitKat 4.4.2 [20]. Its approximate idle battery life is 220 hours (this value was obtained with the smartphone on standby). This value will be used as a reference throughout the analysis of our results, herein presented.

10.1 Battery Consumption

As previously said, we decided to monitor battery level and its drainage caused by the sensor readings and data processing within a controlled environment. All background services and apps of the smartphone were disabled to ensure that WeDoCare and Google Play Services were the only software running (not taking into account the necessary processes required for a normal operation of the smartphone). It is important to note that all tests were executed in the same physical location and using the same Wi-Fi access point, to avoid outliers due to inconsistent Wi-Fi and GPS connections.

Location is essential to our application. We need to know at all times (if possible) the user's exact location so that the app can message others the position of the individual in danger. If this location is inaccurate it is possible that a user trying to help is sent to a wrong location – this cannot happen. For location awareness we use Google Play Services Location API [21]. This API gives us entire freedom when choosing certain parameters such as the priority of the location request as well as the rate at which this request is made (interval in milliseconds).

There are three possible variants for the priority: *PRIORITY_LOW_POWER*, *PRIORITY_HIGH_ACCURACY* and *PRIORITY_BALANCED_POWER_ACCURACY*.

- *PRIORITY_LOW_POWER* – This setting has an accuracy of approximately 10 kilometers. We considered this level of accuracy to be too coarse and, thus, discarded this setting.
- *PRIORITY_BALANCED_POWER_ACCURACY* – This setting has an accuracy of approximately 50 meters and is likely to consume less power. With this setting, the location services use Wi-Fi and cell tower positioning.

- *PRIORITY_HIGH_ACCURACY* – This setting has the most precise location possible, with an accuracy of about a few centimeters. This setting uses GPS to determine location.

To test the battery's life, we created two different test suits, one using the *PRIORITY_BALANCED_POWER_ACCURACY* setting and the other using the *PRIORITY_HIGH_ACCURACY* setting. These settings reference the locations accuracy. Since we need our application to be as accurate as possible it is normal to assume that the *PRIORITY_HIGH_ACCURACY* setting is the most suitable; nonetheless we wanted to check the impact these settings have on the smartphone's battery. As said before, the location update interval is also adjustable; therefore, we also performed tests using three different location update intervals.

In terms of testing different time intervals (at which the sensor data is read and processed), we considered three different values: five minutes, one minute and thirty seconds. Since scream recognition tasks are in real-time, our application needs to be aware as much as possible. As such, the interval at which we pull sensor values must be as minimal as possible for better results with greater accuracy and less non-detected screams. We realized that the interval at which collect data from microphone is not relevant in face of location detection. The battery duration was nearly the same, averaged 32 hours, for all three interval values. Therefore, we focused on balancing the usage of the location services.

In the first test we set the location priority to *PRIORITY_BALANCED_POWER_ACCURACY* and the interval at which we requested the user's location was 1 minute.

There was a shortening in battery life by 84,5% (note that this percentage is relative to the duration time when smartphone is untouched and in standby) which lets us conclude that, in fact, there is a great amount of battery drainage when using the smartphones sensors. However, the battery drainage is not too different when comparing different sensor reading intervals.

Setting the location priority to *PRIORITY_HIGH_ACCURACY* while keeping the location update interval at 1 minute, resulted in a reduction of battery life by 93,2%, which is a difference of 8.7% compared to the previous setting. However, since our app must be as accurate as possible (location wise), this may actually be a better solution for our use-case. Furthermore, we focus on determining an interval at which location updates should be requested to improve battery life.

By keeping the priority set to PRIORITY_HIGH_ACCURACY but changing the interval at which location updates are requested to five or ten minutes, we can see that the battery drainage can be drastically improved to levels closer to the ones achieved with *PRIORITY_BALANCED_POWER_ACCURACY*. This way, we can achieve great accuracy on the user's location with a battery drainage similar to the one of a less accurate mode. With these tests, we can now find an interval for regularly updates on the users' locations that we find most convenient.

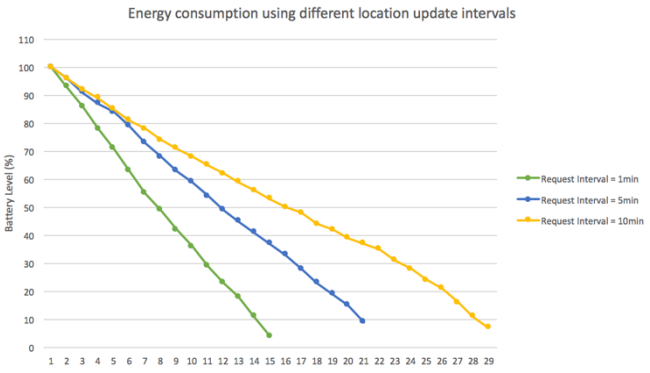

Fig 6 - Energy consumption experiments using different update time on user's location.

Since our application needs to be as accurate as possible, the most adequate setting is the high priority setting. In these tests we found that the balanced priority setting often gave us dull locations that weren't even close to our real location. Since this is a huge problem this setting was discarded. Although it was curious to see that the high priority setting drained the battery more quickly, with an appropriate choice for the interval at which the requests are made we can increase the smartphone battery life. It is important to take in mind that mobile phones nowadays usually have between one or two days of battery, and so our results reveal that our application doesn't affect the smartphone's usage significantly.

10.2 The beacon system

Our application can send out alarms to users within a 2km radius as long as Internet is available. Nevertheless, if an Internet connection isn't available, the user can opt to activate the beacon system. The reach of this beacon system is important due to the fact that the greater the area covered the higher the probability of the message with the endangered person's location to arrive user's that want to help. This feature, in combination with an accurate location, can be used for example in refugee camps, where many women are sexually assaulted within a few meters without people realizing it.

Since Google's Nearby API uses Bluetooth, Bluetooth Low Energy, Wi-Fi and near-ultrasonic audio to communicate between devices it was expected that the distance of this beacon system was the same distance that Bluetooth technology could cover. This was, in fact, the case; the beacon system could cover about 55-60 meters, both indoors and outdoors. These results are approximately the same as the range of any Bluetooth device [22]. Moreover, Bluetooth technology is always evolving and Bluetooth 5.0 is now on the rise with a coverage of 300m.

10.3 Inquiries

During our tests, we did a questionnaire to a group of immigrants about the application. Three question were asked:

- Would you use such an application?
- What would you add to improve our application?
- What do you think about the usability of the application?

Most of the respondents said, undoubtedly, that they would use WeDoCare, in fact only 20% of respondents said they wouldn't use it. The majority of people who would use the app, said they would use it because it brings them huge advantages that other maps apps don't bring and that they would like to help and connect to other people. Some think that the application is a great idea and suitable for children and women. Concerning the second question, there were many suggestions, however most of them refers to an association with authorities, this is, when a person is in danger it automatically contact authorities. Another suggestion we found quite useful was to incorporate a list of useful contact information such as father/mother or partner, so the close ones would immediately know about your situation when in danger and perhaps send out an sms. Finally, about the usability, the respondents all answered that it was simple and easy to use.

11 CONCLUSION

In this paper, we presented a solution that attempts to help solve issues in real-time and in real-world scenarios, such as, the refugee crisis. We also explained how the scream recognition feature – which is the main feature of this application - was implemented and how it works. This system is still under development and new features, such as the ability of adding photographs of danger zones, will be added. Since this solution has to last as much as possible, we studied the impact of the interval at which sensors were read on the smartphones battery life. We found that the distance covered by the implemented beacon system can cover up to 60 meters which is consistent with todays Bluetooth technology. In the future we will add a multi-hop mechanism that increases the coverage of the beacon system.

ACKNOWLEDGMENTS

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An Architecture For Emotional Smartphones in Internet of Things

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***Abstract* — In the past few years, the idea of the "Internet of Things" (IoT) has been developing rapidly, with sensors and machines communicating with each other through the Internet. These new technologies can be used to support new types of Cyber-Physical Systems (CPS). Even though CPS consider humans as a part of themselves, they still treat humans as external elements, with unpredictable behavior. In fact, in order to the new IoT serves human needs better, it has to take into account all sorts of psychological and emotional states.**

Smartphones present an excellent opportunity to do so as they are a key element in IoT and they contain several sensors that allow us to collect information about user movement, location, environment, and interactions with other people. This type of mobile device usually accompanies the user anywhere he goes throughout the day.

This paper presents a work about a new paradigm that integrates human in the IoT. This paradigm is validated by the implementation of 3 applications that are detailed in this paper - HappyWalk, WeDocare and HappySpeak.

Keywords - "Human-in-the-Loop", "Ubiquitous Computing", "Behavior Inference", "Smartphone", "Cyber Physical Systems", "Behavior Change Intervention", "Emotional Sensing", "Artificial Neural Networks"

I. INTRODUCTION

The world faces many social problems such as child labor, health access or the current migrant crisis. Over the recent years, technology has been developed to mitigate these problems, providing education for children in underdeveloped countries 0, health management in underprivileged areas 0 or outreach programs to help refugees start new lives 0. IoT and all of its devices is the path forward to solve many more of these problems. IoT is based on lowcost technologies, like wireless sensor networks, and on smartphones, and as such IoT represents an enormous potential as it can be used by all, even poor people.

In this context, we explored and developed 3 solutions based on our Happy System architecture that integrates the Human in IoT: HappyWalk, HappySPEAK and WeDoCare. These 3 projects are built upon the Happy System, an architecture that aims to use sensors to infer human emotions, and use the knowledge it gains to improve the user's life. Smartphones are the perfect tool for this, as they are becoming more widespread and possess an array of sensors that can be used to monitor the user and his environment.

We developed HappyWalk to detect one of four emotions: Euphoria, Calmness, Anxiety and Boredom. Boredom and Anxiety are considered to be negative emotions, and when detected, the systems shows the user places he may like to go to in order to improve his mood.

For the HappySPEAK and WeDoCare systems we mainly focused on two groups of people: migrants and refugees. In order to understand the needs of migrants, we exchanged knowledge and formed a partnership with Associação Fazer Avançar (AFA) and its program SPEAK.

SPEAK0 is a cultural program designed to bring people together by promoting language learning. Its premise is simple: the main barrier that stops foreign people from bonding is language. SPEAK tries to bring down this barrier by allowing anyone from anywhere to sign up and learn or teach other languages. It goes even further by organizing social events with the purpose of creating a bond between participants.

Migrants mostly move to a new country to find better standards of living (due to financial or social needs), but sometimes can't speak the language and they travel alone. Not knowing the language makes it hard for them to socialize and meet new people. This is where HappySPEAK tries to help.

HappySPEAK replicates SPEAK's platform, allowing users to register, and view future SPEAK events in their area. Also, it collects information about the user, such as messaging and call logs, in an attempt to detect if the user feels lonely. This information is then used to suggest the user places he can visit or SPEAK events he can attend.

As we have stated before, one the main social issues in Europe is the huge influx of refugees due to the war in Syria. Millions of refugees are trying to get to Europe in order to escape war in their country. To help with these efforts many refugee camps have been created, but, due to a lack of resources and manpower, security in these places is becoming scarce. To help with this problem, we also created WeDoCare. This system aims to detect violent attacks against refugees. The app

collects data from motion and sound sensors of the smartphone from time to time, and if an attack is detected, it sends a distress signal to nearby people and policemen.

This paper intends to describe these 3 applications in the context of integrating the Human in the future Internet - Internet of Things. Section 2 describes the theoretical work supporting the integration of the Human in the IoT. As far as we know, this topic is innovative and will have a great potential in the future Internet. Section 3 presents our Happy System model that we developed and is the base for the integration of Human in IoT. Section 4 is the proof of concept where the 3 applications that we developed are presented. Section 5 discusses future work and concludes the paper.

II. Related Work

A. Human-in-The-Loop

The Human-In-The-Loop (HITL) paradigm considers humans as vital part of the control loop. It can be divided in three main components: the human being, its environment and the system.

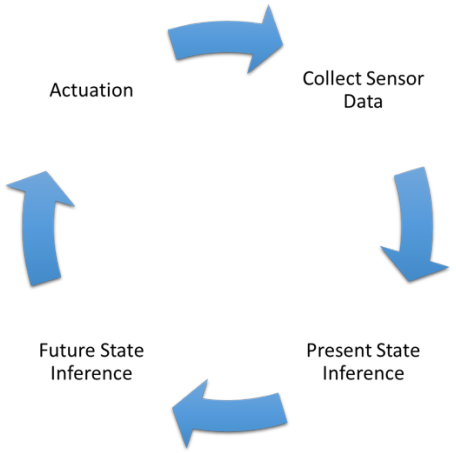

Figure 1- HITL control loop

In figure 1, we can see how the HiTL control loop works. Everything is centered on the human being:

- Data acquisition - Sensors collect information about the user and his environment.
- State inference - It infers how the user is feeling.
- Future State Inference - It uses previous information to improve its accuracy in future inferences.
- Actuation - The system tries to expose useful data to the user, in the form of information or suggestions.

There are many real-world applications that use this paradigm. Some of those are:

- Electronic Health systems that monitor patients to reduce human error. This system monitors, for instance, heartbeats and oxygen to calculate the appropriate amount of medicine that should be injected 0.
- A wheel chair with assisted driving that avoid obstacles such as stairs or drops 0.
- A memory jog system for supportive information in meetings and collaborative workspaces 0.
- A system that suggests a better path to get to a destination, in order to avoid high traffic areas 0.
- An electrical grid management system that uses information from its users to create and improve inter/intra-enterprise processes 0.

B. Behavior Change Intervention

Behavior Change Intervention (BCI) systems aim to alter human behavior in a positive way. These interventions are mainly focused on giving advice and expose information that will help the user correct negative behavior (such as a sedentary lifestyle, smoking, overeating, etc.).0

This type of system requires a degree of information about the user and his activities. Smartphones are extremely useful for this because they accompany the user for most of the day and have sensors that can be used to infer how he feels and the state of environment around him.

These interventions traditionally occurred in therapeutic sessions between two or more people, but are also starting to occur through the Internet and in smartphones.

C. Cyber-Physical Systems

Today's technology has evolved to a point where machines and sensors communicate with each other seamlessly, giving way to the so called "Internet of Things". This allows new types of Cyber-Physical Systems (CPS) to be developed. While CPS today are built around human interaction, many of them just consider humans as external, unpredictable element to the control loop.

Other than e-Health, there is not much scientific work done about the human context in the control loop of CPS 0. Smartphones present an excellent opportunity to do so. They possess the processing power and the array of sensors required to develop CPSs to the next level. In short, when we start using this type of mobile devices to evaluate and monitor human nature, humans become a part of CPSs. This brings us to Human-in-The-Loop Cyber-Physical Systems (HiTLCPS).

By inferring emotional and psychological state of the user, as well as actions and behavior we can increase the accuracy of the control-loop. For instance, let's take into account cruise control systems. If the user is tired, it could suggest to him that maybe he should consider turning cruise control on.0Since human beings are considered to be extremely unpredictable this presents an enormous challenge.

D. Recommender Systems

Recommender Systems (also known as Recommendation Systems) have become widespread in recent years. Many well-known companies are using them to improve their services and expose new products to their customers. These include Amazon, that uses content-based recommendation to suggest

items the user may want to buy, based on previous purchases; Netflix combines 107 recommendation algorithms to form a single prediction and suggest new video content to their users. Many other companies like Facebook, Twitter, Google and LinkedIn use recommendation engines to expose interesting information to their users.0

These systems usually use one of two approaches: Collaborative Filtering or Content-based filtering. Hybrid approaches also exist.

Collaborative Filtering is based on user behavior, and can construct its model from it or from the collective behavior of users with similar traits. In essence, it aggregates users based on their preferences and recommends content based on it.

III. The Happy Sysyem

For a system of this nature to work properly we primarily need a sensor array that allows us to measure human behavior and his environment, and optionally, a server to save and process information. Fortunately for us, today's smartphones come equipped with many sensors, such as:

- Accelerometers - Provides information about user movement.
- Microphone - Can measure the amount of activity around the user.
- GPS - Allows us to see where the user is, at what time and consequently at what speed he is moving.
- Temperature - Measure ambient temperature.
- Ambient Light – Measures the amount of light around the smartphone.

A. Happy System Architecture

The Happy System is an architecture designed for smartphones that allows users to select a set of features and use them for emotion inference using a neural network. Its architecture can be described by the following figure:

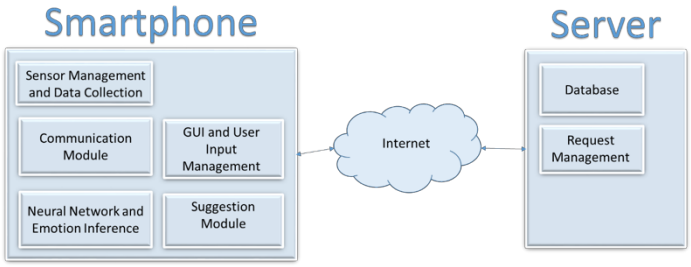

Figure 2-Happy System Architecture

In the smartphone system, we have four different components:

The **Sensor Management and Data Collection module** manages what sensors must be activated and what data must be collected. It also processes the data and saves it into the appropriate data structures.

The **Communication module** establishes connection with the server and handles all incoming/outgoing requests.

In the **Neural Network and Emotion Inference module** a neural network is "fed" with sensor data and infers how the user is feeling. This module also takes feedback for the user in order to increase its accuracy over time. Even though the base system uses a Neural Network, the model used for emotion classification can easily be switched by another one.

GUI and User Input management present the several user interfaces and handles all of the user input.

The **Suggestion Module** generates a suggestion for the user to improve his behavior.

A server-side application can be connected to the smartphone in order to save data or do processing in the cloud. In the server component we have two different components:

- **Database**- Saves incoming data from the user and saves it for future analysis.
- **Request Management**- Handles all incoming/outgoing requests from the user.

IV. Proof-Of-Concept

In this section we will describe how we implemented several systems that derive from the Happy System architecture.

A. HappyWalk

HappyWalk is a Behavior Change Intervention system that estimates the users' current mood and tries to improve their physical and mental well-being. It does this by monitoring user activity, using smartphone sensors, and inferring the users' mood. If the system detects that the user is in a bad mood, it will suggest that he takes a walk by displaying several points of interest in a map.

This app employs a full closed HiTL control- loop:

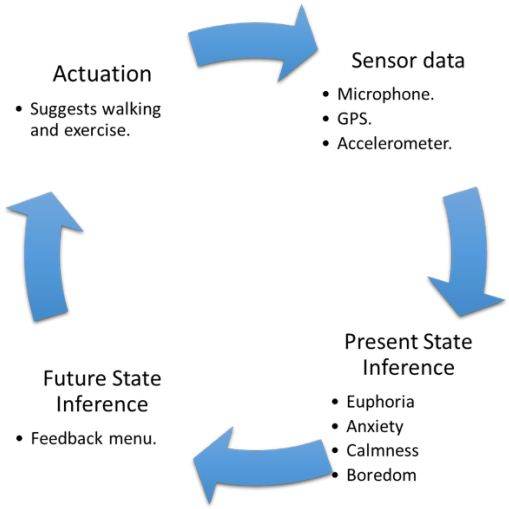

Figure 3-HappyWalk HITL implementation

HappyWalk uses data from the smartphone's microphone, accelerometer and GPS sensors as inputs in a neural network. The output will be one of four emotions: Euphoria, Boredom, Calmness and Anxiety. This system considers euphoria and

calmness as positive emotions so it only gives the user suggestions if it detects Boredom and Anxiety.

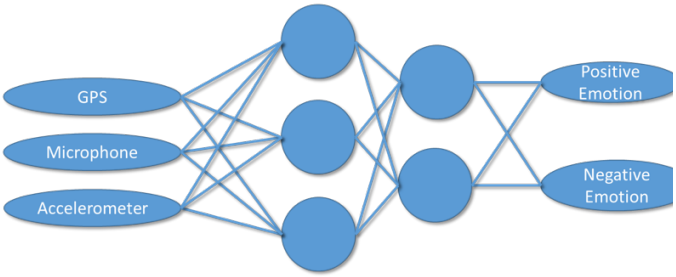

Figure 4 - HappyWalk Neural Network

This Neural Network is trained by asking the user for feedback on how he is feeling from time to time.

B. *HappySPEAK*

In the past decades the world has been witnessing a huge increase in the number of migrants, searching for better standards of life. The reasons that make people migrate are varied, and can be classified as:

- Economical
- Social
- Political
- Environmental

Moving to a different country isn't easy. Cultural differences and linguistic barriers make it harder for migrants to connect with citizens of the hosting country. This can lead to migrants feeling lonely, especially if they came to a new country alone.
This is where SPEAK tries to help. First it tries to connect them with people in the same situation, by organizing dinner parties and events that brings them together and makes them learn more about one another.
SPEAK0 is a cultural program designed to bring people together by promoting multiculturalism and the democratization of language learning. It provides courses and encourages people from different cultures to share their interests and break any prejudices they may have about foreigners.
The neural net that is currently implemented is a Feedforward neural network with a sigmoid function.
After the data is collected the following features are extracted:

- SMS ratio: Division between received and sent text messages that show if the user is sending more messages than he receives.
- Call Ratio: Division between the number of calls the user received/made.
- SPEAK attendance: If the user is registered in SPEAK classes, we check his attendance record, in order to see if he is trying to socialize with other people.

If the network detects that the user feels lonely, it triggers the map activity which displays suggestions of SPEAK events occurring soon and places that can help him meet new people. These suggestions will help the users to socialize; thus, reducing his isolation.

C. *WeDoCare*

WeDoCare is a system built upon the Happy System that aims to prevent violent attacks on refugees. It takes advantage of the mechanisms built in HappyWalk for detecting human emotion and applies it to this kind of situations, trying to help people by warning nearby policemen and common citizens that someone is in danger.
The app periodically collects data and uses it to check if the user is in a danger situation. The data comes from three sensors: the accelerometer, GPS and microphone, and is able to work with Wi-Fi, mobile networks and Wi-Fi beacons.

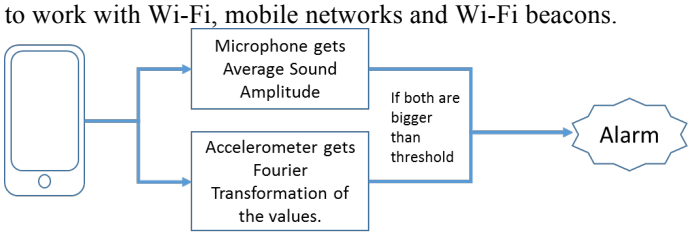

Figure 5-WeDoCare Attack classification

IV- Conclusions

The developed systems show the versatility of the Happy System Architecture, as we were able to apply it to different user classes and contexts. We can improve the architecture even further by experimenting with other classifiers such as SVM, Naive Bayes and Deep Neural Networks. The suggestion module can also be improved by using Social Network information to direct users to places they like or to services they enjoy. The architecture may also be complemented with more advanced emotion recognition techniques such as using deep learning to recognize emotions via speech, searching for specific keywords in text messages among others.

Acknowledgment

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Tech4SocialChange crowd-sourcing to bring migrants experiences to the academics

Humanitarian Challenges and Opportunities, Connectivity & Communication

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Abstract— **There are already numerous tools for sharing stories about the new life of migrants. Social networks are used daily with this very purpose. However, the main purpose of social networks in these cases is simply to raise awareness. Tech4SocialChange is not a social network. It is a system that takes a proactive approach to transform social challenges into concrete challenges to be solved by engineers. In this paper, the case studies of "How to stop the attacks on women in refugee camps?" and "How to measure the isolation of migrants in an automated way?" are presented by using the method of Tech4SocialChange for problem definition and solving. This method takes advantage of the academic world that sometimes wants to help but doesn't know how. We have researchers and professors that struggle to find interesting subjects for their work and/or classes; students that, on the other hand, may have a greater interest in working on real-world projects, instead of assignments with mere academic value, and, of course, traditional volunteers: people with a passion for solving social problems of this nature and willing to lend a helping hand. These are the intended users, for the prototype developed, to show this innovative process.**

[1] ***Keywords—social problems; academics-society; innovation; entrepreneurship; problem solving; crowdsourcing;***

I. INTRODUCTION

Researchers are sometimes accused of trading the applicability of their work on real world problems and social issues, in favor of a more scientific gain. Obviously this is not the general case, given that some of the work, developed by researchers, is derived from problems affecting the real world and the society. In this paper, an innovative model to bring researchers, students and professors closer to these problems through crowdsourcing is presented. In the creation and development of this model the following issues were addressed first:

- How can we collect relevant information about social problems or initiatives?
- How to prioritize and measure the complexity of the solution and potential of social impact?
- Should we break big problems into smaller ones? If so, how to do that? What are the rules?
- Once a team takes a project - how can we monitor the progress of the development in an automated way?

For the implementation and testing of this method, a prototype, comprising of a web application, was developed and can be accessed in www.tech4socialchange.org. This is the Tech4SocialChange platform that lets researchers create projects based on problems and also share their work with the community. The problems are submitted in the platform by users who face or know them in real life.

To show the applicability of the method and the platform, two case studies are presented. These are based on real problems currently being addressed by the team of researchers

of the University of Coimbra that is also involved in Tech4SocialChange.

Section II describes other projects and platforms similar to Tech4SocialChange and in section III it is presented the method for problem and solution gathering, as well as the main similarities and differences between Tech4SocialChange and the state-of-the-art. Section IV presents the case studies, based on real world problems, used to build this method and to develop the prototype. Section V defines the future work and research goals for Tech4SocialChange.

II. TECH4SOCIALCHANGE

The main public for Tech4SocialChange are the people of the academic community, more specifically: researchers, professors and students.

Researchers sometimes struggle to find interesting subjects to work on or have difficulty in getting this work to environments where it could be used in real life situations. Professors have to come up with interesting assignments for their classes, which sometimes its only objective is for the students to develop technical skills, leaving others, like decision making skills, aside. Students create these projects with the single purpose of completing the academic assignment; hours of work to be put away in the end.

The proposed solution combines all the needs of these individuals into a database/repository that allows users to submit problems and create projects to solve them. This way, researchers and teachers have access to problems with real impact in the world, that they can work on solving, or, in the case of teachers, use them as subjects in course assignments. Students can create projects that have, not only an academic purpose, but also a real value in the world. This allows students to increase their own value professionally and train and develop logical and designing skills. It is also included a feature for researchers to share their work with other people so it can be used in solving problems and be referred in the final solution developed.

It was referred in section I some issues first identified with this initial approach. The following are the solutions found for each of them:

How can we collect relevant information about social problems or initiatives?

After studying the problem criteria that HeroX provides, some guidelines were identified in common and adapted to the context of Tech4SocialChange (people that have no experience with this kind of platform):

- Why does this problem exist?
- What is going to change in the world after the problem is solved?
- What product could be invented? What impact it should have?
- Is there a complete or partial solution to this problem? What is its limitation?
- Do you have something that might support a solution?

It is expected that these guidelines provide researchers, and other solvers, the initial amount of information necessary to start building projects.

How to prioritize and measure the complexity of the solution and potential of social impact?

It is up to the solvers to plan and develop a solution that creates a big impact in the problem and the environment that is meant to be integrated. To achieve such a solution, it is important to provide them with enough information about the problem. For this, the guidelines alone might not be enough. It is also assumed that the people submitting problems have no experience with problem solving, project development or engineering.

A question-answer model is provided to help complete the information in the guidelines. With this model, the solvers can ask questions about the problem to the people that submitted it.

Should we break big problems into smaller ones? If so, how to do that? What are the rules?

It was decided to not break problems apart. However, some ideas are being considered for this scenario, in the eventuality of it becoming a frequent case.

Once a team takes a project - how can we monitor the progress of the development in an automated way?

When a team of solvers starts creating a project, it is necessary to confirm if a project's requirements correspond to the needs of a problem. For this it is useful to the solvers, to first define their project's requirements and then start developing.

A. Users

There have been identified three types of users after addressing the issues presented before:

- Problem Maker
- Problem Solver
- Problem Specialist

Problem Makers submit problems and manage them. They are also responsible for answering solvers questions and choosing a solution for the problem.

Problem Solvers are researchers, professors and students that create projects associated with problems. They can ask questions and build project requirements for the Problem Makers to evaluate and decide if the project can be used for the respective problem.

These two types are unique to each user; this means that a user is either a Problem Maker or a Problem Solver. However, this is not the case for Problem Specialists. This is an experienced user in problem solving and analyzing the problem's criteria. His responsibility is recommending projects based on its requirements and on the problem needs.

B. Workflow

The workflow in Fig. 1 has been developed after addressing the initial issues. The first step is the submission, by the Problem Makers, of the problem with all guidelines answered. Secondly come the questions; here all the Problem Solvers can ask questions to the Problem Makers, in order to better define the problem criteria (the answers given in the guidelines when the problem is submitted initially). This phase has duration set by the Problem Makers. After the deadline is reached, the problem moves on to the next phase.

In the requirements, the Problem Solvers plan and submit the requirements for the project they are proposing as a solution for the problem. This process also has a deadline set by the Problem Makers and the proposed requirements must be in accordance to the criteria/guidelines refined in the previous phase. During this phase, users who are also Problem Specialists can recommend projects to Problem Makers in order to help with the choosing phase.

In Choosing, Problem Makers must choose which of the proposed projects is to be developed and ultimately become the final solution. They can also choose not to advance into development and, instead, revert to one of the previous phases. This phase has no duration set, being of the responsibility of the Problem Makers to decide, at their own pace, which path to take.

Solving corresponds to the actual development of a project that has been chosen in the previous phase to solve a problem. This phase has the duration of the completion of the project, set by the Problem Solvers.

In the final phase, the project has been completed and ready to be implemented in the context of the problem. It is up to the solvers to provide the Problem Makers with the right setup to make the project work.

Workflow for problem criteria definition and solving

C. Research module

Researchers can choose to share their work with the community of solvers. These can then reference the researches in their projects.

This allows, not only, the researchers to reach a wide crowd of people interested in new technologies, but also, Problem Solvers to use innovative work in their projects.

The way this sharing is done is by providing the necessary files of the work and an explanation of what it does and how to implement it.

III. PROTOTYPE

As mentioned before, a web application was developed as a way to implement and test the method of problem definition and solving created. This web application can be accessed through www.tech4socialchange.org. The following technologies were used:

- HTML5/CSS3 in conjunction with Bootstrap
- AngularJS
- Spring framework

The prototype focused on these features:

- Registration of users
- Creation and management of problems, projects and researches

A. Registration of users

A user can be registered with name, email and password. Afterwards, an email with a verification link is sent so that the account can be activated.

After the activation, the first time a user logs in, it is required that it chooses the type of user - Problem Maker or Problem Solver, and if it wants to become a Problem Specialist.

B. Problems

Problems can only be created by Problem Makers. Every problem has a profile and an editing area. In the editing area, the problem information, questions, projects and users in the team of Problem Makers can be changed or added.

The required information to create a problem is its title, although after creating is possible to enter the rest of the fields in the editing area:

- Description
- Keywords
- Deadlines for the requirements and question phases

It is also possible to add an image to be viewed in the problem profile.

Problems have three states: draft, private and public. In draft only the team of Problem Makers responsible for it can access it. In private, only the Problem Makers and the users that submitted projects can access the problem profile. When a problem is Public, everyone can access it.

C. Projects

Projects are always associated with a single problem and are created in a problem profile page by Problem Solvers. Like problems, projects are created with only the title as a mandatory field. After being created, the following fields become available for editing:

- Description
- Keywords
- Brief pitch
- Estimated deadline

It is also possible to: add and remove users from the team of Problem Solvers, change the project profile image, make the planning by adding, removing and changing tasks in the project, view the problems and references associated with the project.

A project also has three states: draft, private and public. In draft, only the team of Problem Solvers have access to the project. Private allows visibility to other teams of Problem

Makers associated with the same project in their problems. Public projects are visible to everyone.

Projects can be recommended by Problem Specialists in the project's profile.

D. Research

Researches can be created by any kind of user. A research is created with only the title as mandatory (like problems and projects). Afterwards, a description, keywords and files can be added. The files uploaded are shared with the other users that access the research profile.

Researchers can be referred by Problem Solvers through their research profile, in relation to projects where they have not been referenced yet.

IV. Case studies

To determine which information is necessary and if it is possible to include everything about a problem with the method created, two case studies were analysed.

A. Case study 1: How to detect attacks on women in refuggee camps?

TABLE I. Problem criteria for case study 1

Description	With the recent refugee crisis, there have been detected attacks on women in refugee camps.
Keywords	Violence, Surveillance, Protection, Refugees
Why does this problem exist?	Refugee, migrant women and children often travel on their own at heightened risk as they travel through Europe, sometime at night, along insecure routes or staying at places that lack basic security.
What is going to change in the world after the problem is solved?	By solving this problem, we can decrease violence in refugee camps and help people stay safe from dangerous or xenophobic citizens and through their travel to Europe.
What product could be invented? What impact it should have?	An app that warns others that someone is in danger. Giving these persons the chance of collaboration by helping others stay safe.
Is there a complete or partial solution to this problem? What is its limitation?	There have been some applications or solutions for this problem, but nothing in real-time or that is done automatically. The solutions that exist need a physical input to the application saying that effectively you are in danger.
Do you have something that might support a solution?	These people have smartphones.

After analyzing the initial criteria, we rapidly decided that a smartphone application would be the best solution for this case. Although some questions were still unanswered, like:

- How about battery life of the smartphone?
- How about privacy? Are people willing to share their location?

The questions phase proved useful, as it allowed us to gather specific information for our solution. This resulted on an android application called WeDoCare [1], a Human in The Loop smartphone application that uses the smartphone's sensors, specifically, the microphone, to identify, in an automated way and in real-time, situations of violent attacks against its users, through a scream detector.

B. Case study 2: How to measure the isolation of migrants in an automated way?

The gathered information and guidelines for this problem are presented on Table III.

TABLE II. Problem criteria for case study 2

Description	Migrants mostly move to a new country to find better standards of living (due to financial or social needs), but sometimes can't speak the language and travel alone. Not knowing the language makes it hard for them to socialize and meet new people.
Keywords	Isolation, Language barriers, Socialization, Loneliness, Migrants
Why does this problem exist?	Language Barriers.
What is going to change in the world after the problem is solved?	Migrants have a better integration by providing better ways of socializing in a new environment.
What product could be invented? What impact it should have?	An application that successfully measures if a person feels lonely. The app should suggest activities that may improve the user's mood.
Is there a complete or partial solution to this problem? What is its limitation?	Social Networks. They only provide "static" information about the user and the people it knows.
Do you have something that might support a solution?	Smartphones have sensors and information about the user that can be used to check if he feels lonely or not. This information can be used to actively change the user's mood.

After the gathering, and once the planning started for an application, there were still a few questions without answer, as predicted, such as:

- What is the nationality with the biggest representation?
- When they arrive, usually come alone or accompanied?

The questions phase proved useful in this situation. The project created with the information gathered is HappySPEAK. It is an android app, developed within the University of Coimbra, that joins the social network of SPEAK organization [2] and the Human-in-the-Loop concepts [3]. By analyzing the messages and calls logs, the app creates a ratio of calls and messages made/sent and received to use as input of a neural network that classifies the person as isolated or not.

Since this was an internal project, the requirements were made specifically and always in contact with the SPEAK organization (interested part) as to best integrate the isolation network with their community of migrants.

V. Related problem-solving platforms

A. HeroX

HeroX [4] is a profit platform that lets users to create a competition and defines the criteria for winning that competition. A competition is sponsored by the entity that creates it and it is based on problems that are to be solved by the combination of crowdsourcing, competition and collaboration.

People around the world have the opportunity to solve or build a solution for a competition and the winner gets a prize money. To help define a problem, some guidelines [5] are provided by HeroX:

- What problem do you want solved?
- Why does this problem exist?
- What breakthrough are you committed to creating?
- What is the "finish line" or bullseye?
- How long will this challenge last from day 1 to day "won"?

These competitions are managed by an HeroX team that takes care of management function like: team selection (they choose who enters the competition; the criteria for this choosing depends on the requirements set for the competition), and judging.

To participate, users must pay a fee; this assures the entity sponsoring the competition that there is commitment by the competitors to find a solution to the problem being tackled.

The winning criteria is set at the beginning and is used by the HeroX team to determine the victor of the competition.

The rights to the final solution can differ from challenge to challenge. They can be attributed to the developers, the creators of the competition, HeroX or put under some specific license.

B. OpenIDEO

This platform allows the splitting of the innovation process into phases and building on the ideas of people.

Challenges and programs are created, using crowdsourcing, as a way to tackle problems around the world.

A challenge has a duration of three to five months and is based on an issue that the community can work on to find and develop a solution. A program is a long-term partnership where a specific grand issue (climate change, for example) is tackled and numerous challenges, events or other activities are released [6].

All challenges require a sponsorship to cover the costs associated with managing and providing tech and community support.

The approach for problem-solving is based on IDEOs design thinking. Tim Brown, CEO of IDEO, states that:

"Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success." [7].

This method makes use of skills that people possess but get overlooked by the standard/popular problem-solving methods. This concept allows for the final solution to be emotionally meaningful and also functional as it integrates feeling, intuition and inspiration with rational and analytical. There are three concepts to keep in mind with this method: inspiration (the problem or opportunity that motivates the search for solutions), ideation (process of generating, developing and testing ideas) and implementation (path that leads the project to the real world).

The winners are chosen by the sponsor of the challenge and the OpenIDEO team. This selection is based on the challenge criteria and on OpenIDEO team's skills to implement it. All other ideas can be developed further and used/adapted on other challenges that meet their purpose.

C. Comparison

The audience of Tech4SocialChange is mostly comprised of people from the academic world and there is no need for sponsorships to submit and tackle problems.

The common motivation is the opportunity to build a project that will be implemented in a real world situation by people that have a genuine interested in using that solution. Although, both OpenIDEO and HeroX use prizes and sponsorship to motivate their audience into participating, Tech4SocialChange deviates from monetary prizes. The motivation behind it is the direct contact established between the academic audience and the people submitting the problems, which sometimes is very difficult to create due to large distances, language barriers or simply not knowing where to look for the people facing the problem being solved. Since students are also a huge part of the academic world, these benefit greatly from the opportunity of working and having something, that they built, being used somewhere in the world and helping people.

Another difference is the need of specialized teams to select and gather information about the problems, judge the projects built and, in OpenIDEO, build the final solution. This approach may slow down the whole process of problem-solving, even though it is safer since all management is handled by them. One of Tech4SocialChange's main characteristics is being automated, from defining the criteria of the problems, to reaching a final solution.

Projects do not say idle in Tech4SocialChange, they can be improved and used in different problems. This is not the same for HeroX, where final solutions are delivered to the entities that created the problem and suffer no more changes through HeroX. In OpenIDEO, projects can be reused but cannot be improved much more since each one is built for a specific problem.

VI. Conclusions

The immediate goal for this project is to get organizations and universities to register in the platform and start populating the system with problems, projects and researches.

Since this is an initial implementation method, it is of interest to receive the user's feedback as to continue to improve it as well as the user interaction with the online prototype.

The main objective for the creation of the method of problem solving of Tech4SocialChange is to approximate universities, NGOs and real world problems. For this it is needed to understand the terminology that each use. Researchers use different terms and approaches for different situations, the goal is to identify these and create a relationship with problems submitted in the platform.

Companies may also prove to play an interesting role in this method, as so, a model where companies, universities and NGOs can all collaborate to solve social problems is also being developed.

Intellectual property is also another matter that needs to be address in the future. In the eventually of supporting the deployment and giving access to the projects, what kind of licenses should be supported? Should all be open-source or use some more restricting licenses?

Currently there has been an increased use and exploration of solutions based on Internet of Things (IoT). What kind of support should be given to solutions like this? How to use the data collected from problems and projects and use them in IoT?

This paper presented an initial approach at getting the academic world closer to the problems of the real world. There is also a very important connection that is hoped to be established with entrepreneurship, as many world changing ideas may come from this project.

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Tech4SocialChange: Technology for all

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Abstract. Universities and other educational institutions are sometimes accused of not being involved in real world problems, focusing more on the scientifically value of the work produced and not on the humanitarian value. A way of encapsulating the second with the first is the main goal of the Tech4SocialChange that is described here. An innovative database/repository of challenges with real impact in the world is created and given access to people with skills and knowledge to tackle them. Also the work made by researches can be stored and used in a project and the researcher gets recognition for it by becoming referenced in that project. A web application has been built as a prototype for this process and can be accessed in www.tech4socialchange.org. It has been planned and developed by a team of students and researchers of the Department of Informatics Engineering of the University of Coimbra and is currently being constantly altered according to feedback received by the testers in the same team. This paper presents an application that aims to help people that face certain challenges every day and motivate those that have the skillset, to tackle these challenges, into doing so.

Keywords: social problems; university-society relation; innovation; entrepreneurs; problem solving;

1 Introduction

By taking advantage of the academic world, which is sometimes accused of not taking into account real world situations, and providing a database/repository of problems that have a real and direct impact in the lives of people someplace in the world, the means and/or knowledge to tackle these problems are provided.
Tech4SocialChange's goal is to be this bridge that links universities to the problems affecting people around the world.
Researchers that sometimes struggle to find interesting subjects for their work get a database where they can consult and start building solutions to be applied in the real world.

After publishing their work, they can also share it with the community, so it can be used in projects that have an impact.
Students are also an important part of this process. Typically, they have assignments in their courses that have a purely academic value. By letting students work on real world problems, the assignments would gain an increased value with real impact in the world, which also gives the student an increased value and knowledge for their professional career.
The problems can be submitted by anyone that faces or has knowledge of some kind of challenge or difficulty, in either their own or someone else's life, and that would like to see it solved/tackled by people with the skills to do so.
The process that leads to the solving of a problem is incremental. First it needs to be clear and well defined to let the solvers understand the context and needs of the problem. Next, based on the information provided about it, the solvers need to come up with ideas and develop a project that answers all or most of the problem's needs.
After this, a project must be chosen to be developed and applied in the real world. This choice must be made by the ones that are closer to the problem. In this case, they are the ones who submitted it in the first place. However, some people might not have the skills or knowledge to verify if a project actually responds to all of the requirements in the problem's description. For this situation, specialists are needed; they are people with experience in analyzing and verifying the requirements of a project and validating these in respect to the problem.
In this process, three types of users have been identified:

- Problem Makers create/submit problems.
- Problem Solvers come up with ideas and create projects with the intent of solving the problems.
- Problem Specialists have experience in matching a problem's needs and a project's requirements.

Also, all three types of users can help in the first phase (definition of a problem) by asking questions about the problem to the Problem Makers. In the second phase, the Problem Solvers use the information gathered to think up solutions and create projects. In the third phase, with the help of Problem Specialists that recommend projects to the Problem Makers, a decision has to be made about which of the proposed projects will be developed in the next phase to, ultimately, solve the problem.
The fourth phase is the actual development of the project. In this phase, a simple tracking method is provided with a task list. This list is updated every time a new step in the project planning is created or concluded. This way, the Problem Solvers can give feedback on the project's progress.
The fifth and final phase corresponds to the project in its final state: ready to be implemented and used in the real world. It is the responsibility of the project's team to evaluate if its final state has been reached.

The five phases can be better observed in Fig. 1 where each one is named respectively.

Fig. 1. Phases of a problem

To submit, and to help with the definition of the problem, some questions are provided in the beginning to the Problem Makers. These questions act as guidelines and must be answered before presenting the problem to the community:

- What problem do you want to solve? Or what do you want to change?
- Why does this problem exist?
- What is going to change in the world after the problem is solved?
- What product could be invented? What impact it should have?
- Is there a complete or partial solution to this problem? What is its limitation?
- Do you have something that might support a solution?

The first two guidelines aim to gather information about the environment in which the problem occurs. The next two are about what to expect of the solution to build and the impact that it will cause in response to the problem. The last two guidelines are optional and refer to the existing alternatives or solutions to the problem: why they don't apply to this problem in specific and if there are resources available that can be used in the final solution.

2 State of the art

There are already projects with the goal of tackling social problems and developing solutions to them. Tech4SocialChange innovates over these through a novel process of processing problems, which is described in section III.

2.1 HeroX

HeroX [1] is a profitable platform that allows anyone to create a competition and define the conditions for its completion. These competitions are funded by whoever launches them and are based on unsolved problems that are to be solved by combining crowdsourcing, competition and collaboration.

A challenge is an online competition where people all over the world have the opportunity to solve or build a solution. The winner gets prize money, awarded by the entity that created the competition. To help turn a problem into a challenge, some guidelines [2] are provided by HeroX:

- What problem do you want solved?
- Why does this problem exist?
- What breakthrough are you committed to creating?

- What is the "finish line" or bullseye?
- How long will this challenge last from day 1 to day "won"?

These competitions are managed by an HeroX team that takes care of team selection (they choose who enters the competition or not; the criteria for this choosing depends on the requirements initially set for the competition), management and judging.

To participate in a competition, the users must pay a fee; this ensures that the competitors are committed to finding a solution to the problem being tackled. It also creates a sense of assurance to the entities or groups funding these competitions.

A competition´s winning conditions are set on the beginning and are used by the HeroX team to determine the end victor.

The rights to the final solution can differ from challenge to challenge. They can be attributed to the developers, the creators of the competition, HeroX or put under some specific license.

2.2 OpenIDEO

It is a platform that allows for the splitting of the innovation process into phases and building on the ideas of people.

Challenges and programs are created, using crowdsourcing, as a means to tackle problems around the world.

A challenge can last from three to five months and is focused on a single issue that the community can work on and find and develop a solution. A program is a long-term partnership where a specific grand issue (climate change, for example) is tackled and numerous challenges, events or other activities are released [3].

All challenges require financial sponsorship to cover their own costs associated with managing and providing tech and community support. This approach is based on IDEOs design thinking. Tim Brown, CEO of IDEO, states that:

“Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.” [4].

This methodology uses skills people have but get overlooked by the standard/popular problem-solving methods. This concept allows for the final solution to be emotionally meaningful and also functional as it integrates feeling, intuition and inspiration with rational and analytical. There are three concepts to keep in mind: inspiration (is the problem or opportunity that motivates the search for solutions), ideation (process of generating, developing and testing ideas) and implementation (path that leads the project to the real world).

In the end, there is a selection of winners, chosen by the sponsor of the challenge and the OpenIDEO team. This selection is based on the challenge criteria and on the OpenIDEO team’s skills to implement it. All other ideas can be developed further and used/adapted on other challenges that meet their purpose.

2.3 Others

A. Innocentive

Innocentive uses crowdsourcing solutions that are built for business, social, policy, scientific and technical challenges. These challenges are competitions where the objective is to find a solution to a problem that a client (group or company) has submitted into Innocentive. This submission is based on some criteria, relevant information about the problem (Innocentive helps determining what is important or not) [5]. Also, the winner is determined by the entity that created the challenge and also the award. Innocentive can help with the winner selection but ultimately the decision is of who submitted the problem.

After a challenge ends, the whole solution is given to the entity, including the rights.

The problem solving network and tools that Innocentive already has presents a big motivation for groups, companies and other entities to submit their problems and have them being solved by other people. To the solvers (single individuals or teams), the prizes that are awarded are the main motivation to use Innocentive to work on the solving of problems presented in the platform.

B. CodeForAmerica

CodeForAmerica partners with local governments to build open-source technology and train groups of people to improve government services. It focuses on four key government services:

- Health and human services
- Economic development
- Safety and justice
- Communication and engagement

The way CodeForAmerica gets people and governments to participate is through a fellowship program. This program joins technologists and local governments across America for a year, while working full-time. During this period, the technologists become a part of the community, researching user needs, meeting with stakeholders and proposing solutions. This way, with collaboration from the government, it is possible to build technology that is user-centered and data-driven [6].

The final product of this fellowship is, generally, an early stage application that improves a government service or function. The period of fellowship is a way to encourage innovation and improve risk tolerance inside the government.

Every year, eight to ten governments are selected and twenty-four to thirty people are chosen to the fellowship program through a competitive selection. The government selected has to be in the United States and has to want to work on projects involving health, economic development, safety and justice. They also have to provide support to the technologists that are helping and also be able to support the work that these leave by the end of the fellowship.

To enlist in the fellowship as a fellow/technologist, an application has to be submitted through the page in the website of CodeForAmerica.

Usually a fellowship costs 440.000 dollars. Of this investment, 50% is covered by the local government, to cover for expenses of the team (benefits, travel, training, salary). The other half of the investment is raised by the government with the help of corporations, foundations and individuals, which helps cover the costs of management of the fellowship.

C. Hack4Good

Hack4Good [7] is an event where any technology enthusiast can participate.

Each event has problem as its main theme. The goal is to find a way to solve or change people's actions towards this problem. The event is global; in a single day, groups of people around the world gather to build prototypes that address different challenges inside the problem.

The problem is divided into challenges to let people focus on more specific issues instead of trying to find a solution to a broader one, like climate change. These challenges and the problem itself are set by NGOs, government organizations and experts in fields related to the problem.

Teams of solvers have one days to find a solution, create a prototype that tackles the problem and make a deep impact in the world. Judges, in each location, are made up of technological experts and are from fields related to the problem being addressed at the event.

The judging is based on the potential of impact that a solution might cause. After a first selection, a solution will move on to a judging at the global scale, competing with the best selected from other locations with different judges.

There is no specific prize for the winners. At 12 of September of 2014, where the theme was climate change, the solutions selected at the global scale were presented as a part of New York City Climate Change Event alongside with the United Nations Climate summit.

3 Tech4SocialChange

Students often have assignments with mere academic value. If these assignments could be directed to real world problems then not only it would serve as an increase in the assignment's value, but also as a real world work experience.

Teachers sometimes struggle to find exciting work subjects that incorporate all of the essential class material. Having a place where they could find projects or subjects that allow the students to come up with ideas to work on during the course would be a major help. This also works for researchers that have difficulties finding exciting subjects to apply their work, or even share their results with people involved in projects with a real or big impact in the world.

As such, all these people would be making the world a better place while improving the value of their own work. This is Tech4SocialChange´s audience and goal: to bring the academics' technical knowledge closer to solving the world's problems.

In this section we present a prototype (1) that implements the process presented in section I. This prototype consists on a web application that has the following main objectives:

- Create a user
- Create problems
- Create projects associated with problems
- Correctly manage the phases in which a problem is presently in
- Allow researchers to submit their work
- Reference researches in projects

2.1 User perspective

There are three roles already mentioned before: Problem Maker, Problem Solver and Specialist. In addition to these, there is the researcher. This last one is not a role but a type of user, as any user can submit research and thus be recognized as a researcher in the application.

A. Create user

To register a user, it is requested the input of the name of the user, an email to use in the login and a password.

After the registration, an email is sent to the address provided, asking the user to verify its account. This helps in identifying the active users in the application. If, after two days, the user doesn't activate his account, it is deleted.

When the activation is done, the user can login into the application with the email and passwords provided.

The first time the user logs in, it is prompted to choose whether it wants to become a Problem Maker or a Problem Solver, and if he wants to become a candidate to Problem Specialist. This choice can be viewed in Fig. 2.

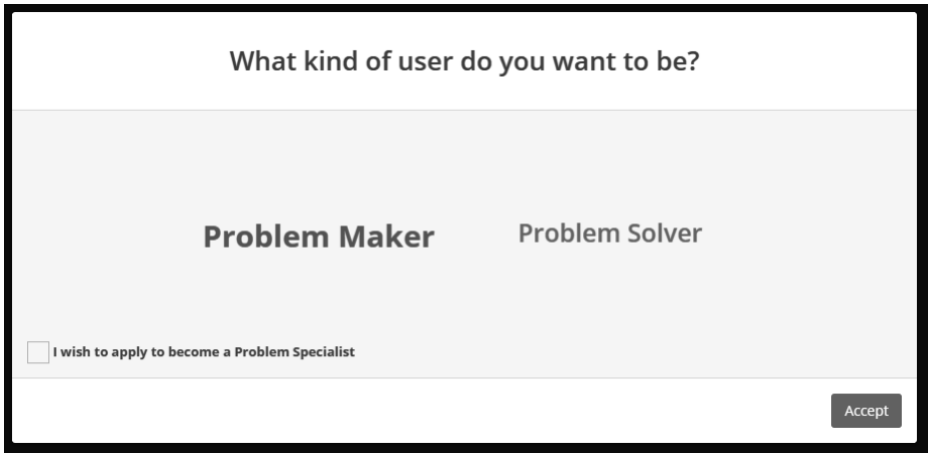


Fig. 2. Choosing the type of user

B. Create problem

If the user chooses to become a Problem Maker, he can create a problem in the platform. To create the problem, only a title is asked initially. Problems have three states:

- Public, every user in the application has access to the problem
- Private, only the Problem Makers in the problem's team and the Problem Solvers in the solution's team can see the problem
- Draft, only the Problem Makers in the problem's team can see it

After submitting the title of the problem, its state is set to private and its phase to the first, with no deadline set.

The problem can be edited in the page shown in Fig. 3. This page asks for the title of the problem, a brief description (or pitch), keywords (which are used when searching for the problem and that represent the fields or subjects where the problem is inserted) and the deadlines for the Questions and Requirements phases. The first deadline must be set before the second and none of the two can be set before the present date.

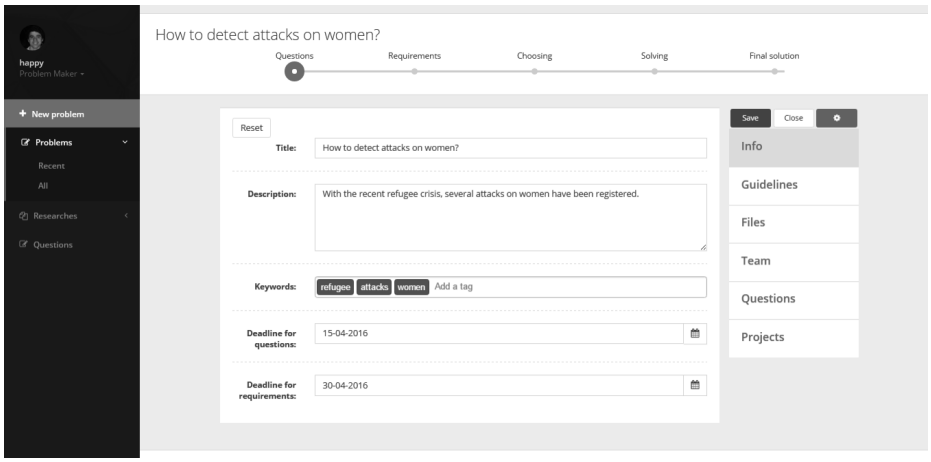


Fig. 3. Editing a problem

The guidelines used to define the problem can also be set in the page of Fig. 4. All the obligatory guidelines (the last two are optional) must be filled to set the problem public and be accessible by other users.

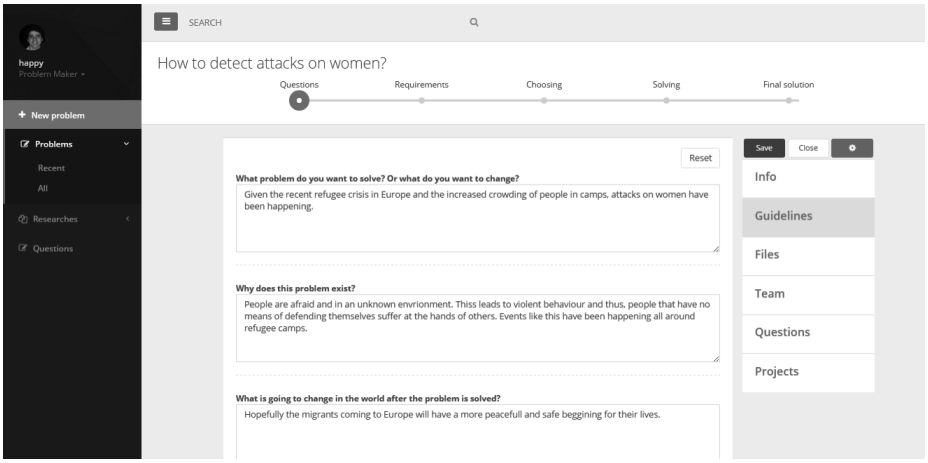


Fig. 4. Editing a problem

Files can be shared with team members and new members can be added to a problem. Another component that can be managed in the problem edit page, are the questions that are posted by users. In Fig. 5 questions are shown to be divided into answered and unanswered. A comment in an unanswered question can be marked as an answer and the question is

moved to the corresponding list. The only users that can mark a comment as an answer are the Problem Makers in the problem's team.

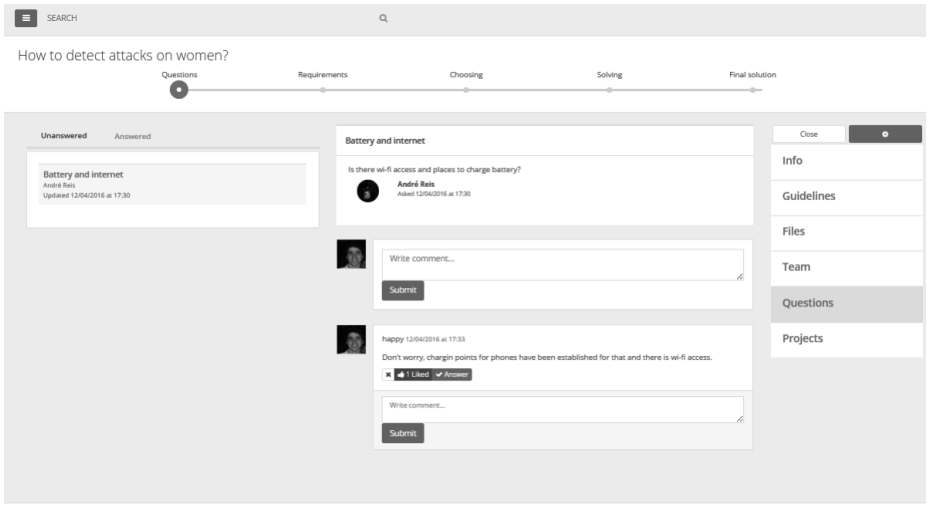


Fig. 5. Questions on problem edititng

When all the obligatory information is set, the problem can be set to public in the settings or editing pages.

The problem profile can now be seen by every user in the platform as it shown in Fig.6. At the top of the page, the problem's current phase is indicated.

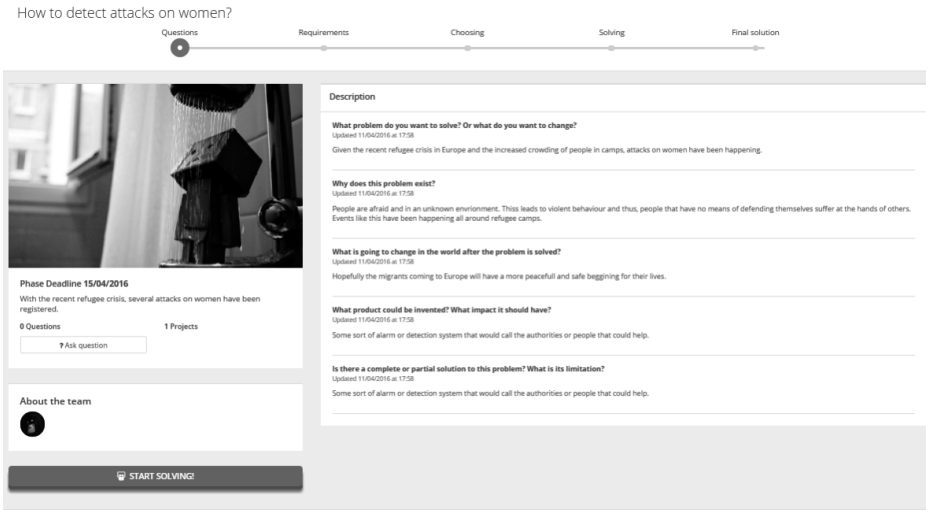


Fig. 6. Problem profile

C. Create project

A Problem Solver can only create a project if it is associated with a problem. This means that he first needs to access a problem profile in order to create an associated project.

Just like a problem, a project only needs the title to be created, being immediately set to private after its creation.

Following the creation is the editing page, in Fig. 7. This page allows the Problem Solver to edit the title and type a brief description (or pitch), keywords representing the subjects/fields where the project is inserted, a full description of the project and an estimated deadline for the completion of the development.

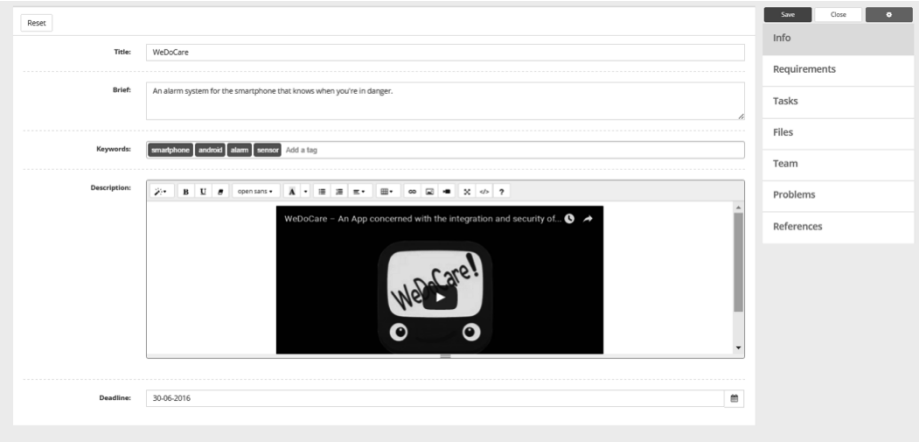


Fig. 7. Editing project

In the editing zone it is also possible to add the project's requirements, as seen in Fig. 8. These requirements are then shown in the project's public profile and can include images, video and text.

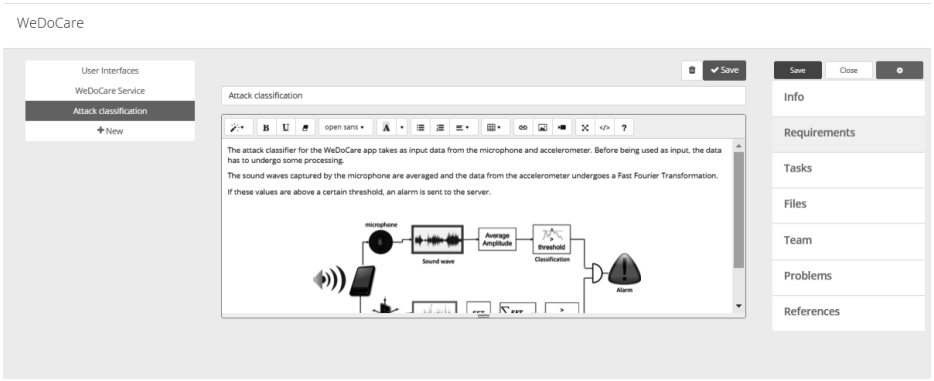


Fig. 8. Project requirements

The Problem Solvers working on the project can also manage the tasks involved in its development, like it is represented in Fig. 9. These tasks have three states: to-do, ongoing and completed. They can also be dragged from one of these lists to the other.

A task needs a title. In fact, it is the only obligatory field; it also possible to add a description, assign one or more persons from the team to complete the task and define a due date.

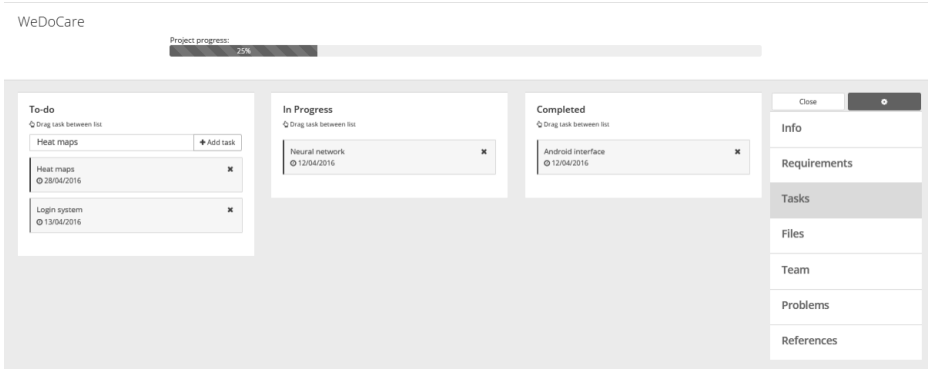


Fig. 9. Project tasks

Like a problem, files and new team members (Problem Solvers) can be added to the project. Also, the problems that the project is associated with (trying to solve) can be listed in the editing. Another component that can be listed are the researches being referenced by the project.

The project's state can be changed in the settings, although to make it public, the project needs a deadline (estimate) for its completion. Also in the settings it is possible to delete or leave the project.

If the project is public, then everyone can access its profile (Fig. 10). Here, the project's profile image (which can be set in the files area in the editing page), title, description, keywords, team and requirements are presented to the other users of the application.

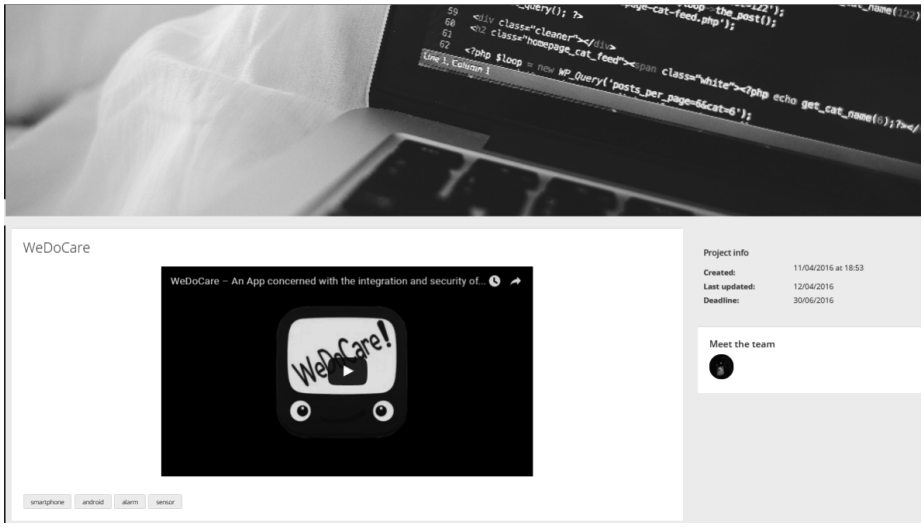


Fig. 10. Project profile

A Problem Specialist not belonging to the project's team can recommend the project as a solution, through the project's profile.

D. Create a research

Any user can create a research by only typing the title of the research. After a research is submitted, its editing area (shown in Fig.11) is made available, allowing the change and input of new information. Title, description and keywords to use in the search for this article can also be changed in this page. The research has two states, public and private. By default, the latter is enabled.

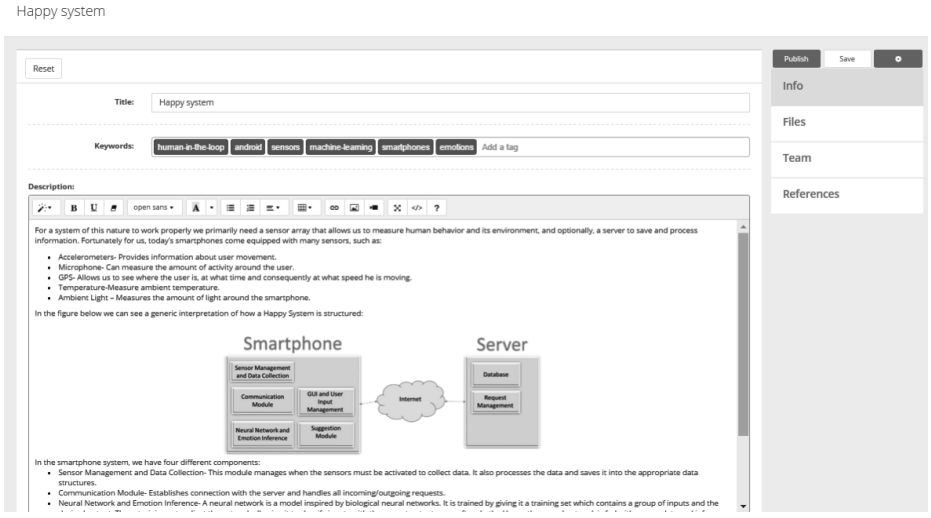


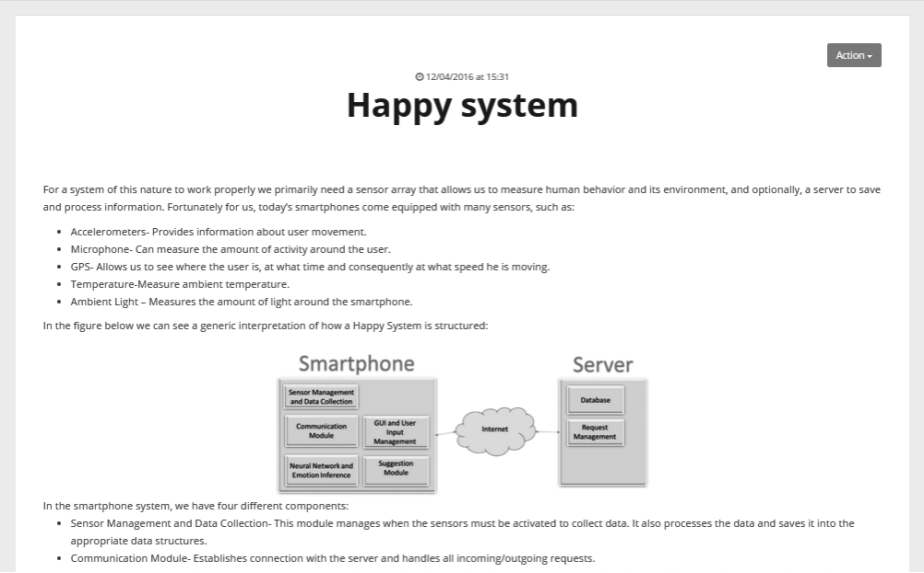
Fig. 11. Editing research

Files can also be uploaded to a research, although, contrary to problems and projects, these files are shared with the community and are considered attachments to the real research developed by the user.

Similarly, to problems and projects, new users can be added to the team of the research. Projects that referenced this research are also listed in the editing area.

When a project is set to public, its profile is provided and shown to other registered users. If the user accessing it is a Problem Solver, then an option to reference a particular research is enabled. Comments by other users can be left in the research's profile.

Fig. 12. Research profile



2.2 Comparison

Table 1 shows how similar aspects of two different platforms work in comparison to Tech4SocialChange. Even though others were studied, only two were included due to being the ones closest to the context of Tech4SocialChange.

Table 8. Comparison with state of the art

	Tech4SocialChange	***HeroX***	***OpenIDEO***
Audience	Students, teachers, geeks and researchers	Anyone with sponsorship	Anyone
Motivation of use	Have problems tackled by experienced people in various areas Work on problems that have a real impact in the world Have research work be applied in projects that impact people's lives	Monetary prizes Sharing of competition-based know-how, for a fee	Solutions need to be sponsored Work on problems that affect the real world
Problem/Project selection and support	Anyone can submit a problem Problem criteria is defined by community and submitters Submitters choose the final solution; they can ask for help that is provided by Problem Specialists Projects only advance to development after they have been chosen. This prevents wasting time and resources building a solution that is not used after	Only accepts challenges that are sponsored Provides guidelines to define the problem An HeroX team manages the competition HeroX team helps in the choosing of a solution. along with the creator of the competition	Only problems that are sure to become projects A team from OpenIDEO defines the criteria for the problem The submitter and the team of OpenIDEO choose the solution according to the challenge criteria and the skills needed to build the solution
What happens when a solution is chosen?	Delivered to the NGO or other entity that submitted the problem Projects can be further developed and used on other problems	Prizes are awarded to the winner and project stays idle	Solutions are delivered to the OpenIDEO team that builds it and delivers it to the problem submitter. The solvers stay idle

		as well as the project

HeroX allows for any sponsored entity to create a challenge/competition, which is normally based on a problem that the entity is currently facing. It provides management and counselling along the way for a certain fee. Also, to participate or access a challenge the user needs to pay, this ensures commitment and also helps in covering the costs of the competition.

OpenIDEO lets anyone submit a challenge or a social problem, to be evaluated and defined more clearly, ensuring that only problems that are sure to become projects are released to the community. Moreover, the selection process of solutions is based on OpenIDEO team's skills. This might result in a great solution being discarded.

Tech4SocialChange is aimed at a different audience, which is interested in the problem's context and the experience and recognition to be gained. Anyone can participate in submitting, defining and solving a problem. Even though prizes aren't awarded when a problem is solved, the Problem Solvers are given full recognition from Tech4SocialChange´s side.

Some additional features are also provided based on the audience:

- All problems and projects are stored in the system and are accessible at all times. Projects can be re-used in different problems.
- Projects that have not been chosen do not stay idle; Problem Solvers can further develop them and present them on other problems.
- A research repository is also provided, letting researchers and scholars submit their work where it can be used and referred in projects and receive comments or ideas that may contribute towards its further development.

However, there are some concepts from problem solving that were adapted from other platforms into Tech4SocialChange.

For example, OpenIDEO's methodology of using skills people have that would otherwise get overlooked by the standard/popular problem-solving methods was taken advantage of. This concept allows for the final solution to be emotionally meaningful and also functional as it integrates feeling, intuition and inspiration with rational and analytical support. There are three concepts to keep in mind: inspiration (is the problem or opportunity that motivates the search for solutions), ideation (process of generating, developing and testing ideas) and implementation (path that leads the project to the real world). The three concepts motivated the creation of the different phases that a problem undergoes until a solution is found.

Also, HeroX's understanding of problem criteria was used to learn the key guidelines on how to better define/explain a problem, previously mentioned in section I.

3 Innovative research issues

As it is important to make a link between the researcher's work and real-world problems, the same link may also be applied a company's projects. As such, a search engine that

makes a matching between research, companies and problems is necessary. A first version of this function is being developed using ElasticSearch - an open-source, scalable, full-text search and analytics engine. It allows to store, search and analyze big volumes of data and is highly used in applications that have complex search requirements.

At a structural level, the matching is done with simple text, matching the titles and keywords that represent the areas or subjects that a certain project/research/problem is inserted on.

Another important research venue is that of the intellectual property of the projects developed. Currently, the projects that are submitted to Tech4SocialChange are completely open-source and anyone can make use of the information and the products made available by the Problem Solvers. Those that do not wish for others to access their work can do so by setting a project as either "private" or "draft" (the first option shares it only with other teams that work on target problem, the second shares it exclusively with the team of the project itself). However, this might not be ideal for companies that wish to participate in Tech4SocialChange. As such, improved models of intellectual property will be object of future study and applied to the prototype.

A related research objective is understanding the language that both companies, entrepreneurs and NGO's have and create a bridge between them: what terms and visual aids can be used to minimize the gap between these three?

There is an interesting approach, presented in [8], concerning web-based collective design platforms. These platforms make use of their community to design and build solutions. OpenIDEO and another platform, Quirky, are studied to determine the main values that such a platform needs in order to motivate users and enhance the quality and diversity of solutions that are built. Tech4SocialChange is such a platform and since the study used, as case study, one of the platforms in the state of the art, it is interesting to determine how these values apply in Tech4SocialChange, which focuses on the academia and social problems, and perhaps further improve these values and/or set new ones.

Another objective is creating a model of specialization in different areas. What this means is that Problem Specialists are not only people specialized in problem definition but can also be specialized in different areas, or subjects, and be recognized as such. This way, projects can receive support from users that have knowledge about their specific subjects. It is a way of introducing help to inexperienced people (students for example) from others with greater experience on the field. This results in both better project results and greater learning experiences for students.

To determine and select the experienced people (Problem Specialists), a points system is currently being developed, and refined, based on the events, actions and achievements of the users (e.g. having a project chosen as a solution).

Nowadays people's interests and lifestyle are increasingly more integrated into the Internet: the Internet Of Things (IoT) uses low-cost technology that has a high potential of solving people's everyday issues in an non-intrusive way. Using this information to better match Solvers and Specialists to problems and researches that have a bigger connection with them is another research objective. Motivate people to work on subjects that interest them more. This would obviously be a major asset to problem solving and help tackling the challenges presented by Problem Makers.

4 Conclusions

There is already a prototype of the application that can be accessed in www.tech4socialchange.org. It was developed by a team of students and researchers of the Department of Informatics Engineering of the University of Coimbra.

By allowing social problems to reach the academic world, we intend to not only solve them but also to approximate universities and institutions to real world situations and create many opportunities and cases of big impact in people's lives, in various parts of the world.

The next steps involve changes according to feedback being received by people that are helping in testing the prototype and also better support to tracking the contribution of people involved in problems, projects and researches.

An important link that it is hoped to be established is with entrepreneurship. How can Tech4SocialChange help the growth and establishment of entrepreneurs by finding situations in which their ideas and projects can be applied?

Acknowledgements

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Appendix B

Forms for National and International Competitions

Form for the HeroX Social Competition

Title
WeDoCare – An App concerned with the security of children and women.

Short description
WeDoCare aims to detect violent attacks against users through a scream recognition algorithm, using the smartphones microphone. It takes advantage of this mechanism to help people by warning nearby citizens that someone is in danger. Helpful locales, like hospitals or police stations, are shown on a map. The map also shows zones where attacks occur more often. When a user approaches such danger zones the application warns the user to make a small detour (avoiding these areas) and to be careful.

Scope of Complexity
How computationally difficult is the solution? How will your idea challenge our platform?

The computational part of our solution is quite complex because it involves machine learning techniques and signal processing algorithms. However, this is not an issue, in the sense that we have already implemented and successfully tested a very feature-complete working prototype.
Our solution will definitely challenge your platform for two reasons: scream recognition has never been attempted before on a smartphone adding to the fact that this application has the potential to change and safe lives.

The Problem and Market Research *
What is the problem that your solution aims to solve? Who is affected by the problem? What is currently being done in an attempt to solve the problem?

Violence resulted in the deaths of 1.28 million people in 2013 alone. Reportedly, 0.3-11.5% of these were women who suffered from sexual assault, in fact, domestic violence has reached high numbers in the last

couple of years. To be more precise, 4,774,000 women experience physical attacks by their corresponding partners, every year. Another type of abuse that has emerged in recent years is bullying, according to statistics reported by ABC News, nearly 30 percent of students are either bullies or victims of bullying, and 160,000 kids stay home from school every day because of fear of bullying.

Currently, police resources do not allow them to always be present when needed, especially in alleyways or less busy streets. Applications that currently exist in the market requires an input from the user, such as a push of a button or a phone call to be made, which is often impossible to do since victims may be taken by surprise or the attacker seizes their mobile phone. This prevents them from asking for help or making a call to the police. We aim to solve these issues by keeping people safe in a collaborative manner and in an automated way.

The Solution *

What is your proposed solution? How does it help solve the problem? Who does it impact? How? Where?

The scream recognition feature can help protect women and children in the most dangerous neighbourhoods from acts of great violence or even sexual abuse by xenophobic citizens or transgressors. The security of women and children is difficult to achieve and most of them turn to their phones in emergency situations trying to call their closest one or the police, but often or almost every time they may not have time or the calmness to react in an immediate-danger situation. With our application the victim can scream when under attack, which will trigger the transmission of an alarm signal to other app users nearby to ask for help.

We want to give the opportunity to people who are willing to provide collaborative assistance. The application also shows on the map areas where crime is more accentuated through intensity heatmaps. Thus, women or children are able to avoid these sites and, at the same time, quickly reach essential locales such as hospitals or police stations. In conclusion, we expect the application to help people stay safe and provide them with a tool to walk around a city without being worried of being robbed or raped. This

is achieved through collaborative altruism, without the need for grabbing the mobile phone or using external buttons. We also intend for people to able to make friends by thanking the ones who helped them in times of need.

CORE Usage *

How does your proposed solution use the CORE platform? List and describe the features of CORE that make your solution possible.

Our application has been developed using various open source technologies from enterprises, such as Google. The application is deployed on our own servers at the University of Coimbra which can serve up to thousands of request per second making the application easily scalable, secure and redundant. Moreover, we can easily adapt our servers to a more CORE technology to reduce costs and add new functionality.

Innovation *

This application is unique in the way that it uses smartphones to recognize screams for the detection of emergency situations in distressing scenarios, which is something that has never been attempted before. This mechanism is implemented in the person's own mobile phone which brings great advantages since these devices are used by the vast majority of the population, so there is no need for extra accessories. Often, when travelling or walking around a new city, the only device people have is their mobile phone, so we find it essential that this mechanism is embedded into it. The application also contains an innovative beacon system so that communication with nearby or surrounding people isn’t limited to an internet connection, this way any user can stay safe even if there isn’t any mobile network, thereby increasing the effectiveness of our application.

Practical Usability *

How can it be used by specific users to achieve the goals you've identified? How feasible is it for relevant nonprofits to adopt this solution?

From the user's point of view, the application is quite simple to use. The app contains a simple and intuitive UI based on Google’s new Material Design guidelines. Since the app is always listening to our surroundings and the processing segment is done in real time the user just needs to have the mobile phone in his pocket and hence scream detection is always

achievable. Once an alarm is received, the application sends a notification alerting the user that someone is in danger nearby. By simply clicking the notification the user can view the location of the person in danger on the map. All this makes our application practical and easy to use without any complication.

For non-profit organizations this application can help combat many of the problems that they face, for example, associations that are against or fight domestic violence or bullying situations. It is also possible to work in collaboration with municipalities or police departments, with the same purpose. These associations can easily distribute and promote the application to the ones in need.

Image

Form for the European Social Innovation Competition

1. Project name (10 words max).

WeDoCare – An App concerned with the integration and security of refugees.

2. Tweet your idea (140 characters).

Are you in danger? WeDoCare detects violent attacks and warns nearby citizens that you're vulnerable. It also shows danger zones and helpful locales on a map.

3. Provide a summary of your idea, highlighting how it aims to facilitate the reception and integration of refugees and/or migrants in Europe (100 words max).

WeDoCare aims to detect violent attacks against users through a scream detector, using the microphone and the accelerometer. It takes advantage of this mechanism to help people by warning nearby citizens that someone is in danger.
When one user helps another, a connection is established and the app facilitates the trading of contact information, thus, facilitating integration and socialization.
Helpful locales, like hospitals or police stations, are shown on a map. The map also shows zones where attacks occur more often so user can avoid these areas.

We provide a video demonstration of our idea:
https://youtu.be/D6mEXun8Bbw

4. Explain why your idea is innovative in the country or context where it will be implemented. Alternatively, if your idea is based on an existing concept, explain how your idea differs to this (250 words max).

This application is unique the way that it uses smartphones to recognize screams and agitated movement for the detection of emergency situations in refugee scenarios, which is something that has never been attempted before. This mechanism is implemented in the person's own mobile phone which brings great advantages since these devices are used by the vast majority of the population, so there is no need for extra accessories. Often, when travelling or walking around a new city, the only device people have is their mobile phone, so we find it essential that this mechanism is embedded into it.
The application also contains a beacon system so that communication with nearby or surrounding people isn't limited to an internet connection, this way the immigrant or refugee can stay safe even if there isn't any mobile network, thereby increasing the effectiveness of our application.
Finally, we want to add that the application will respect all privacy issues and user information will only be shared if given consent.

5. Describe clearly how your idea is expected to have an impact (250 words max).

Since the immigrant is new to the city the application shows on the map areas where crime is more accentuated through intensity heatmaps. Thus, migrants are able to avoid these sites and, at the same time, discover essential locales such as hospitals and police stations, establishing and locating themselves in the new city. The application also helps refugees prevail on their journey to Europe.
The scream recognition feature can help protect refugees in Europe from acts of great violence or even sexual abuse by xenophobic citizens or transgressors. When under attack, the victim can scream and move abruptly, which will trigger the transmission of an alarm signal to other app users nearby to ask for help. Additionally, when a person helps another, the app creates a connection, this is, the app "senses" that a possible helper is nearby and if so it asks the user if he wants to trade numbers with that person, a bond is then made with the two individuals in question.
The integration of immigrants, such as refugees, is sometimes difficult and most of them turn to their phones and social media for affection. We do not want, by any means, create another social media or messaging platform. We only want to facilitate the connection between people who are willing to

help and immigrants with difficulties to adapt to a different country or lifestyle.
In conclusion, we expect the application to help immigrants integrate more easily and make good friends thus decreasing their time of adaptation.

6. Indicate at what scale your idea will operate initially and how it could be implemented at a larger scale in the future, for instance in another region of your country or in another European country (200 words max).

Scaling a new mobile app to support throngs of users is never easy. In the world of crowd-sourcing mobile apps, how fast an app can scale can mean all the difference. Initially we'll pick a high-traffic placement which will perform well at the user acquisition level such as countries or regions with high immigration level. Once we get an understanding of what success cases look like from those placements, we can better tune the application to shoot towards new regions.
Our application is a distributed tool which can grow easily. The distribution is linked to the movement of people, which is the intermediary of the product. The more users we have the better it works, since our database will become richer.
We also want to mention that there are many people in Europe willing to help and enrich our platform.

7. Specify how your idea could be sustained over the next three years (200 words max).

The world as we know it is dynamic, people are always on the move seeking a better lifestyle. This progress has turn Europe into a melting pot, making it common to find someone who feels they do not belong. Taking into consideration that the reality of immigration is not reversible and the need to facilitate adaptation and international relationships will always be present, our product is timeless and therefore will be sustained while emigration exists.

Our app will motivate volunteers since the app will include a leaderboard to distinguish users who help more and compare the users progress with that of

their friends. This is a great way to encourage social competition and make the user feel good by helping others.

In a more technical perspective the application is deployed on our own servers which can serve up to thousands of request per second and sustain that level for a long period of time.

Financially, our revenue stream will focus on advertising, enhanced by location data allowing marketers to attract nearby audiences and help publicize their businesses to new citizens, and patronage through partnerships who are willing to support the cause.

Form for the *EDP Solidária* competition

1. ENTIDADE PROMOTORA

1.1. Nome: Universidade de Coimbra

1.2. Missão: A Universidade de Coimbra é uma instituição de criação, análise crítica, transmissão e difusão de cultura, de ciência e de tecnologia que, através da investigação, do ensino e da prestação de serviços à comunidade, contribui para o desenvolvimento económico e social, para a defesa do ambiente, para a promoção da justiça social e da cidadania esclarecida e responsável e para a consolidação da soberania assente no conhecimento.

1.3. Áreas de intervenção: Entre outros, contribuir para a concretização de uma política de desenvolvimento económico e social sustentável, assente na difusão do conhecimento e da cultura e na prática de atividades de extensão universitária, nomeadamente a prestação de serviços especializados à comunidade, em benefício da cidade, da região e do país.

1.4. Com fins lucrativos: Não

1.5. Morada: Paço das Escolas, 3004-531 Coimbra

1.6. Código-postal: 3004-531 Coimbra

1.7. Localidade: Coimbra

1.8. Concelho: Coimbra

1.9. Telefone: 239859810/20/40/90

1.10. E-mail: gbreitor@uc.pt

1.11. Natureza Jurídica: Pessoa Colectiva de Direito Público

1.12. Data da constituição: 1290-03-01

1.13. NIPC: 501617582

Outras entidades: Associação de Apoio à Vítima (APAV), SOS Racismo

2. RESPONSÁVEL EXECUTIVO DA ENTIDADE PROMOTORA

2.1. Nome: Amílcar Celta Falcão Ramos Ferreira, Vice-reitor

2.2. Telefone: 239859810/20/40/90

2.3. Telemóvel:

2.4. E-mail: gbreitor@uc.pt

3. DADOS DO GESTOR DO PROJETO

3.1. Nome: Jorge Miguel Sá Silva

3.2. Telefone: 239790000

3.3. Telemóvel: 919408785

3.4. E-mail: sasilva@dei.uc.pt

4. DADOS DO PROJETO

4.1. Nome: WeDoCare

4.2. Área geográfica: Portugal

4.3. Problema(s) identificado(s)

A violência e exclusão sociocultural são transversais a vários países e Portugal não é exceção. Infelizmente os órgãos de comunicação social inundam-nos diariamente com notícias de crimes contra mulheres, práticas de *bullying*, ataques a minorias étnicas, entre outros. Infelizmente, alguns grupos sociais e algumas minorias tendem a ser mais vulneráveis e a isolar-se sobre si mesmas, aumentando ainda mais o problema.
Este trabalho pretende tirar partido dos recentes avanços na área da Internet das Coisas, do *mobilephone sensing*, dos novos sistemas de comunicação e das técnicas de *machine learning* para ajudar na resolução de um drama a que se continua a assistir: o sofrimento de grupos mais vulneráveis. Este é um problema por vezes negligenciado e não havendo uma solução eficaz, a dificuldade persiste. O projeto WeDoCare pretende ajudar a mitigar o problema, usando meios tecnológicos para proporcionar maior proteção a estes grupos potencialmente mais susceptíveis.

4.4. Descrição do projeto
[Explicitando a(s) Solução(ções) para os problema(s) identificado(s)]

WeDoCare é uma aplicação para telemóvel que deteta, de um modo automático e em tempo real, ataques violentos contra pessoas socialmente suscetíveis, recorrendo a novas técnicas de *machine learning*. O WeDoCare também contém um sistema inovador baseado em *beacons Wifi* através do qual os sinais de alerta são enviados a pessoas que se encontrem até 100 metros de distância, mesmo que a vítima e estas pessoas nas proximidades não possuam ligação à Internet, por limitações económicas ou por falta de cobertura da rede. Na ocorrência de um ataque é apresentado às pessoas que se encontram nas imediações o mapa com o local da agressão, complementado por uma seta dinâmica para apoiar a deslocação rápida do ajudante para o local do ataque.
O WeDoCare já foi testado em protótipos. No seguinte link é apresentado um filme do protótipo implementado na Universidade de Coimbra:
https://youtu.be/_RmFV3QQ6uM

4.5. População-alvo

4.5.1. Género (Feminino; Masculino; Ambos): Ambos

4.5.2. Faixa etária (Não específico; Crianças; Adolescentes; Adultos; Terceira Idade): Não específico

4.5.3. Perfil [Não específico; crianças e jovens em risco; desempregados; dependentes (drogas/álcool/outras substâncias); estudantes; emigrantes; pessoas com necessidades especiais (deficiência mental); pessoas com necessidades especiais (deficiência física); pacientes (doenças crónicas/raras/outras); minorias étnicas; minorias de género; reclusos; pessoas sem abrigo; vítimas de violência doméstica]

Pessoas socialmente vulneráveis - um protótipo do WeDoCare foi desenvolvido e testado, inicialmente, em refugiados e minorias étnicas.

No entanto, é objectivo deste projeto que o WeDoCare seja estendido a outros cenários e a outros grupos sociais, nomeadamente crianças e jovens, mulheres vítimas de violência doméstica e pessoas idosas.

4.6. Beneficiários diretos

4.6.1. Número: 50

4.6.2. Método utilizado para estimar o número:

Segundo dados da PSP em 2011, por exemplo, existiram 18.493 ocorrências registadas de maus tratos. No entanto, segundo o relatório de 2014 da APAV 16.881 dizem respeito a atos de violência doméstica. Ou seja, se forem contabilizados outros crimes, como discriminação racial, violações, agressões, homicídios, o número total de crimes cresce significativamente.
No caso das pessoas idosas vítimas de crime, o acesso destas a serviços de apoio e ao próprio sistema de justiça penal, é mais difícil. Este é um problema "escondido" e os indicadores pecam por defeito.
No entanto, estes números são relativos a potenciais utilizadores da aplicação WeDoCare no território nacional. Na presenta candidatura propomos 50 beneficiários diretos, ou seja pessoas que irão testar a nossa aplicação durante o período de execução do projeto para garantir o seu correto funcionamento.

4.7. Duração do projeto: 12 meses

4.8. Parcerias concretas para financiamento e/ou operacionalização do projeto

A presente candidatura conta com a participação da associação SOS Racismo e da Associação de Apoio à Vítima. Estas são duas associações que lidam diariamente com o problema da violência, em diferentes vertentes, e que irão desempenhar um papel de extrema importância no projeto proposto, nomeadamente na fase da especificação dos requisitos e dos testes.
Por outro lado, espera-se ainda que este projeto promova o envolvimento da comunidade académica e científica em mais ações de natureza social. Assim, esta candidatura propõe-se, ainda, implementar um Laboratório de Investigação Social (Tech4SocialChange) baseado na Web que permita, por um lado, a qualquer cidadão o registo via Web de problemas e desafios tecnológicos e, por outro lado, a consulta a estes registos por parte de investigadores e estudantes nas áreas das novas tecnologias que tenham interesse em conhecer e solucionar desafios tecnológicos reais, preferencialmente usando tecnologias de baixo custo.

5. ORÇAMENTO DETALHADO DO PROJECTO

5.1. Despesas de investimento

Equipamento informático: 18.000€ UC
Dois servidores (principal e de backup - Dell PowerEdge R530 E5-2609 | 8GB | 1TB), 2 portáteis (Macbook Pro 13"), 50 telemóveis Android (Alcatel One Touch Pop 3), 50 cartões SIM.

5.2. Despesas de exploração

Custo RH da entidade promotora: 11.485€
Recursos Humanos da UC e da APAV

Honorários: 14.396€
Honorários para um jovem investigador da UC dedicado 100% ao projeto e um recurso humano para APAV.

Outros (viagens): 700€
Viagens para reuniões e testes

6. INFORMAÇÃO ADICIONAL

Com base no descrito nos pontos 4 e 5, responda assertivamente às seguintes perguntas:

6.1. Foram equacionados mecanismos para captar mais parceiros ou contribuições para a continuidade do projeto após o término do apoio da FEDP?
Em caso afirmativo, indicar quais serão esses mecanismos.

Atualmente não existe nenhum repositório onde o cidadão comum possa colocar problemas de resolução tecnológica. Por outro lado, professores e investigadores debatem-se com dificuldades em encontrar problemas para os exercícios das disciplinas que leccionam e para alguma da investigação que produzem.
Para dar continuidade a este projeto, propõe-se desenvolver um Laboratório de Investigação Social - Tech4SocialChange, para recolher informação relativa a problemas sociais e disponibilizá-la ao meio académico. Proporcionando uma base de dados/repositório de problemas com impacto social direto na sociedade, estão reunidos os meios para a continuidade deste projeto e para a criação de outras soluções de cariz social no futuro.
Os estudantes são também um elemento importante no Tech4SocialChange ao dar-se-lhes oportunidade de trabalhar em projetos reais e de valor social.
Foi já implementado na Universidade de Coimbra um protótipo do Tech4SocialChange que pode ser testado em: www.tech4socialchange.org.

6.2. O projeto poderá ser escalável para alcançar um maior número de beneficiários? Em caso afirmativo, indicar se este aspeto foi considerado no projeto apresentado.

A aplicação WeDoCare baseia-se num paradigma distribuído e, como tal, é facilmente escalável. Por outro lado, quantos mais utilizadores aderirem ao WeDoCare maior será a base de dados de informação suportada e maior o número de voluntários disponíveis para ajudar.

Ao Tech4SocialChange podem ainda associar-se empresas que poderão financiar alguns dos desafios sociais introduzidos. Consegue-se, desta forma, não só tornar os desafios mais aliciantes para os investigadores como encontrar financiamento para a implementação prática das soluções encontradas.

6.3. A solução pode ser replicável noutro local geográfico?
Em caso afirmativo, indicar se este aspeto foi considerado no projeto apresentado.

O WeDoCare é um sistema distribuído e, com facilidade, pode ser implementado em qualquer parte de Portugal e da Europa. O sistema de detecção de ataques e alertas funciona em qualquer situação, mesmo quando não existe ligação à Internet. Esta só é necessária quando se pretende aceder aos mapas e aos respectivos locais de apoio.
A plataforma de apoio Tech4SocialChange apresenta também uma considerável autonomia em qualquer situação, seja na recolha de informação de um problema ou na sua solução. Esta autonomia é conseguida exatamente pelo uso de *crowdsourcing*, não sendo necessário uma equipa a gerir cada fase do problema.
O Tech4SocialChange diferencia-se ainda por não ser necessário qualquer tipo de pagamentos para utilizar as funcionalidades do sistema. O acesso a um repositório de temas interessantes e a oportunidade de ver o seu trabalho aplicado no mundo real, motiva quem constrói e desenvolve projetos a utilizar o Tech4SocialChange.

6.4. Como será concretizada a monitorização e avaliação do projeto?
Descrever sucintamente o(s) procedimento(s) para monitorizar e medir os resultados obtidos.

O grupo proponente da presente candidatura tem já uma vasta experiência na gestão de projetos nacionais e internacionais como o: FP5 E-NET, FP6 NoE E-NEXT, FP6 IP EuQoS, FP6 IP WEIRD e FP7 Ginseng.
Para este projecto será delineado um planeamento com etapas e metas a cumprir. Os resultados serão medidos através de *releases* periódicas juntos dos parceiros.
Serão realizadas reuniões semanais e reunião informais diárias entre todos os membros da equipa que desenvolve o WeDoCare. Nestas reuniões serão

analisadas as tarefas desenvolvidas nas últimas semanas e agendadas as próximas tarefas.
A equipa de desenvolvimento estará em permanente contacto com a APV e a SOS Racismo, principalmente na fase da definição de requisitos e na fase de testes.

Form for the Nokia IoT Open Innovation Challenge 2016

Submission Title:
HugMe - IoT for All

Description of your submission:

With our project we will develop an application that assists its users to better identify and understand their own emotional states in a non-invasive way.
Additionally, the application will also proactively advise the user on actions that he can take to improve his emotional state, such as taking a walk, relax or helping nearby citizens in need.
To do this, the application collects information through the smartphone's sensors such as ambient noise through the microphone, agitation through the accelerometer, position via GPS, weather status via a web API and cross information from social media such as Facebook. It can also use additional hardware to collect information, such as collecting heart rate information through a smart shirt or a fitness band if the user has one paired with the smartphone.
By using machine learning techniques, we aim to better understand the impact of workload stress, sleep patterns, physical activity, socialization and varying emotional states to improve the well-being of each individual user in a personalized fashion, at scale.

Which problem does your submission solve?

We live in a culture obsessed with youth, financial success and achieving happiness. This mindset leads many people that seek to live meaningful and authentic lives to sometimes go through phases of depression in which they experience high levels of anxiety and stress.
This focus on the pursuit of happiness has led to unhealthy emotional behaviours. Many people try to force themselves to feel happy by denying to acknowledge any negative feelings whatsoever. They avoid dealing with sadness and often experience depression for long periods of time. Depression that remains undiagnosed, unrecognized, untreated or mistreated.
Stress is another strong negative emotion that many people feel in their daily lives. While some levels of stress are normal, excessive stress can interfere with

productivity and performance — and impact both physical and emotional health. One's ability to deal with stress can often be the difference between success and failure at work or the difference between happiness and sadness.
The application we propose seeks to measure the user's mood to detect early signs of depression, and when appropriate to lead the user to proactively improve his health. This is done by suggesting opportunities for the user to socialize that may lead to a more positive state of mind, e.g. by attending social events, or participating in locally organized picnics.
This application can potentially also assist companies in assessing the emotional state of their employees, and help in the search for new motivation strategies.

What are the benefits of your submission for Nokia, for IoT ecosystem, for end-users?

The IoT industry, in general, tends to focus mainly on integration and networking of intelligent devices. To be more relevant and useful, the applicability of the IoT industry must go beyond simply sensing and communication between sensors or devices. In addition to allowing us to better know and control our environment IoT must also make it possible to use this information to intuit and infer new conclusions about human behaviour that are difficult to reach by other means. IoT should take human element into consideration and provide in large scale the sort of personal intuitions that were once only available with extensive one on one observation.
This is the type of benefit that our application brings to the IoT ecosystem, to provide the user with a better understanding of his psychological state by passively monitoring his day to day actions, and to help him to modify his behaviour, leading to improvements in his psychological state, by suggesting activities that are considered to be beneficial for him at that moment.
In a perfect future scenario, the human element and behaviour will be no longer be considered an external and unknown factor but become an integral part of the IoT. The system will infer the user's intents, psychological states, emotions and actions through sensors in a constant feedback loop that is personalized by learning the specificities of each individual user, while at the same time benefiting from the aggregate knowledge gained by interacting with the full IoT.
There are significant advantages for the end user besides the heath issue that is the target of the current applications. This submission is materialized in the form of a cell phone application. This means that as long as the user has a smartphone (most users already have one and the trend is for a significant part of the population to have its own smartphone) he will have no need for additional hardware such as computers or dedicated sensors. The application uses the computational power of the smartphone itself and the sensors that are also included in the smartphone,

meaning that the user will have no need to purchase additional hardware to enjoy the benefits of the application. If the user does choose to purchase additional hardware, the application will be able to use additional external sensors like those included in smartshirts or the PPG sensor in a smartwatch; however the computational burden will continue to be performed on the smartphone alone because these devices have evolved considerably in recent years when it comes to processing power. The fact that this type of technology helps the user to improve his quality of life in an unobtrusive way is also an additional advantage.

What is the competitive advantage of your solution?

Mobile apps deployed through app stores are gaining influence and momentum within the business world. In many cases, these applications provide a more flexible framework and a better way to control and manage institutional content.
From a financially sustainability perspective, a mobile applications provides unique advantages in marketing to consumers/users. The content can be delivered asynchronously and be consumed when it best fits the user's preferences. Because the application uses push notifications, 100% of the users will be subject to the advertisement, so long as they continue to use the application. Additionally, because this application addresses a specific problem with well-defined types of users, it makes it easier to target companies that wish to address this user base. Companies are always ready to invest in reaching targeted consumers directly and this application provides them with a platform to do just that.

P**lease describe your business model:**

Our business model is one frequently used in the mobile applications industry. The application shall be free to use, so as to maximize the number o users of the application.
In this way we will gather a large user base that we can use to gather statistical information and to help he application to learn to identify different states of mind.
Additionally we will sell the ability to advertise on the application to companies that wish to address the application user base, be it to promote their products/services/events, thus creating the necessary cash flow to support the application's costs and produce profits.

Appendix C

Detailed Buisness Plan for the European Social Innovation Competition

Detailed plan

1. About you / your organisation

- Name: University of Coimbra (Portugal)
- Contact Person: Jorge Sá Silva
- Contact Details: sasilva@dei.uc.pt
- Website: https://wedocare.dei.uc.pt/

2. Executive summary

WeDoCare uses the smartphone's microphone, to identify in an automated way and in real-time, situations of violent attacks against its users. This is done by using machine learning techniques to detect screams. The application sends out indications to nearby citizens warning that someone is in danger, without depending on an Internet connection. The application has also a map that shows helpful locales such as hospitals and police stations, as well as dangerous areas that should be avoided. The application also warns the user whenever he approaches one of these dangerous zones.

We have already implemented a first prototype that is presented in next figures:

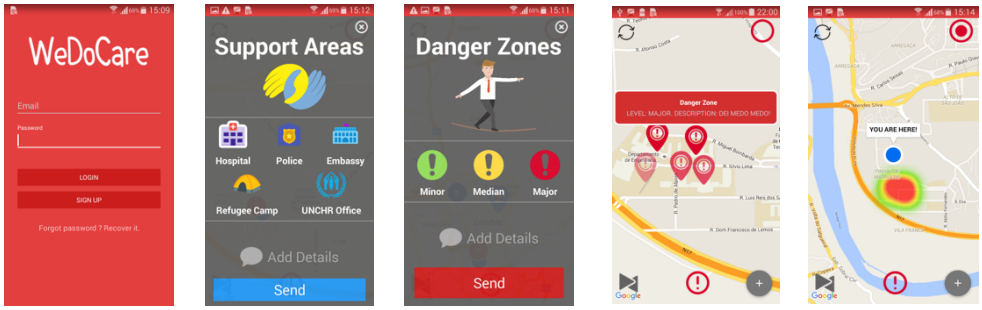

Fig 42 - Application screenshots.

The business plan is to develop the application in way that it becomes self-sustainable. This will be achieved by allowing municipalities and other public services to pay to publicize their initiatives that target the application's demographic as well as locations that they wish to make known and that WeDoCare's users might find useful. We approach the application development as a business, that must strive for profitability to guarantee its own sustainability. Through developing the application as a sustainable business we can continue to provide the service indefinitely and future costs associated with scaling the service can be covered without the need for further funding.

3. The idea

a. The issue

So far this year, more than 644,000 refugees and migrants have arrived in Europe by sea. According to the United Nations for Human Rights (UNHCR), of these, slightly over a third – 34 per cent – are women and children. They are particularly vulnerable to abuse as they transit Europe, especially in overcrowded reception sites, or in the many locations where refugees and migrants gather, such as parks, train stations, bus stations and roadsides. Refugees, migrant women and children travelling on their own, are also at heightened risk of being attacked as they move through Europe, sometimes at night, along insecure routes or when they are forced to stay in places that lack basic security. This is a neglected problem and an effective solution has yet to be achieved.

With all the violence that has emerged in the world, we want to take action and help save lives of innocent refugees, women and children, as well as provide them with a safe route to Europe. We want to prevent sexual abuse in the refugee camps, stop the violence that occurs in many country borders and increase security even in the most deprived locales.

Taking advantage of new technologies, we propose to reduce this problem in two ways, which will lead refugees and migrants to feel safer in traveling through Europe, and to their better integration:

1. By reducing the number of attacks – If we can help refugees and migrants to identify the areas where attacks are likely to occur, they can choose

travel paths that go around or avoid those areas altogether, therefore avoiding possible attacks.

2. When an attack takes place we can warn people in surrounding areas, so that they come help and stop the attack as soon as possible, avoiding damage to the targeted refugee or migrant. On the other hand, when one user helps another, an emotional connection is established and the application facilitates the trading of contact information, thus, facilitating integration and socialization.

We provide a video demonstration of our prototype: https://youtu.be/D6mEXun8Bbw

This application is unique the way that it uses smartphones to recognize screams and agitated movement to detect emergency situations in refugee scenarios. This is something that has never been attempted before. This mechanism is implemented in the person's own mobile phone. This brings great advantages because the vast majority of the population already uses these devices, meaning that there is no need for extra hardware or accessories. Often, when travelling or walking around a new city, the only device people have with them is their mobile phone, so we find it essential that this mechanism is embedded into it.
The application also contains an innovative beacon system that allows mobile phones to communicate with other mobile phones nearby. This makes it possible to communicate with surrounding people even when there is no Internet connection available. This way the refugee or migrant can stay safe even if there isn't any mobile network, thereby increasing the effectiveness of our application.
WeDoCare will respect all user privacy, and his information will only be shared with his consent.

b. Your theory of change

ACTIVITIES	ASSUMPTIONS	OUTCOMES	IMPACT
	INNOVATION IMPACT		
5. Please list the key activities you need to carry out to achieve your outcomes and impact	**2b.** What are the assumptions behind these outcomes?	**2a.** What innovation do you aim to create?	**1.** What is your ultimate impact goal? • RMs avoid attacks

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Refugees and Migrants (RMs) install and run the existing WeDoCare application prototype that is already ready for testing.RMs accept the default Google App Story policy (auto update apps when a new release is launched).
RMs answer the feedback surveys (Their feedback is crucial to improve and adapt our application.)

</td>
<td>

RMs need to have a phone.
RMs need to use the WeDoCare application (in significant numbers).
RMs need to find our application useful.
European people who want to help also need to install the WeDoCare application in their phone (in significant numbers).
Companies and public entities will accept to use and sponsor our application.

</td>
<td>

If a RM is attacked, WeDoCare detects the attack automatically, in real time.
If attacked, RMs receive help from other refugees and general European people.
The RMs exchange contacts with the other RMs or Europeans that helped them (using the WeDoCare app), for future socialization, thus benefitting from the connection created when one person helps another and feeling more supported and integrated.
RMs will identify danger areas where attacks occurred.
RMs seek safe heaven
The RMs are permanently connected to the community, recognizing the benefits of WeDoCare’s innovative and free system that does not need an Internet connection.

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RMs are helped if they are attacked
RMs socialize more with Europeans and with previously unknown RMs.
The damage caused to RMs by attacks is reduced.
RMs feel safer while travelling through Europe.
RMs feel more integrated because of their socialization with otherRMs and with Europeans.

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<td colspan="2"><u>INNOVATION CAPABILITIES</u></td>
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<td>3b. What are the assumptions behind these outcomes?

Users like competition when it is targeted towards positive goals.
Data collected on the app about RM's statistics is useful for the police and for governmental entities to improve their knowledge about refugees and migrants, and to implement strategic decisions.

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<td>3a. What capabilities do you aim to stimulate?

European volunteers will feel motivated by the gamification elements to be introduced in the WeDoCare application..

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<tr>
<td colspan="2"><u>INNOVATION ECOSYSTEM</u></td>
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<td>4b. What are the assumptions behind these outcomes?

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<td>4a. What influence do you aim to have on the ecosystem?

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b. Having an impact

Mobile phones have become personal computers that serve as personal assistants helping us to be more efficient in everyday tasks. They are versatile computational resources with great sensing capabilities. Nowadays mobile phones are ubiquitous even in underdeveloped countries where poverty is high. Even the cheapest mobile phones have flexible sensors, such as the microphone. Their advanced capabilities reduce the need for extra accessories and other devices. By only using smartphones our solution increases its effectiveness within populations living in debilitated economic situations which would be hard pressed to buy extra hardware on top of what they already possess.

Smartphones embody an ideal solution to the problem at hand. Any smartphone can be turned into a personal security device, allowing users to detect emergency situations around them, 24 hours a day.

With WeDoCare we propose to use the smartphone's sensors to help refugees and migrants (1) avoid areas where they are likely to be attacked, (2) receive help from nearby people if they are attacked and (3) reach safe heaven (police station or hospital) when fleeing an attacker or seeking treatment.

Migrants that were previously attacked can identify the locations where they were attacked, and in this way warn other migrants that the area is dangerous should be avoided if possible. Attacks reported to local authorities can also be inserted in the WeDoCare database. In fact, the software will identify in real time the areas where attacks are most likely to occur, by using deep learning and machine learning algorithms that consider the number of previous attacks in each area, and the time passed since each attack. The result will be displayed as red areas in a map (based on google maps) so that migrants can select the best/safest path to go to their destination, avoiding attacks.

If an attack takes place, WeDoCare recognizes the user's screams and tries to alert nearby people who also have WeDoCare installed in their phone. In addition to the Internet connection (if available), the application uses an innovative beacon system based on wireless network meshes to alert other nearby users. By foregoing the need of Internet connection or even mobile network signal, we increase the number of people that may be warned of the attack, increasing the effectiveness of our application.

However, there is a catch: to detect the screams during the attach the monitoring should be carried out continuously. This means that the monitoring process may easily drain the smartphone's battery if the detection algorithm and monitoring intervals aren't carefully designed to reduce power consumption. Thus, we took

battery consumption requirements very seriously, and created an application that is both lightweight and efficient. We will further investigate which time interval between sequences of sensor readings and data processing, β, is the best to extend the smartphone's battery time. If the interval β is high, there will be less probability of catching an attack but less battery drainage; on the other hand if β is small, it is more likely for the app to detect alarm events, but we suspect that the battery drainage will be more substantial. To better understand this, we will record the battery's usage percentage value over time for different β intervals and adjust the application throughout multiple update versions do be deployed automatically through the Google Store.

We decided to introduce gamification elements, which are pervasive in many contemporary cell phone applications, because they stimulate users to return to the application. Frequent use increases the chance that users will spread the word to their friends leading to more WeDoCare users. It is not our intention to transform WeDoCare in to a game, but we feel that these gamification elements may be beneficial in attracting more users (especially Europeans) which will benefit the community.

The following table to shows our key targets, indicators and outcomes. The timeframe for the targets is 24 months compared to initial survey data, unless stated otherwise.

IMPACT GOAL	**INDICATORS**	**TARGETS**
RMs avoid attacks	In-app survey – % of users attacked	75% reduction
RMs are helped if they are attacked	In-app survey to verify if the user has received help	50% of users attacked receive help
RMs socialize more with Europeans and with previously unknown RMs.	Number of contacts exchanged per user (measured automatically)	5 contacts exchanges per user per semester
The damage caused to RMs by attacks is reduced	In-app survey to verify if the user has received help that stopped the attack while it was occurring.	40% of users attacked receive help that stops the attack while it is occurring
RMs feel safer while travelling through Europe	In-app survey to measure the user's feeling of safety while travelling.	75% increase

RMs feel more integrated because of their socialization with other RMs and with Europeans.	In-app survey to measure the user's feeling of integration (cross reference with number of contacts exchanged through WeDoCare).	5% increase per contact exchanged in the last year.
OUTCOMES	**INDICATORS**	**TARGETS**
If a RM is attacked, WeDoCare detects the attack automatically, in real time.	In-app survey – has the application detect all the attacks suffered by the user?	90% success
If attacked, RMs receive help from other refugees and general European people.	In-app survey to attacked users– has the user received help during of shortly after the attack?	50% of users attacked receive help
The RMs exchange contacts with the other RMs or Europeans that helped them (using the WeDoCare app), for future socialization.	Number of contacts exchanged by the attacked RM in the 24 hours after an attack (information collected automatically by the application)	1 contact / user / attack
RMs identify danger areas where attacks occurred	Number of attack locations reported	20% growth month over month
RMs seek safe heaven	In-app survey to verify if the user has used the application to seek a hospital or police station.	10% of respondents each year
The RMs are permanently connected to the community, recognizing the benefits of WeDoCare's innovative and free system that does not need an Internet connection.	User churn rate / attraction rate (collected automatically by the application)	Under 25% per year
European volunteers will feel motivated by the gamification elements to be introduced in the WeDoCare application.	Number of log ins / user (automatically collected)	Users in the 10 % of their friend group log on 100% more times than their friends.

c. Measuring your impact

The integration of immigrants, such as refugees, is often difficult. Most of them turn to their phones and social media for affection. We do not want, to create another social media or messaging platform. We want to facilitate the connection between people who are willing to help and immigrants with difficulties to adapt to a different country or lifestyle. These two groups might benefit from connecting with one another and never cross paths without external help. We expect the application to help immigrants integrate more easily and make good friends thus decreasing their integration time.

We have already had some meetings with United Nations for Human Rights (Switzerland) and social organizations that help refugees like AFA - *Associação Fazer Avançar* (Portugal). Their feedback was important to the development of some of WeDoCare properties already implemented.

All the feedback necessary to measure the application impact, both towards the application's social objectives and the technological aspects under testing will be collected through the application itself.

Technologically related feedback can be automatically collected while the application is in use. Where direct user input is necessary to the feedback collection, we will use in app questionnaires. Feedback of a qualitative nature will be collected using a nine-point scale. The stakeholders for this feedback, will be the application users (RMs and Europeans). They have first-hand knowledge of the application performance, and are critical to the application's success.

The user base of the application will be a mix of RMs and Europeans that wish to help RMs in need. Due to the social nature of the application and of the positive focus of the users that it will likely attract, we believe that the level of response to in app questionnaires will be high. Each questionnaire will state why it exists, so that users know that they are cooperating in the application development.

Technologically related feedback, such as variation of battery usage depending on the time intervals between sequences of sensor reading, will be continuously collected and used in subsequent application iterations to optimize this parameter. The same is valid for the number of attack locations reported by users. This is feedback that can be passively obtained without disturbing the user.

Surveys related to the accuracy of the application will be collected in the following way: one week after an attack detected by the application the user will be surveyed to confirm the attack (the time lag means to allow the user to psychologically

process the attack). Upon validation the user will be asked if he received help from nearby users, if he reached safety and if he used WeDoCare to do so.
On installation of the WeDoCare application and every six months thereafter, the user will be surveyed on how safe he feels travelling through Europe and if he was attacked during the last period. Answers will discriminate between RMs and European. This will allow us to evaluate the feeling of safety and if by selecting travel paths that don't cross the "hot/danger zones" the number of attacks is reduced.

In an initial phase we plan to involve some municipalities as beta testers for free. This will be important to test WeDoCare and to gain some visibility in the media and to promote our application.

4. Innovation

Several applications have been created to solve this issue, although they have great limitations. Safelet is a bracelet that lets you warn others that you are in danger. This special piece of hardware contains a button that once triggered emits an alarm to the user's friends and family. The user's smartphone also begins recording. This is useful because it gives the ability to check later what really happened in the emergency situation. But this solution has an important limitation which is the extra hardware the user has to acquire. The bracelet is only accessible for the most economically advantaged and it will hardly be acquired by people undergoing economic difficulties as is the case of many refugees. Also, emergency contacts may be unable to help, due to not being in the user's surroundings.
Another similar solution is Athena. It is based on a round button that clips onto a person's belt and is dedicated to prevent physical assaults by emitting loud alarms whenever the button is clicked. It also sends out text messages with the user's location to their designated emergency contacts. This solution is similar to the previous one with the advantage that it can be used anywhere; that is, it can be hidden from the persecutor unlike Safelet, which is placed on the user's wrist and can be easily removed. However, it also requires the user to buy extra hardware which greatly limits the target audience.
We want to provide technology-based solutions within most people's reach, therefore, we sought to use only the smartphone. With the recent rise in machine learning on mobile phones, new applications that use the smartphone's sensors to improve the quality of human life or to infer human activity are increasing. All

mobile phones have a microphone; despite of being rarely seen as a sensor this component allows us to obtain a lot of information. In fact, we can develop many applications using sound to obtain information about the environment (loud environments can be stressful or joyful, depending on the context) and the user. Voice can transmit moods or emotions. The microphone can even detect screams or gunshots. Much research in the field of scream recognition or gunshot recognition exists but a simple and useful application to decrease violence has never been developed.

Our idea is unique in the way that it uses smartphones to recognize screams for the detection of emergency situations and promotion of collaborative help in the face of refugee migration. This is something that can be scalable to other scenarios and has never been attempted before. This mechanism is implemented in the person's own mobile phone which brings great advantages because these devices are used by the vast majority of the population, so there is no need to purchase or carry extra accessories. Often, when travelling or walking around a new city, the only device refugees have with them is their mobile phone, so we find it essential that this mechanism is embedded into it.

The WeDoCare application also contains an innovative beacon system developed in our research group, so that communication with nearby or surrounding people isn't limited to an Internet connection. This was an important requirement identified in the meetings that we had with United Nations for Human Rights. Refugees and migrants often don't have access to a mobile network, or to mobile data (internet), and this beacon system is supported on wireless network meshes, which increases the effectiveness of our application. Because the user does not have to pay for the mobile data plan, the beacon system provides an alternative solution that is free to use.

The WeDoCare application has great potential scalability to address multiple different needs, using the same type of technology. We envision adaptations to solve problems in other contexts, namely in:

- Elderly or dementia monitoring systems, where adequate solutions are currently lacking;
- In preventing domestic violence, where it may additionally help the victim prove, and motivate her to come forward and report the situation;

- In preventing physical assaults in troublesome neighbourhoods, where the application additionally can be developed to automatically warn the police for additional effectiveness

Additional scenarios are bound to arise as new candidates to benefit from this type of system.

5. Development and Delivery

a. Roles and responsibilities

In the first phase of our project our members will support all the technological tasks. Our group has a vast experience in the communications and programming areas, and is currently very active in research projects in the areas of Internet of Things, Android programming and wireless sensor networks.

On the other hand, in this first phase we will also support the commercial tasks and the contacts with municipalities and potential costumers. However, in the future we plan to hire someone. The intellectual property tasks will be supported at beginning by the University of Coimbra's office on intellectual property.

b. Stakeholders

We will advertise WeDoCare to organizations that target migrants and refugees and camps that provide asylum to them, so that they collaborate in making the application known to migrants and help spread word of mouth. This is an application that can potentially help any refugee and migrant and will help the work of these organizations, making them natural partners. Once the user has tried the application, we expect him to organically spread the word to his friends.

We will also advertise WeDoCare to municipalities that are receiving a significant number of migrants, as a tool to help protect refugees and migrants, aiding them in their integration and therefore minimizing the known negative side effects of a badly achieved integration, e.g. violence.

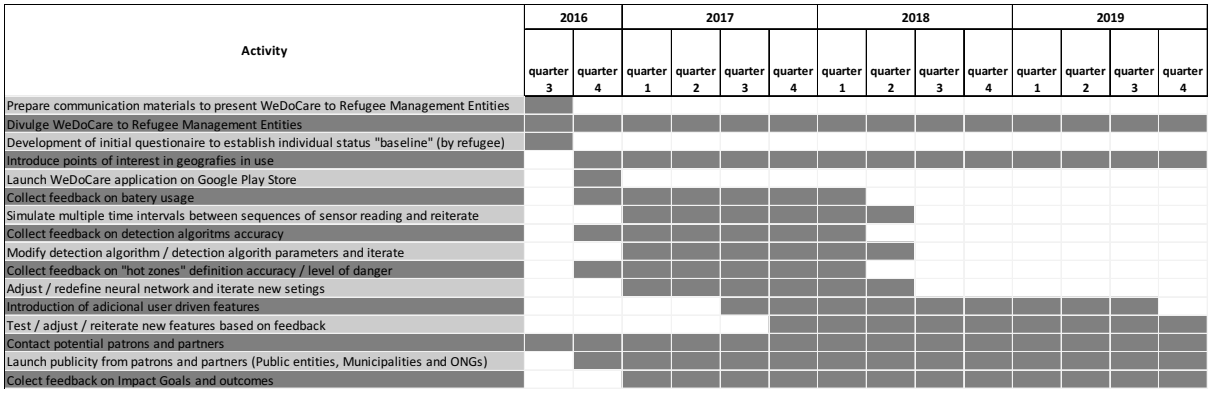
During the development of the WeDoCare application, we have had some meeting with the United Nations for Human Rights (Switzerland), to get inputs based on their knowledge of the specific current conditions in refugee camps and the habits of refugees and migrants during stressful migration periods. We have also met with social organizations that help refugees, such as AFA - *Associação Fazer Avançar* (Portugal), to get input on the habits and perceptions of refugees and migrants in more positive or desirable integration scenarios. Their feedback was important to

the development of some of WeDoCare's properties and functions already implemented.

The WeDoCare application will have an in-app feedback channel and contact information to reach the development team. This will help us gather additional information directly from the application's users about their needs and decide on which new features to introduce or improve in the future.

We can publicize future initiatives instantly to all users using the same channels that we provide as a paid service to other stakeholders such as Public entities, Municipalities and ONGs.

c. Delivery Plan



WeDoCare is a mobile phone application deployed through Google Store. Based on the feedback from the users and from the application we will continually develop the application and resubmit it to the Google Store automatically updating it in all the phones where it is installed and benefiting all users.

d. Safety

WeDoCare is an electronic application. Our team doesn't need to be in direct contact with the applications users in uncontrolled locations, so no safeguarding measures are necessary. WeDoCare will respect all privacy issues and user information will only be shared if given consent.

e. Budget Forecast

We would use the €50,000 cash prize to support the costs of installing the platform, travelling and human resources. These costs are divided as follows:

- Servers: 3.000€
- Human resources: 1 person * 24 months * 1500€ = 36.000€
- Travelling to contact with refugees and obtaining sponsorship: 11.000€

The human resource will be a computer-science engineer with master degree.

Our business plan foresees the self-sustainable develop the application, so that we can guarantee that the service can be provided indefinitely, or at least for as long as the need for it to exist continues. We will propose a paid service to public entities, such as municipalities, victim support groups, etc… to use the platform to make their initiatives known. This will include initiatives organized that target refugees and migrants, but also safe heavens or other interesting locations that they wish to publicize.

The main costs associated with the project are the purchase and set up of the servers, the costs related to travelling to contact both refugees and sponsors, and the computer science engineer that will continue the development of the WeDoCare application.

Regarding profits, we have estimated as follows. Staring from Q4-2016, WeDoCare will sign one municipality and one patron. From them on, as the application gains visibility and further proves the concept, it will sign at least one more municipality and one more patron that in the previous quarter.

Municipalities will pay a 5.000 € sign in fee, and a maintenance fee of 10% of that value every year. Patrons will pay a 3.000 € sign in fee, and a maintenance fee of 10% of that value per year. As the number of signed municipalities grows, so the number of users will grow. We have estimated a starting user base of 1.000 users per municipality, that will grow 20% every quarter.

In the table below you can find a detailed evolution of WeDoCare expected costs and profits.

		2016		*2017*				*2018*				*2019*				
Items	**Detail**	**Quarter 3**	**Quarter 4**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Total**
15																
Municipalities Sponsorship	*Divulge iniciatives and local points of interest*	€ 0,00	€ 5 000,00	€ 10 125,00	€ 15 375,00	€ 20 750,00	€ 26 250,00	€ 31 875,00	€ 37 625,00	€ 43 500,00	€ 49 500,00	€ 55 625,00	€ 61 875,00	€ 68 250,00	€ 74 750,00	€ 500 500,00
Patrons	*Divulge iniciatives and local points of interest*	€ 0,00	€ 3 000,00	€ 6 075,00	€ 9 225,00	€ 12 450,00	€ 15 750,00	€ 19 125,00	€ 22 575,00	€ 26 100,00	€ 29 700,00	€ 33 375,00	€ 37 125,00	€ 40 950,00	€ 44 850,00	€ 300 300,00
Total (including VAT)		€ 0,00	€ 8 000,00	€ 16 200,00	€ 24 600,00	€ 33 200,00	€ 42 000,00	€ 51 000,00	€ 60 200,00	€ 69 600,00	€ 79 200,00	€ 89 000,00	€ 99 000,00	€ 109 200,00	€ 119 600,00	€ 800 800,00
Expenditure																
Staff and volunteer costs																
Computer Science Engineer		€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 4 500,00	€ 63 000,00
Traveling to contact refugees and sponsors				€ 2 000,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 1 800,00	€ 21 800,00
Overheads																
Servers	*Dell PowerEdge R530 E5-2609 | 8GB | 1TB*	€ 3 000,00														€ 3 000,00
Capital																
		€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00
Total (including VAT)		€ 7 500,00	€ 4 500,00	€ 6 500,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 6 300,00	€ 87 800,00

The application is unlikely to generate any liability. All care was taken to protect the privacy and data of all its users following current best practices. We should note that the application does not guarantee that every attack will be detected or

that every user attacked will receive help (such a guarantee would indeed open us to liability). The WeDoCare application improves the probability that if a user is attacked, that attack will be automatically detected, and nearby users will be notified to come and help, therefore improving the general safety of each application user.

6. Future ambitions

a. Sustainability

As discussed in item 5e), our business plan foresees that the application will generate positive cash flow mainly by selling advertising to:

- Public entities wishing to divulge their initiatives to refugees and migrants;
- Companies interested in reaching refugees and migrants;

b. Scale

The world as we know it is dynamic, people are always on the move seeking a better lifestyle. This progress has turned Europe into a melting pot, making it common to find someone who feels they do not belong. Taking into consideration that the reality of immigration is not reversible and the need to facilitate adaptation and international relationships will always be present, our product is timeless and therefore will be sustained while emigration exists.

Scaling a new mobile app to support throngs of users is never easy. In the world of crowd-sourcing mobile apps, how fast an app can scale can mean all the difference. Initially we'll pick a high-traffic placement which will perform well at the user acquisition level such as countries or regions with high immigration levels. Once we get an understanding of what success cases look like from those placements, we can better tune the application to shoot towards new regions.

Our application is a distributed tool which can grow easily. The distribution is linked to the movement of people, which is the intermediary of the product. The more users we have the better it works, since our database will become richer.

In the future, we would like also to study and evaluate the possibility of extending WeDoCare to other contexts as elderly or assaults monitoring systems.

Appendix D

Press release for the European Social Innovation Competition 2016

PRESS RELEASE
14 JUNE 2016

WeDoCare selected as semi-finalist in European Social Innovation Competition supporting integration of refugees and migrants

2016 European Social Innovation Competition to award three €50,000 prizes for best ideas for 'Integrated Futures' in Europe

Today, WeDoCare has been selected from over 1,000 applicants from 36 countries as a semi-finalist in the 2016 edition of the European Social Innovation Competition. Open to applicants across Europe, this year's Competition theme 'Integrated Futures' saw the judges choose entries with the potential to address the reception and integration of refugees and migrants in Europe.
See the full 2016 Competition announcement and 30 semi-finalists here: http://bit.ly/2016semi-finalists.

WeDoCare is a mobile app that detects violent attacks, through a scream detector, and warns nearby citizens that someone is in danger. It Uses machine learning and signal processing algorithms to infer emergency situations by processing data from the smartphones microphone. The application can use the Internet to transmit alarms but, if no network is available, an alternative beacon system can also be used. Helpful locations, like hospitals or police stations, are shown on a map. The map also shows zones where attacks occur more often so users can avoid these areas, in fact, the app warns the user whenever the user gets close to a danger zone.

This year, 5 semi-finalists are projects based in Germany, 4 from Italy and 4 from the UK. Other successful applications came from Austria, Belgium, Croatia, Denmark, Finland, France, Greece, Ireland, Poland, Portugal, Slovenia, Spain, Turkey as well as Ukraine demonstrating a widespread commitment to using social innovation to find solutions to integration in all corners of Europe.

The competition seeks creative approaches that help realise the potential of refugees and migrants, enabling them to contribute to the social, economic, cultural and political life of their host countries. Along with 29 other semi-finalists,

WeDoCare will be invited to the social innovation mentoring academy to progress their ideas with tailored support and workshop sessions.

The social innovation academy is to be held from 4-6 July in Berlin, where semi-finalists will take part in workshops and visit German examples of collaborative approaches to helping with integration. Following the academy, ten finalists will be selected by the jury and the three most effective projects will each be awarded with a prize of €50,000 at the awards ceremony in Brussels in October 2016.

Organised since 2012 in memory of Portuguese politician and social innovator Diogo Vasconcelos, the European Social Innovation Competition gives a platform to social innovators across Europe, helping ideas to turn into impactful and sustainable projects.

For full details please visit: http://ec.europa.eu/growth/social-innovation-competition

Follow us on Twitter: @EUSocialInnov #diogochallenge

Photo

Fig 43 - WeDoCare app logo.

NOTES TO EDITORS

About the European Social Innovation Competition

The European Social Innovation Competition, launched in memory of Diogo Vasconcelos, is a challenge prize run by the European Commission across all European countries, now in its fourth year. The 2016 competition is themed around *Integrated Futures* and seeks to find innovations in products, technologies and services that can support the integration of refugees and migrants.

The competition is organised by the European Commission, supported by Nesta, Kennisland, Shipyard, Impact Hub and Matter&Co.

For information about previous competitions and winning projects see:

2015: http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8567&lang=en&title=These-are-the-winners-of-the-2015-European-Social-Innovation-Competition

2014: http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=7531&lang=en&title=Three-projects-meet-the-European-Job-Challenge-and-receive-the-Social-Innovation-Prize

2013: http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=6699&lang=en&title=Best-social-innovation-ideas.-New-ways-to-create-new-jobs-and-businesses

About WeDoCare

This work aims to take advantage of recent advances in the areas of Internet of Things, mobile phone sensing, new communication systems and techniques of machine learning to help solve a problem that continues to survey: the suffering of most vulnerable groups. This is a problem often overlooked and there is not an effective solution, the difficulty persists. WeDoCare aims to help mitigate the problem by using technological means to provide greater protection to these potentially more susceptible groups.

For more information on WeDoCare please visit wedocare.dei.uc.pt or contact ashley.figueira@uc.pt

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