UNIVERSIDADE DE LISBOA
Faculdade de Ciências
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Biographical Aids For People with Dementia

João Filipe Clemente Martins

DISSERTAÇÃO

MESTRADO EM ENGENHARIA INFORMÁTICA
Especialização em Engenharia de Software

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To my family and friends.

Resumo

Sistemas assistivos são sistemas que mantêm e/ou aumentam as capacidades de pessoas com deficiências. A maior parte dos sistemas assistivos para pessoas que sofrem de demência, tem como objetivo melhorar o funcionamento enquanto se executam tarefas do dia-a-dia, por exemplo, utilizar um eletrodoméstico ou efetuar uma chamada. Tipicamente não consideram todo o ecossistema em que a pessoa com demência está inserida e os conteúdos disponibilizados são muito reduzidos ou dão demasiado trabalho aos cuidadores.

As próteses cognitivas, que fazem parte dos sistemas assistivos, estendem a capacidade cognitiva ou sentido de perceção de um ser humano. Como tal, tem que ter capacidades de recolha e inferência de informação para poderem prestar um melhor serviço a apresentar conteúdos.

O nosso sistema, que atua como uma prótese cognitiva tem as seguintes funções: (1) obter dados acerca da vida de uma pessoa que sejam representativos e precisos de forma automática; (2) disponibilização desses dados através de serviços disponíveis online para permitir a criação de ferramentas de visualização de conteúdos.

A recolha de informação de forma automática é feita de três formas diferentes: (1) obtenção de informação contextual no smartphone do utilizador; (2) preencher faltas de informação através de um mecanismo de *friendsourcing* de informação. Este mecanismo consiste em fazer perguntas à rede de suporte do utilizador numa rede social, neste caso o Facebook. Quando a informação possui um determinado grau de certeza, é considerada como válida e guardada. A rede de suporte do utilizador também pode enriquecer eventos através de comunicações realizadas por telemóvel como, Short Messaging Service (SMS) e Multimedia Messaging Service (MMS), em que as mensagens possuem formatos pré-determinados; (3) utilização de serviços disponíveis online conhecidos como *Application Programming Interfaces (APIs)*, serviços esses que ajudam a enriquecer os eventos com imagens e outra media associada a locais ou a pessoas conhecidas. Os serviços são utilizados também quando se pretende transformar dados em bruto em algo mais fino e compreensível por seres humanos, por exemplo, passagem de localizações compostas por latitudes e longitudes para moradas.

Esta informação é então disponibilizada através de serviços web. Estes permitem a consulta por outros serviços ou por interfaces de utilizador que, têm como objetivo a

apresentação de conteúdos de forma adequada para pessoas idosas que possam sofrer de perdas cognitivas. Estes estímulos visuais tem como objetivo melhorar a comunicação e memória proporcionando uma melhor qualidade de vida, ao mesmo tempo que reduz o trabalho realizado pelos principais prestadores de cuidados.

Este trabalho inclui duas ferramentas de visualização. Cada ferramenta tem um objetivo diferente, no entanto, têm como principal motivação melhorar a comunicação, a memória e a qualidade de vida do utilizador.

A primeira ferramenta foca-se na visualização de dados diários dos utilizadores, também conhecidos como rotinas. As rotinas dos utilizadores estão intimamente ligadas com aquilo que gostam de fazer ou tem que fazer por alguma razão específica. Esta ferramenta foca a visualização diária de dados para tentar dar segurança e ajudar à reafirmação daquilo que foi o dia de uma pessoa.

A segunda ferramenta foca-se nos eventos criados pela rede de suporte do utilizador na rede social Facebook e na media adicionada a esses eventos. Através da ampla disseminação que as redes sociais têm, aproveitou-se a interface de lifelogging do Facebook para construir a vida de uma pessoa de forma cronológica com o maior grau de certeza possível. Como o Facebook é a rede social mais utilizada foi escolhida como sendo a mais adequada para chegar a um maior número de pessoas que possam contribuir para ajudar alguém.

No final, avaliámos a nossa prótese cognitiva e as nossas duas ferramentas de visualização. Para a aplicação móvel de recolha de dados contextuais realizámos um estudo quantitativo dos dados recolhidos relativamente às fotografias e rotas de seis utilizadores diferentes. De seguida, esses dados são utilizados na criação da interface de visualização diária de rotinas dos mesmos. Esta avaliação foi realizada dois meses depois da primeira o que permitiu perceber se os utilizadores se lembravam do que se tinha passado e nos casos em que não se lembravam, se a ferramenta os ajudava de alguma forma.

Por último, fizemos uma avaliação da ferramenta de memórias geradas pela rede social de uma pessoa idosa, que neste caso não sofre de demência. Para avaliar esta parte do sistema do ponto de vista dos utilizadores, rede de suporte e utilizador beneficiário do resultado final, fizemos uma avaliação qualitativa do mesmo. Primeiro encontrámos uma pessoa que atuou como o gestor do perfil de Facebook do utilizador. De seguida, pedimos a um conjunto de pessoas com e sem Facebook para criarem eventos de uma pessoa enriquecendo-os e partilhando-os com ela. Depois disso pedimos à pessoa para utilizar a nossa ferramenta enquanto observámos o que ela fazia e como interagia. No fim reunimos com os membros da rede de suporte e fizemos perguntas acerca do sistema, das dificuldades que tiveram e de como procederam à criação de eventos.

Palavras-chave: Demência, Recolha dados automática, Reminiscência autobiográfica, Redes de suporte

Abstract

Assistive systems are systems that maintain and/or augment the capacities of people with disabilities. Most assistive systems design for People with Dementias (PDs), aim at improving the functioning while performing everyday tasks. However, these systems fall short when it comes to gather precise and meaningful information about someones daily events.

Our assistive system that has these functions and goals, is known as cognitive prosthesis and augment the cognitive capacity of a human been or his sense of perception. The cognitive prosthesis has two different functions: (1) gather data about someones life that is precise and representative in an automatic manner; (2) provide that data through services available online to allow the creation of tools to present content.

The automatic gathering of information is performed in three different ways: (1) gathering of contextual information from the smartphone; (2) fill information gaps through a friendsourcing mechanism; (3) use online services commonly known as APIs to enrich events with images and other media associates to places and/or known people. They are also used to transform raw data into higher level knowledge, for example passing latitude and longitude locations into addresses.

Also, this information is represented in our web server that places it available through web services. These web services enable the consultation by other services or User Interfaces (UIs) that aim to present content in an adequate way for older people that may suffer from cognitive disabilities. These visual stimuli try to improve communication and memory by providing a better life quality at the same time they reduce the work that has to be done by the main caregivers.

Several tests were performed in order to validate our different components. One to validate our cognitive prosthesis and other two to validate the visualisation tools. The first study focus on the a technical validation of the mobile application where we perform a quantitative evaluation. The last test was performed to the friendcrafting memories visualisation tool. This tool focus on the events created for a user by his support network in a social network. To assess this part of the system from the user's point of view, support network and beneficial user we performed a qualitative evaluation.

Keywords: Dementia, Automatic Data Gathering, Autobiographic Reminiscence, Support Networks

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Chapter 1

Introduction

This thesis is on the subject of aiding People with Dementia (PD) through the automatic gathering of biographical data and creation of visualisation tools. This first chapter presents our motivation in this subject. We also present the objectives, contributions and publications of this dissertation. Finally, we provide an overview of the thesis' structure.

1.1 Motivation

Dementia is the decline of cognitive capacities beyond what is reasonable from the process of ageing. Around 3% of the population ranging from 65 to 75 years old have dementia and over 20 to 47% of the population over the age of 85 have some form of dementia. Demographic changes in age of the population makes it a disease increasingly more common, it was estimated that 35.6 million people lived with dementia worldwide in 2010, with numbers expected to almost double every twenty years, to 65.7 million in 2030 and 115.4 million in 2050. In 2010, 58% of all people with dementia lived in countries with low or middle incomes, with this proportion anticipated to rise to 63% in 2030 and 71% in 2050 [33]. The most common form of dementia is Alzheimer's Disease (AD). Dementia can only be detected with a high degree of certainty through biopsy or autopsy, that allow the examination of the brain tissue. Although, many PD display a certain set of symptoms that can be used to identify the disease.

It is a progressive disease that usually starts with the loss of short term memory, communication problems and confusion [39]. With time, the loss of these cognitive abilities will be increasingly more noticeable, whether by forgetting more important things - such as names - or through repetition of questions and actions. At this middle stage of the disease, the PD looses track of where they are and notion of time and may start to be angry or show aggression due to frustration, depression and/or anxiety. In the latest stage of the disease, the PD might only have lapses of recognition of people and whereabouts, having trouble performing every day activities such as eating, incontinence and the increasingly aggravated decay of every cognitive ability.

Science is still unable to provide a cure to dementia related diseases. The most common treatment is the pharmacological, that does not halt the progression of the disease or reverse existing brain damage, although some manage to slow down the progression of the disease or ease the symptoms that the PD may experience throughout the several stages. Also, many PD, at a early stage, may benefit from the execution of tasks that aim to improve a cognitive function by using Reminiscence Therapy (RT) and cognitive training [38].

Millions of people worldwide spend a significant amount of time and money to help PD. In the United States of America alone there are about 52 million caregivers of which only 9.4 million provide care for someone that suffers from long-term illness. Of these, only 5 to 7 million provide care to someone with 65 years of age or older and only 3 million people care for someone with dementia [35]. The number of people that provide care for PD corresponds to a very small part of the caregiving world. Furthermore, 75% of the caregiving is provided by spouses or kin. The other 25% corresponds to additional caregiving services acquired by the PD's family members. There is such a difference in numbers due to the expensiveness of professional caregiving services. Although, traditional caregiving doesn't come without costs. In most cases, family members pay a high emotional and financial cost they can't bare [18]. Caregivers tend to display signals of stress and depression due to the chronic illness and cognitive decline of the PD [36, 24].

1.2 Objectives

Our goal in performing this project is obtain autobiographical information from an active person in an automatic way that, when presented to a PD, promotes communication, reminiscence of past events and life quality; also, improve Quality of Life (QoL) of PD and its caregivers taking into account their needs, wishes and cognitive abilities.

To achieve these goals we gather the data and build the necessary UIs to present content to the PD. The data gathering is performed in three different ways:

1. *Mobile*: context aware mobile applications contribute greatly to log and share contextual information. As these systems evolve, by collecting more and more useful information, it is possible to obtain a better representation of someones self. We provide an autonomous mobile application that is context aware, through the gathering of indoor and outdoor location, accelerometer values, photos explicitly taken, amplitude and frequency data all annotated with timestamps that are sent to a web server.

2. *Crowdsourcing*: with availability of several people that know relevant information about someone, we can start asking them questions to fill information gaps. Information such as: where, what, when and how is sometimes missing. Together with

information we already have and the formulation of questions on social networks, we can obtain the ones we don't have and use the answers to have a better understanding of several activities. Also, supply several friendsourcing services, such as: scheduled events from Google calendar and information from people contacting the user's smartphone through Short Messaging Service, commonly known as SMS and Multimedia Messaging Service commonly known as MMS to understand day to day life of the PD.

3. *Web*: world wide web can be used to obtain a lot of supplementary information. Information such as: location coordinates from names; complete biography about an entity such as an actor, musician or a relevant place may only be processed from already existent online APIs. APIs like Google geocoder, Panoramio and Wikipedia are used to get this supplementary information allowing us to enrich and improve information already obtained.

   We use Google geocoder to make sense of location coordinates and location names, we also use Panoramio where we obtain public pictures of specific locations and Wikipedia to get background information. These APIs allows us to enrich and improve information already obtained.

Also, we created two visualisation tools that use visual stimuli to promote communication and life quality [7]:

1. *Daily lifelogging*: based on the contextual information gathered from the mobile application display information in a map about the routes and places where the user went to as well as present pictures the user explicitly took.

2. *Friendcrafting memories*: Use Facebook profile information such as: events, interests, places and people to furnish enriched autobiographical life reviews that are complemented with information gathered from services available online like Panoramio, Wikipedia and Google geocoder. Friendcrafting memories aims at organising memories and mementos in several different dimensions.

1.3 Contributions

These days, there is still a gap in assistive technological systems that target PD's support network as a way to provide content and at the same time relief caregivers burden. Most of today assistive technological systems focus on improving accessibility in task execution. These systems tend to work for a very short period of time since the ability to perform functioning activities, while suffering from dementia related illnesses, is severely affected. Our main contributions with this dissertation are:

- **AidedMemory Library**: mobile contextual information gathering library for PD focusing in relevant data for activity inference and display. The library requires no interaction from the user to automatically gather data.

- **GSM Friendsourced Prototype**: take advantage of Global System for Mobile Communications to monitor user smartphone communication. Also, enable the creation of reminders and extraction of life events from those communications. SMS messages are typically more suitable for reminders and MMS messages to more relevant life events due to the ability of adding media, like pictures, videos and sound. This one to one communication allows to maintain some privacy with information the PD does not want to disclosure.

- **Day to Day Event Visualisation Prototype**: based on the locations and photos taken by the user, create a visualisation tool to improve communication and functioning by reviewing daily life.

- **Friendcrafting Memories Prototype**: using Facebook social network to extract relevant information from the users profile and create automatic content such as: photo albums by presenting events and their participants; interests with background information; people and the events where they were with the user and relevant places in the user's life.

1.4 Publications

During the Master Thesis period I co-authored the following publications:

- João Martins, José Carilho, Oliver Schnell, Carlos Duarte, Francisco M. Couto, Luís Carriço, Tiago Guerreiro (2014). *Friendsourcing the Unmet Needs of People with Dementia.* W4A2014 – Communication, April 7-9, 2014, Seoul, Korea. doi 10.1145/2596695.2596716

- José Carilho, Oliver Schnell, João Martins, Luís Carriço, Carlos Duarte, Francisco M Couto, Tiago Guerreiro (2014). *Predicting Relevant Events in the Life of a Person with Alzheimer.* LASIGE, Informatics Department, Faculty of Sciences, University of Lisbon, Portugal. Poster presented in Braga at University of Minho.

1.5 Document structure

This document is organised in the following way:

- Chapter 2 – Background : Presents the background that is divided into five sections. In the first section we describe pervasive healthcare technologies and how

they are being used to help PD. Also within this section, we explore several contextual frameworks that, fall into pervasive healthcare technologies, and provide automation for daily life (ADL). After, in the second section we survey different ways to source for information and several existent tools that source for information online are investigated. In the third section we delve into the reminiscence world, how are these therapies processed and how it can help PD. Next, we explore the concept of lifelogging and systems that collect people's day to day life and represent it in a graphical manner that is easy for them to see. In the end, we provide a small discussion about the overal related work.

- Chapter 3 – Mobile and Crowd-Powered Memory Prosthesis : In this chapter we describe our prototype system. We present the system requirements and use case scenarios. Also, we present the system design and important components.

- Chapter 4 – Applications : In this chapter we present our two visualisation tools, one for the friendcrafted memories of family members and friends and one for day to day activities. We explain the concept and objectives behind it as well as the design and implementation.

- Chapter 5 – Evaluation : In the end, we present an evaluation of our prototypes. First, we present an interview to preliminary assess the validity of our concept. Also, three different evaluations are made one for each component of our system to validate the work done.

- Chapter 6 – Conclusion : Presents a small conclusion, a discussion about the overall work, and future steps towards improving our prototypes.

Chapter 2

Background

The present chapter is a critical overview of the state of the art concerning this work. First, we explore pervasive healthcare technologies and how they can have an impact on PD. Second, we explore ways of sourcing for information online and how capable they are of providing accurate information. Third, we present several reminiscence functions and their benefits to memory. Forth, we enter in the world of lifelogging systems. Finally, we provide a small discussion about the gaps on previous work in these areas and how we intend to fill them.

2.1 Pervasive Healthcare Technologies

Pervasive computing has a more relevant role in today healthcare systems, features like remotely monitor and analyse patients and the widescale deployment of wireless networks make this technology the new trend. Pervasive healthcare technologies also increase the effectiveness and efficiency of healthcare professionals [40]. There are several characteristics that make a system pervasive, location independence and the existence of a context aware component that perform automatic data analysis [29]. These systems target scenarios where the patient is at home or in a mobile setting. Pervasive healthcare technologies can be divided into two categories like in Figure 2.1.

The organisational category tries to improve a certain process while in the other hand medical can be divided into other two more specific categories:

- therapy and rehabilitation: the pervasive system has the capability of healing the patient.

- prevention and care: tries to slow the progression of a disease or provide well-being. Our systems falls within the prevention and care category under the medical aim.

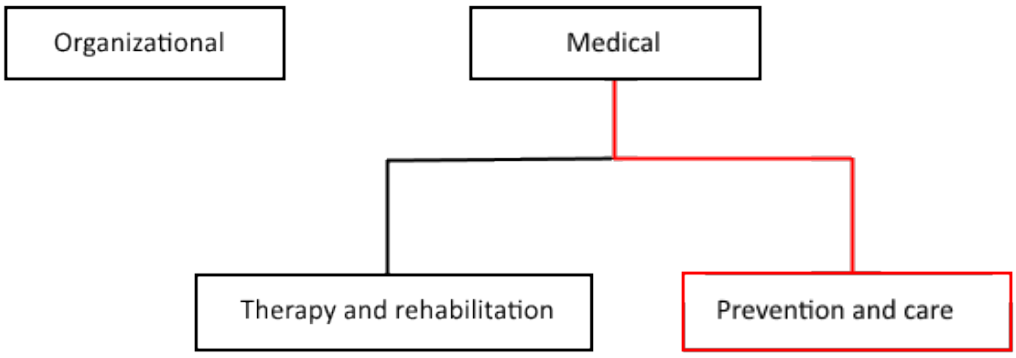


Figure 2.1: Different categories and sub-categories where different pervasive healthcare technologies fit.

2.1.1 Pervasive Healthcare in Dementia

Pervasive computing can have a key role in supporting a number of challenges that PD face. Most of the technology that tries to support PD is delivered in the form of cognitive prosthetics. Since patients at early stages are still capable of sustaining a normal life style and use almost every cognitive function, with new advances in technology, namely in the area of mobile devices, there is a possibility to create mobile cognitive prosthetics that are with the patient at all times. A cognitive prosthetics is any computer-based system that has been designed for a specific individual to accomplish one or more designed tasks related to activities of daily living, including work (Lynch 1992). Cognitive prosthetics are used as treatment expanding cognitive abilities and act as an alternative to pharmacological treatment. The cognitive prosthetics combined with the user contextual situation are used to improve the user's capacity to function properly [9, 31].

Cognitive Prosthetics

The cognitive prosthetics works as a memory aid [10] by prompting visual elements, i.e. reminders, related to what the patient is currently doing or is about to do. Reminders are prompted automatically but can also be added by patient and/or caregiver(s).

The first memory aid that acted as a cognitive prosthetics was the 1990 Michelle S. Bourgeois's memory wallet, that showed that PD are still capable of using memory wallets [13]. Memory wallets are made to improve patient communication skills with familiar partners about subjects they have pleasure talking and that they not only improve the content of the conversation but also stayed in the topic, produced novel statements, less ambiguous utterances and errors.

The memory wallet [14] was tested in a daycare centre, containing 15 to 20 pictures and sentences about familiar people and events that the patient has trouble remembering. Also, there is a group meeting with all the necessary stakeholders for the system to work.

From paid caregiver(s) to volunteers and family members, so that they can provide biographical information and to receive the instructions in how the meeting should go and the type of stimuli they should provide to the patients, e.g. "Yes, that is true", to improve confidence.

Results were that, once the patients start using the wallet they refer to factual past events more often. These results clearly show to caregivers and family members the importance of a memory wallet device to improve communication skills. Also, caregivers and family members proved to be capable of providing suitable and relevant information to a specific patient.

More recently, a system called Cogknow Day Navigator (CDN) emerged. CDN intends to fulfil PD main needs: help them remember, preserve social contact, provide feelings of safety and encounter enjoyable activities [25]. This system is composed by several parts: a sensory home integrated in a stationary device that is very important in the remembering on how to do chores and a mobile smartphone that can be taken everywhere. CDN is a cognitive prosthetic that includes a number of services like remembering based on the PD schedule, task assistance with the sensorised home that monitors door and fridge use.

2.1.2 Developing for people with dementia

Understanding what people with dementia and caregivers really want from systems is a hard and extensive job. To properly assess the needs of PD, workshops and interviews need to be conducted with the PD and its caregivers [34]. As it would be expected, a device developed to be used by someone suffering from dementia has to be easily accessible, operated and understood.

Usually very basic interactions and technologies are preferred as ways to help PD, preferably with intuitive interfaces, composed by basic instructions. Several requirements are said to be the most prevalent in today's society:

- *Memory support*: one of the biggest unmet needs stated by PD is forgetting appointments. PD suffer from time disorientation which by itself, increases the memory deficiencies. Electronic calendars and agendas are considered to be a very helpful feature in supporting devices. Not only the content needs to be presented in simple ways but also it is generally accompanied of simple representative images. Due to the time disorientation it is also important that time is one glance away. Memory problems also translate into frequently loosing items like house keys and other relevant items. As such, features that allow to locate several items are to be considered as well.

- *Support for social contact*: forgetting family meetings or even the simple disability to perform phone calls, enhances the feeling of loneliness from PD. Patients usu-

ally have difficulty in dialling phone numbers and performing calls. One of the requested feature is that it is possible to perform phone calls with one click on the person's they want to call picture.

- *Enjoyable activities in daily living*: again, the main reason for the lacking of finding enjoyable activities is tied with the difficulty in time orientation. Also, the difficulty in performing sequenced activities like dialling a phone call or turning on the television or the radio prevent the enjoyment of such devices. Playing their favourite music and television shows is a widely required feature for such devices as well as simple instruction in how to use the oven or the microwave. Global Positioning System (GPS) based navigation is also a very sorted feature specially when it helps the PD reach somewhere.

- *Supporting feelings of safety*: it is not unusual that PD feel insecure. This insecurity can be overcome when in contact with someone they trust and recognise. Most of the times, this person is the PD primary care provider. The touch of a help button to speed dial a call into this person is a highly requested feature. The care provider can then help the PD in performing an activity or relief this feeling of insecurity.

2.2 Crowdsourcing

With Internet and social networks becoming more important everyday people started outsourcing for information online to other people. It is considered a new arrangement for doing work that under the right conditions the quality of information gathered can outperform experts in a certain area [15]. This, eventually lead to the creation of a concept named Crowdsourcing. Crowdsourcing is a way to retrieve information we need, ideas, or content by asking it to a large set of people, usually an online community instead of traditional employees or suppliers.

Crowdsourcing is often used to subdivide tiresome work and it can also happen offline [26]. Typically each crowd-worker contributes with a piece of information, and all the pieces tied together will eventually lead into the gathering of the desired information. It differs from outsourcing in that the work comes from undetermined public instead of a selected target group. Crowdsourcing can be defined as an online, distributed problem solving and production model [16]. It can be a split of boring work and applied to more specific requests like a quest for answers about a specific topic.

2.2.1 Key ingredients

To start crowdsourcing there are several needs that have to be there in order to increase probabilities of success in obtaining the desired information:

1. an entity that needs to obtain some information;
2. a community, the crowd, that has a motivation to do it voluntarily;
3. an online environment where the communication between the entity and the crowd is performed;
4. there has to exist benefits for both parties in this exchange.

It is very important to keep a balanced control of the environment used to perform the interaction and the structure of the crowdsourcing. Too much control from the part of the entity and the crowd might not be so receptive in providing the desired answer, too little control from the part of the entity and the entity will have a system, like Wikipedia, where the crowd independently sets their own goals. When all these variables are in place, crowdsourcing has many potentialities, such as: ongoing presence; availability; and speedy reaction from the crowd.

2.2.2 Friendsourcing

Crowdsourcing can solve several problems. Although, sometimes it is not effective since the answers lie in a restricted set of users. This is where friendsourcing comes in, when traditional crowdsourcing mechanisms prove themselves inefficient motivating a large enough group of people that are capable to provide the desired information.

A good example of how friendsourcing is applied to social networks is *Colla*borative *Bio*graphy for short Collabio [11]. Collabio is a tagging game where friends use several words to describe another friend. The first tags are automatically generated by the Collabio bot since users without initial tags usually do not have any more tags. If a user places a tag on someone and that tag is not in their tag list than it is added and hidden. If he guessed a tag then the correspondent tag is revealed in the tag list. The purpose of the game is to assess how people really know someone and how accurately is the information obtained from this friendsourcing mechanism. Also, the subject of the tagging can see his tag list fully uncovered and what people said about him.

Results demonstrate that friends agree in a way to describe a person or what is perceived to be important to that person. Tags were divided in common and uncommon tags but both provided to accurately describe something that the tagged person could relate to.

Another example is VizWiz [12], a crowdsourced smartphone application that aims at helping people with visual disabilities getting real time answers about something that needs visual confirmation. Due to the inability to see, the application implements several navigation mechanism to allow the blind user to navigate and access several features. When in need of an answer about something that needs visual confirmation like ”what type of drink is this?”, the user can take a picture holding the drink and subsequently ask to the crowd workers. The questions will then be answered by them in nearly real time.

2.3 Reminiscence

This section surveys previous work in designing for reminiscence. There are two widely accepted therapies for reminiscence: *reminiscence* therapy and *life review* therapy [19].

In general terms, RT has it's foundations on bringing back and discussing with someone or several people about past activities, events and experiences, using different types of media. It assumes that past memories remain intact until later stages, it may benefit communication skills and it is used to improve patient understanding [8]. The different types of media are gathered and organised with the help of caregivers.

Life review therapy, is similar to RT but tries to explore emotions, such as unresolved situations, feelings of guilt and resentment. These issues are characterised by the difficulty that a PD has to perform this on his own.

Despite the fact that these therapies use different approaches, both are very similar by focusing on the recollection of past activities. Also, in reminiscence the same task is always carried out twice or more and beneficial results are more latent between the execution of theses tasks. Learning might not be possible within a task but it may be across tasks. These approaches can then be combined into several objects to make it easier for the users to relate to. Objects like life history books, autobiographical photo albums, etc.

2.3.1 Benefits

Effects of Reminiscence Therapy can be assessed based on behaviour analysis. Accordingly to [41], there are several primary reasons why people want and like to use reminiscence therapies. Using reminiscence therapies provides:

- Boredom reduction: users that reminisce as a mean to reduce boredom usually do it when there is nothing else to do and see it as an enjoyable activity to kill some time.

- Death Preparation: as bad as it seems, sometimes users need to face that their death is something that is coming sooner than later. By using Reminiscence Therapy users feel they had a full life and learn not to fear and accept death.

- Identity: used by users to get a better perspective of who they are and understanding themselves, how their life was and what they are today.

- Problem-solving: problem solving as a function of reminiscence allows users to act in current and future situations based on previous activities and actions.

- Conversation: used to trigger social interactions through communication. Allows the creation of bonds between participants and to better understand others.

- Intimacy maintenance: provides users with information about loved ones, typically when they are no longer around.
- Bitterness revival: allows users to relive painful and stressful situations. With this, they can have some feeling of closure.
- Teach/Inform: allows users to pass on information about their life to others, usually kin. It is commonly seen as a way of storytelling, for example when a grandfather tells his grandchildren about enjoyable life events that occur back in the days.

2.3.2 Applications

Life History Books

A life history book is a handcrafted book assembled to acquire memories and stories about a person's life. It is a resource that is considered valuable not only by the patient, their family and friends but also, future caregivers. It is also usually seen as an heritage from an ancestor to be enjoyed by future generations [23].

Preparing a life history book can be a gratifying endeavour for a PD. It is important that all the memories and stories inside the book are appreciated and are seen as a way to honour the person and their existence. A life history book can be an important thing to a PD since it focus on long-term memory retrospection. Recall in this way can improve someone's self-esteem and improve their well-being. Also, grandchildren from someone with dementia can benefit from the ability to look through the life history book with their grandfather or grandmother while providing joy.

Caregivers can use it has a part of the care management plan and to learn more about the PD. The degree of a PD's engagement can't be miscalculated; when the right information is presented to the PD several things can be brought back with an unexpected degree of awareness. Also, the construction of the life history book proves itself an enjoyable time for the family members and friend as well as for the PD that feels stimulated when doing it. The life history book has no typical format, nonetheless, it has to be visual and attractive, making the people wishful to look inside, share and engage others to look into it with them. It is important to use the PD's provided content by making them part of the life history book process since there are things they remember better than others and some they do not remember at all. Content is also something that should be allowed to be customisable by the PD due to the same reason.

Interactive photo albums

Another way to present content to PD is through interactive photo albums. Due to the huge numbers of photos taken every day organising photo albums is a massive task as well as an indispensable one [20]. Classic systems for photo management rely on the time when the

pictures were taken or the directory information where they are in. Typically, to organise photos there is semantic information that can be used to do so: information like who is in the photo; where was the photo taken; when was the photo taken; what is being captured and the photo type (portrait, group photo or scenery).

Total automation in organisation of photo albums is still a daunting task due to: difficulties in recognising faces; information gaps, like who is that person in the corner; place recognition and event knowledge. As such, the ones doing the tagging of this information are the responsible by the photo albums. The extraction of information from photos is where the core for creating interactive photo albums lie. Several softwares try to get users to annotate their photos in order to extract relevant information from them [1, 2, 4, 5, 6]. Most of the techniques used to perform the annotation of photos are a mix between automatic clustering of photos, face and scene recognition accompanied with allowing people to tag as well. The reason why there is the need to still allow people to tag is that accuracy is far from desirable.

2.4 Lifelogging

Lifelogging is the construction of a digital archive of our lives. It gathers information ranging from personal information such as conversations, calls, emails and SMS to environmental as well as biometric information like temperature, ambiance light and heart rate measures. Lifelogging's ultimate goal is the creation of an e-memory that surpasses humans capability to remember things and use it to augment our own memory. Features like knowing every one we ever met and everything we do in our daily lives are a precious help to everyone, impaired or not.

Data capture in lifelogging systems has to be done effortless. Typically there are two different classes of lifelogging systems in terms of data capture [37]. There is total capture and situational specific capture. In total capture, the lifelogging systems tries to capture everything that happens in someones life, it targets several types of data and is constantly recording it. It targets documents, whereabouts, automatic retrieval of pictures, video, sound, ambiance light and biometric readings of the user.

First devices appearing to try to fetch this information were wearable devices that have a focus on recording locations, pictures and videos [21]. The wearable devices evolved from head mounted cameras to smartphones triggered at specific times capture images and video. Contrary to total capture, the situational specific capture tries to focus on specific activities or in specific locations. Most systems that use this type of capture tend to focus on work associated situations where organisational information can be kept, search and used. Usually it is seen in smart meeting rooms, classes combining smart boards, to cameras and microphones for video and audio recording.

2.4.1 Design principles

To come to good terms in creating lifelogging systems, i.e. systems that support memory, there is the need to respect several design principles. [43] provides several empirical studies on design principles for lifelogging systems based on user experience. These studies compare unaided memory (UM) with aided memory and how to leverage lifelogging systems to better fit users capabilities to deal with a lot of information and how they interact with these systems:

Interface Richness

In this study it is tested whether the capability of a user to remember is influenced by the richness of the visual interface. Several users used a wearable device called the SenseCam that, in its core, what it does is take pictures when sensors detect specific activities. After a period of time the users of the device are asked to remember a specific day where they used the device. While remembering the users can make usage of the photos taken as they wish with no restrictions.

The final result was that visually rich interfaces did nothing to help the users remember what they did in their day and the reason why was that there were too many images that didn't provide any relevant clues of what happened during the day and the huge amount of images make the process of extracting important pictures ineffective. Also, to backup this result, there is a study made by Sellen et all (2007) that states that simple lifelog images do not improve everyday recall in the long term.

Repository Management

Parents with small children were the subjects to test how is the photo repository management done and how long they took to retrieve a significant photo. Since they assume the role to organise children memorabilia throughout the years, parents are the best fit to answer these questions.

Out of a repository of pictures taken, it was asked to them if they could find photos of a specific event to avoid the possibility that people would choose events they know they can remember and find pictures. Even though events like "First day in school" are significant in their child life, it proved difficult for them to find pictures of those events. In this study they get to the conclusion that people tend to just actively remember pictures and events from a year ago with the ability to find those.

Another reason was that people tend to have 2 types of photo repositories, one digital and one physical. Eventually it gets so big that is no longer clear to them whether the event they are looking for is in their computer or somewhere else around the house. Even those they remember to be in digital format are so unorganised and poorly structured that any reasoning is practically impossible. Also, the number of very similar or repeated

photos is very high but never deleted.

Digital vs physical mementos

By comparing differences and similarities between digital and physical mementos there is the possibility to improve both. This study was carried out in participants houses, where they were asked to show items that they considered to be important and explain why, without mentioning that those items could be digital ones.

Only one participant referred that he had digital records of his bicycle rides, where all others only made reference to physical mementos. Although, when specifically asked, participants started acknowledging that they had several digital mementos such as emails, pictures and others. At first, it was though that this was due to the visibility of physical mementos but most of the times these objects weren't near the participant, usually they were stored somewhere in the house. Also, most items were of functional nature, like toys, books or a teacup. Typically because the items are closely related to enjoyable times for the participants and allowed them to reminisce about their past.

Lifelogging and UM trade-offs

This study was carried out while using several lifelogging systems and observing how participants interacted with them as a way to understand when and why people resort to the lifelog system to help them or when and why they resort to their unaided memory (UM).

Results show that poor organisation in lifelogging systems leads to the usage of UM from participants simply because it is much easier than actually using the system. Also, if someone can remember a specific event there is no need to resort to such a system, so participants only do so when there is some uncertainty about if they remember everything in detail.

These studies support the creation of four design principles:

1. *Selection*: refers to the importance of tracking user interactions and feedback provided when using the lifelogging system. By tracking user implicit and explicit interactions and listening to their feedback there is the possibility to tune up the system accordingly to the user needs. Also, selection implies for a structured lifelogging system instead of all data being widely available.

2. *Embodiment*: due to invisibility of digital archives it is important to merge digital archives with physical objects, for example like in a digital frame.

3. *Reminiscence and reflection*: for the system to be effective it has to allow for its users to reminisce and reflect over their events, emotions and feelings.

4. *Synergy not substitution*: instead of trying to replace the user's memory the system should be able to be used in a context that cooperates with their UM.

2.4.2 Benefits to memory

Lifelogging systems present several benefits for their users, those benefits are represented by the five R's and are all related to memory. The five R's are:

- *Recollecting*: a recollection is something of the past that is remembered, it is the act of remembering something. In lifelogging systems, it provides its users with the ability to re-live situations or experiences that happened in the past. Recollecting is closely related to episodic memory, i.e. the memory that allows us to relate to events that happened in our past. With it, we can remember specific places, times and several emotions. Examples of episodic memories are recollections of our childhood, like the memory we have from when we were five year old. Memories allows us to travel back in time to a specific event and reconstruct our own steps, this is the characteristic that allows to find objects we don't remember where we placed them or details of a specific conversation.

- *Reminiscing*: it is a particular case of recollection with the difference that its main purpose is to dwell with emotions and sentiments associated to a specific memory. It can be used to help users to get closure when emotions come along. Looking into old videos or photo albums is a good example of reminiscing. This memory function is usually done with several people to be a more pleasurable and dynamic activity.

- *Retrieving*: associated with the gathering of digital information like emails, documents and web pages. It is closely related to recollection since to find these specific information we need to remember what was inside the documents and pages. Sometimes we even need to try to see if the document's name is something that might give us clues of what we really want to find. Other information, like file size and type, might also be useful to understand if we want to fetch one document or the other.

- *Reflecting*: is a more abstract concept than all the others of the five R's. It does not focus on specific events, or information, instead it intends to show the user how he acts and feels in different situations and activities. With this, the user can see how he behaves from an outside perspective and understand why something followed a specific path instead of another.

- *Remembering*: or as it is also known prospective memory. It is the capability to understand similar situations that require actions or intentions that the user also used in

previous situations. Routines and pre-determined activities is where remembering comes in, for example if someone buys groceries everyday after work it is expected that the person remembers to do it in the future when the situation applies.

2.5 Discussion

These systems already take into consideration that cognitive prosthetics are an asset when users suffer from cognitive disabilities and can aid patients to deal with those disabilities. Despite, most approaches to support memory, increase social contact and enhance feelings of safety, still fall short showing very low deployment rates. Among other reasons, most approaches seek to provide local solutions to specific needs, failing to consider the whole eco-system around the person with mild dementia. Further, current tools to address the needs of PD place the load in a very restricted set of informal caregivers limiting the success of those approaches and leading those people to excruciating conditions.

Our approach to tackle the unmet needs of PD builds on top of previous research on gathering autobiographical data automatically using mainstream smartphones towards rich cognitive prosthesis. However, we call for a paradigm shift where the PD is placed in the middle of a bigger support network than what usually is the case. Our way of increasing the support network is to use social networks as our lifelogging system with a crowdsourcing ability. The social network, in this case Facebook, emulates a lot of the features encountered in a lifelogging system. Features like photo tagging and repository management related to who, what, where and when photo details.

Besides the social network, we also use the Global System for Mobile Communications, commonly known as GSM to gather more relevant daily information from the PD smartphone.

Chapter 3

Mobile and Crowd-Powered Memory Prosthesis

In this chapter we present AidedMemory, our mobile and crowd-powered memory prosthesis. AidedMemory is part of the non-drug approaches. It focus on integral aspects of care that improve QoL and maximise function. We do so by leveraging existing therapeutic and communication activities like Reminiscence Therapy (RT) to provide crucial support for (1) caregivers and family members by relieving their burden and (2) provide therapists with accurate information for additional assessment of the evolution of the patient's condition such as relevant routines and events.

To jump-start our system we exploit existent technologies, such as social networks and mobile smartphones that are well-known from the public and suitable to gather information about someone. The social network, in this case Facebook, targets the patient support network to gather and enrich life events from the past and present. With the mobile application we gather *insitu* information about the person day to day activities. Based on the information gathered on the mobile application there is a life event and routine detection component that tries to infer a higher level of knowledge. All this is aimed at the creation of visualisation tools that assist the patient, relieve the caretakers or the family and provide more data to therapists.

3.1 Use Case Scenarios

In this section we present several use case scenarios relative to the usage of our three prototypes.

Scenario 1

Alison a 73 year old grandmother of two that suffers from slight cognitive disability, and lives in a nursing home. One of her favourite activities is to talk to her two grandchildren, Arnold and Jack, about her life back in the day when they visit her in the nursing home.

Since her memory is no longer what it used to be due to the disease, her daughter Sally created a Facebook profile for her mother and started gathering a big enough group capable of rebuilding most of her mothers life events. For that, Sally texts several people in order to create, invite and enrich events in Alison Facebook profile page.

One of the persons she texts is Rose, a cousin that lives in the village where Alison was born and lived until she was 22 years old. Rose created several events, from baptisms to weddings of several family members that also lived in the village. Also, Sally texts a longtime friend, Monica that used to work for the same company Alison did. Monica helped create a lot of events from the days they worked together. Several events are created by Monica, from the day the President of the Republic visited the factory to the workers lunch meetings when retired. Engaged by this interaction other family members and friends, that attended those ceremonies and events, helped enriching them with photos and other media. Besides Monica and Rose, most of Alison's family was contacted in order to the same.

Since Alison isn't used to new technologies, her Facebook profile page is managed with the help of her daughter Sally. When Sally understands that some events or pieces of information are missing from conversations with her mom, she rushes creating the correspondent events and contacting people that may contribute to enrich those.

Sometimes, when feeling low, Alison reviews her life events in the Friendcrafting Memories visualisation tool on her tablet. When she does it, she asks Arnold and Jack to listen to her and enjoying that pleasurable moment with her. She specially likes when Jack starts asking questions about her parents and how was life in such a remote village with no electricity and taking care of the farm animals.

In the end, she feels reinvigorated and happy that she was able to relive those enjoyable moments with her grandchildren.

Scenario 2

Antony, a patient suffering from a mild form of dementia, is an outdoor kinda guy that enjoys his afternoon walks with Sparkles, the dog. At around 6:30 pm, when the sun is no longer burning, he leaves his house and heads to a nearby park called pine farm. He specially likes that park due to the big pond in the middle where he can feed the golden fishes, as well as the big and old trees.

Antony found out through Brad, his son, that he could have a mobile application that allowed him to record his daily walks with Sparkles, meetings with friends as well as his favourite activities. Brad installed the AidedMemory application in his fathers smartphone. Excited by this, in that afternoon, Antony went for a hike with Sparkles as usual. Right away he started taking pictures of Sparkles sniffing all the trees. When he got to the lake and saw all the fish waiting for him to give them food, he grabbed his smarpthone and took some more pictures. Antony knows the big fishes so well he can

identify them by colour. On the way home, he encountered some friends he usually plays cards with. When the game is over they take some group photos.

When Antony arrived home from the walk, his son asked him how it went and offered himself to help his father review his daily walk. The two of them, connect to the daily lifelogging tool where they can see the routes and pictures taken through out the walk on a map like interface and correspondent images slideshow. From the get go, Antony was able to identify John, a long time friend who pairs with him in card games. Also, he tells his son how big the fish with the yellow dots got from the very beginning where the fish was only as big as a hand. Furthermore, he spends some time telling his son how fun it is to spend some time with friends in the nature and how bad Carlos is at playing hearts.

Scenario 3

Mr. Tom a 76 year old man was recently diagnosed with an early form of dementia after displaying signals of confusion, anxiety and light cognitive decay. Since the diagnose, Tom lives now at his daughter's Kate house. Due to everyday life restrictions such as Kate's work and the ability of Tom to still function properly, Kate installed AidedMemory mobile application in her father's smartphone so she could provide him with real time reminders.

To function properly Tom needs to take his medication twice a day, one in the morning and one in the afternoon. Most times Tom remembers to take his medication but every now and then has difficulty remembering when to take it and how many pills. To facilitate this process, every morning and afternoon, Kate sends a message to her father's smartphone saying when and how many pills he needs to take. That information is then presented in the mobile application in the form of a reminder.

3.2 System Requirements

The main goal of our prototype, as specified in section 1.2, is to build a mobile application capable of gathering relevant information automatically about someones day to day activities while providing memory support. Taking that into consideration and according to literature review we derived user, functional and non functional requirements.

3.2.1 User Requirements

Here, we explain why the system is needed and what requirements the finished system will cover. These requirements were used as a guide to development and target end users are PD and caregivers. The user requirements are as follows:

- PD:
  - Finding enjoyable daytime activities

  - Relieve memory problems: memory problems are sometimes revealed in the form of disorientation, wandering, getting lost. Also, to prevent distress PD and fasten cognitive decline.
  - Improve communication: provide support and assistance to improve comprehension.
  - Prevent psychological distress: depression, anxiety and bad mood

- Caregivers:
  - Improve psychological distress by reducing symptoms like depression and anxiety.

3.2.2 Non Functional Requirements

Here, we specify the non functional requirements of the AidedMemory mobile application. The non functional requirements define the necessary contributions for the system to achieve its goals, as well as other characteristics like usability, feasibility and performance. As such, the non functional requirements for our context aware mobile application are as follows:

1. performance: mobile application has to be designed in a way that it does not drains too much phone battery too fast.

2. usability: due to the type of users it is important to maintain a simple design and easily understood interface.

3.2.3 Functional Requirements

Here, we specify the functional requirements of the AidedMemory mobile application. The functional requirements define the necessary features for the system to achieve its goals. As such, the functional requirements for our context aware mobile application are the following:

1. Effortless information gathering: its is important that the system automatically gathers contextual information without any tune up from the user.

2. Automatic server synchronisation: to assure further processing of the system there is the need to guarantee that it is possible to send information over the network into a web server.

3. Store temporary data when server synchronisation is not possible: it requires the creation of a database capable to store all the gathered information until its sending.

4. Ability to turn sensors on and off: necessary to guarantee good performance on the system and to decide what information we want to track down or not.

5. Automatic launch: the smartphone can be turned off for several reasons or the application may simply stop working due to outside problems. To assure that the application really gathers the necessary information there is the need to start the application when the smartphone reboots or the application is shutdown.

3.3 System Design

Our prototype system was developed primarily thinking in creating independent long-term care for people suffering from mild dementia that might be living with their partner, with family members or in a care home. Due to the features such as portability, inbuilt sensors, multiple forms of communication from and to, support for different types of feedback, different forms of Internet connection and GPS location, a smartphone is the perfect device to implement a prosthetic memory that is with us at all times. Also, smartphones are widely accepted in our society, i.e. are considered standard items for people to carry, which will prevent the patients from feeling stigmatised while carrying it in public places.

We use mobile devices to gather contextual and friendsourced information about a particular person and its life. As for the contextual information, we gather indoor and outdoor location, pictures explicitly taken with the camera, accelerometer data to measure changes in gravitational pull, sound amplitude measures, check for battery levels, etc. With friendsourcing we have a smaller network that is capable of addressing user specific needs that would not be possible when there is no connection between participants in a network. Friendsourcing with SMS and MMS allows the application to get all the necessary data to understand the user's day to day activities and events. Both contextual and friendsourced information is annotated with timestamps in order to be properly classified in the life event and routine detection.

In this section we introduce and provide an overview of the design of AidedMemory mobile application. The system design purpose is to assure that the mobile application is properly constructed, and can be seen in Figure 3.1.

3.3.1 Architecture

AidedMemory is structured as a multi-layered application composed with: user experience, business and data layer. It is considered a thin-client application because it is fully connected and information processing is done almost entirely on the web server. The different layers present in Figure 3.1 have different roles in the mobile application. The *presentation layer* is composed by two components: the user interface and the user interface process. Both components have user interface related concerns where the first

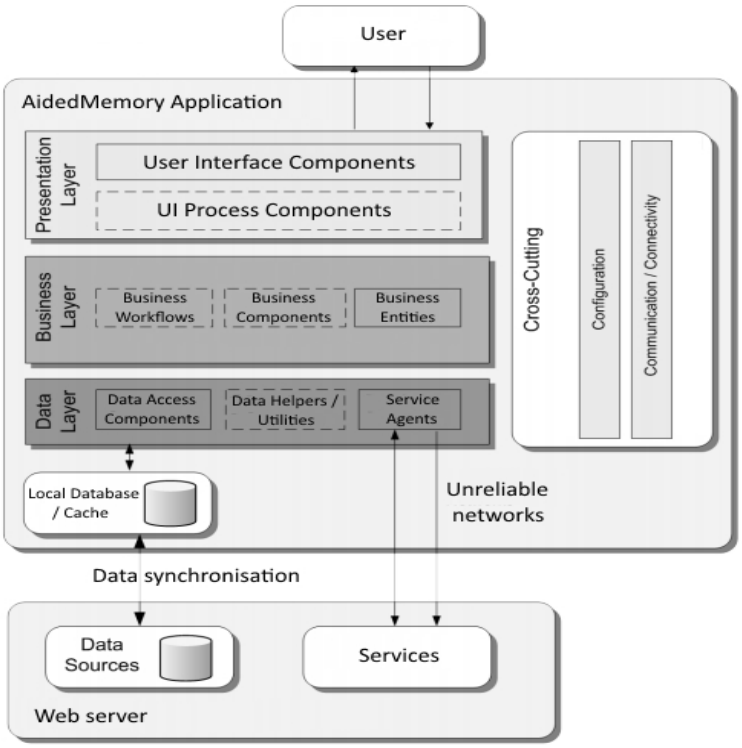


Figure 3.1: AidedMemory contextual mobile application layered architecture and general components

is the actual visual elements used to interact with the user and the second are the necessary classes to react to detected user behaviour. The *business layer* is responsible to perform work on the mobile application, its roles and behaviours are: the business components that provide business services such as processing rules and provide interaction with data access components. For example, a business component implements a specific pattern and another business component can be used to process requests; the business entities represent data passed between business components. In our case, this business entities represent locations, pictures and other database tables. XML files can also represent business entities; finally, the business workflows are used to define and coordinate long-running operations and business processes that require several steps. The *data layer* is responsible for managing the data stored in the database. Example: Helper classes, table classes, etc.

Other design considerations

Another thing we took into consideration when designing was handling connectivity issues. Since connectivity to a web server is required, AidedMemory was provided with a capability to handle cases where network connectivity and availability are of significant importance. In Section 3.3.2 it is explained vital mechanisms to systems designed where connectivity is relevant. There, I explain our caching and data access mechanisms with

intermittent network in mind. Also, we provide the adapter used to encapsulate the data transfer between mobile application and web server. It is used a layered architecture to maximise separation of concerns, favour reusability and maintainability of the application. In the Table 3.1 we have several design decisions that were taken into consideration in the making of several parts of the mobile application and the main reasons why.

Category	Key concerns
Caching	Our tables only have temporary data that once is passed to the server is deleted. This decision was taken, taking into consideration that since the device has limited resources it is not good to store things forever specially since their no longer gonna be needed on the smartphone.
Data accessibility	Implementation of mechanisms to access data that work with intermittent connectivity.
Device heterogeneity	Create user interfaces taking in consideration the different screen sizes and design accordingly to general CPU performances.

Table 3.1: Categories taken into consideration while planing AidedMemory mobile application design

3.3.2 Components

Sensor framework

As you can see in the appendix Sensor Framework we created the *sensor* concept. A sensor is an entity that is responsible to manage a certain type of data. In java we represent a sensor using an interface, the sensor interface. This sensor interface defines method signatures for the type and name of the sensor. There are three different sensor types (1) software sensor that represents a sensor that needs only code to retrieve the data; (2) hardware sensor that represents a sensor that is tied together with an hardware piece and (3) hybrid sensor where a mix of both types of sensors is present. All sensors can be represented using these three different types and they are present in the enum java class SensorType. To keep track of all the existent sensor names we have an enum java class called SensorName.

Currently the mobile app has six different sensors:

1. *LocationSensor* that is responsible for gathering location objects by implementing GooglePlayServicesClient with the best accuracy fusing both GPS and Wi-Fi location and the fastest update interval to have the most up-to-date values;

2. *PhotoSensor* is responsible for monitoring the camera folder for new photos taken, by extending FileObserver we can say what specific behaviour we want to react to and in this case we react to a new file being created under the monitored directory;

3. *AccelerometerSensor* monitors the gravitational pull of a smartphone, accelerometer values can be used to infer activities such as: being still, riding a bike, walking or going on a car. Also, this sensor implements an android SensorEventListener that will be notified and update the variables when accuracy and sensor values change;

4. *BatterySensor* is necessary for the management of battery life and setting configuration throughout application functioning;

5. *EnvironmentalSensor* is responsible for luminosity, orientation and amplitude measures, like the AccelerometerSensor, also implements two android SensorEventListeners one for the light and another for the orientation that will be notified and update the variables when accuracy and sensor values change;

6. *SocialSensor* is the responsible for the friendsourced part of the application, it queries google calendar, SMS and MMS content provider in order to get access to messages and scheduled appointments. Relevant messages to the application have to follow a certain template. Templates for this sensor are very simple: by adding *Reminder*, *To-Do* or *Info* to the beginning of the message.

All these sensors extend the SensorElement abstract class which itself extends android.app.service to run in the background and implements the Sensor interface. The SensorElement interface defines the onCreate, onStartCommand, onDestroy and onBind method for a sensor. The onBind method will allow for the WorkingService to bind to the returned Binder object of a sensor and call methods inside the sensor that return the relevant updated variables, as if they were simple classes. These four methods are the only absolutely necessary for the functioning of a sensor.

By enforcing this architectural style we make the application easily scalable. It is easy to add new sensors to the application without changing anything in it. Every sensor can have its specific components without interfering with the rest of the application. Next, we present an example of how to add a new sensor that currently doesn't exist in the application:

Creating a sensor for proximity information. The proximity sensor measures the distance to an object in front of the mobile device. Depending on the hardware, it can be in centimetres or binary.

1. A new ProximitySensor class has to be created representing a proximity sensor.

2. ProximitySensor class has to extend SensorElement abstract class.

3. To get values from this sensor in android we need to declare it and the sensor manager as follows:

```
Sensor proximitysensor;
SensorManager sensormanager;
private int proximityReading;
```

4. Create the four methods necessary for a sensor: onCreate, onStartCommand, onDestroy and onBind().

5. initialize both proximitysensor and sensormanager in onCreate as follows:

```
sensormanager =
   (SensorManager)getSystemService(SENSOR_SERVICE);
proximitysensor =
   sensormanager.getDefaultSensor(Sensor.TYPE_PROXIMITY);
```

6. register the SensorEventListener inside on start command:

```
sensormanager.registerListener(proximityListener,
   proximitysensor,SensorManager.SENSOR_DELAY_NORMAL);
```

7. create the inner SensorEventListener to get the updated values:

```
public SensorEventListener proximityListener = new
   SensorEventListener() {
    @Override
    public void onAccuracyChanged(Sensor sensor, int
       acc) {
    }
    @Override
    public void onSensorChanged(SensorEvent event) {
            if (event.sensor.getType() ==
               Sensor.TYPE_PROXIMITY) {
                    proximityReading = event.values[0];
            }
    }
};
```

8. finally we need to have a method that returns the proximityReading:

```
public int getProximity(){
    return proximityReading;
}
```

Friendsourcing

The friendsourcing in our prototype comes from two main sources:

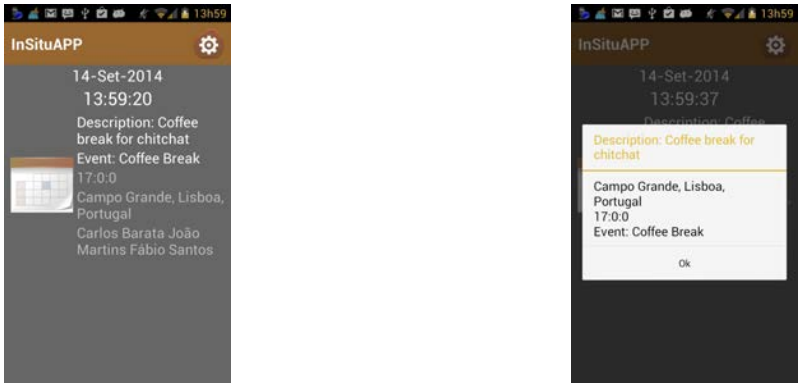
1. Mobile smartphone:

- Google calendar events: AidedMemory has connection into the users Google calendar events. When someone invites the user into an event, that event will appear to the user in the specific day as a reminder.
- GSM: using the Global System for Mobile Communications, more specifically Short Messaging Service and Multimedia Messaging Service we can enrich AidedMemory with friendsourcing information. Appendix B.1 and B.2 show how the main care provider would create reminders to be sent into the mobile application and the details of those reminders. As you can see in Appendix B.2 a scheduled event will have a title of the event, a description, several invited people and a time. Also, as you can see in Figure 3.2 that is how we present the correspondent created event in Google calendar.

2. Facebook social network:

   - enrichment of life events with media from several participants. The support network for the patient although initially has to be motivated with the appearance of events and media provided by a caregiver or manager, eventually will have enough motivation and capacity to self feeding.

By using Google calendar events, GSM and social networks, we utilise existent technologies to leverage our system, i.e, there is no need to develop other technologies to have access to this information.



(a) AidedMemory UI with event (b) When event is clicked

Figure 3.2: Clickable scheduled event from user's Google calendar

Synchronisation mechanism

Another important part of the mobile application is the synchronisation mechanism that can be seen in the Appendix A.1, for financial reasons we only perform server communication when a Wi-Fi connection is available. We save temporary contextual data into a SQLite database on the smartphone. The DataContentProvider class encapsulates the

management of the database, creating necessary methods to interact with the database we need for our app. Methods like query, insert, delete and update. Due to size, DataContentProvider class is not present in detail in the UML diagram.

When a Wi-Fi connection is available we perform the synchronisation by sending the data to the web server and clearing the temporary database on the android smartphone. In our prototype we didn't focus on the communication protocol, although we have created the necessary infrastructure to implement a more complex one by providing several classes that will enable encryption and authentication. First, we have created an Authenticator class capable of fulfilling all account relevant tasks: getting stored auth-token, presenting the account log-in screen and handling the user authentication against the server. All the methods inside this class are stub methods with no implementation provided. Then the AuthenticatorService class provides the authenticator object from the Authenticator class to the SyncAdapter class. The SyncAdapter class handles the transfer of data between the mobile application and the web server. The entire sync adapter runs in a background thread, so there is no need to set up our own background processing. To trigger the SyncAdapter class and perform the actual sync there is a SyncService that, in the background, listens for onPerformSync operations.

Data representation

All data has its own class representation in the mobile application and different types of data are stored in different packages. The classes shown in Figure 3.3 represent all the contextual raw data gathered in the AidedMemory mobile application.

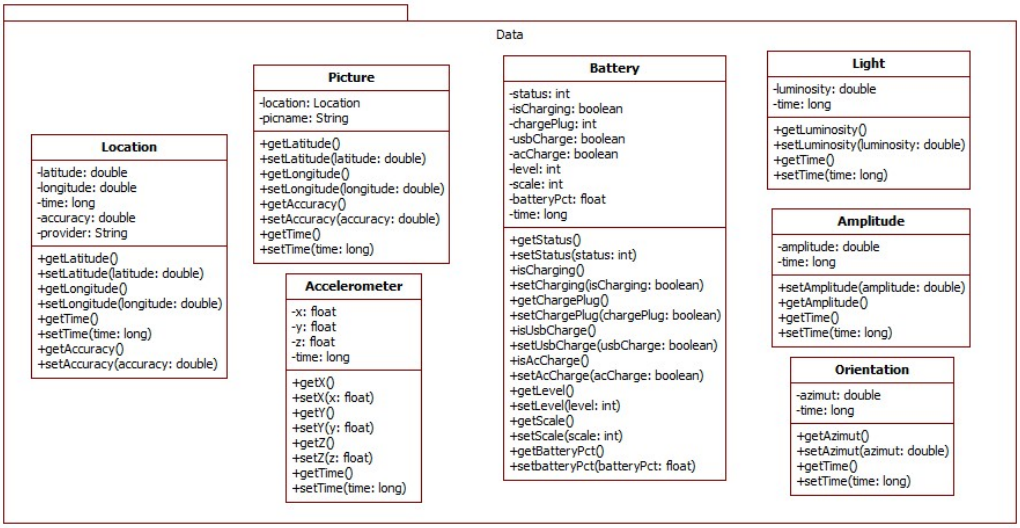


Figure 3.3: Raw data automatically gathered by AidedMemory

Also, for the friendsourced data of the application there are several entities that need to be present to represent a life event. Those classes can be found in Figure 3.4.

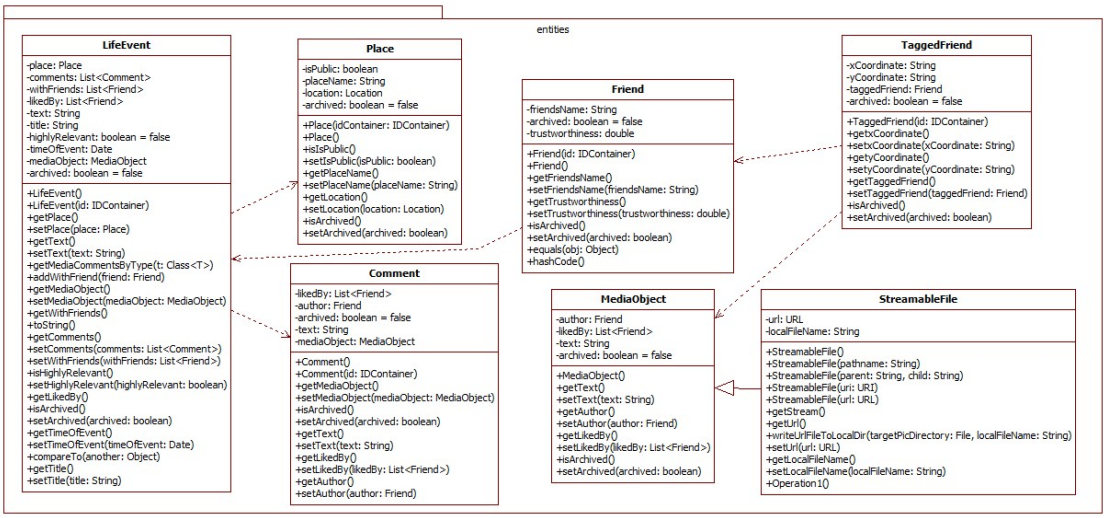


Figure 3.4: Friendsourced data that the application gathers

These classes are what is sent to the web server that saves them into a database for further processing. Also, the temporary tables in the smartphone represent these objects as tables and attributes as parameters for those tables.

Communication

To send data into the web server we use restful web services. Several post operations are used to send data into the web server. RestFul web-services represent different entities with different urls. We use the following operations:

Operation	Name	Description
POST	lifeevent/	allows sending of a life event into the web server. In this case, the life event can have Friends, Comments and MediaObjects inside.
POST	location/	allows sending of a location object into the web server.
POST	accelerometer/	allows sending of a accelerometer object into the web server.
POST	amplitude/	allows sending of a amplitude object into the web server.
POST	battery/	allows sending of a battery object into the web server
POST	orientation/	allows sending of a orientation object into the web server

POST	light/	allows sending of a light object into the web server
POST	picture/	allows sending of a picture object into the web server
POST	image/	allows sending the actual image file into the web server. In this case, it is important that it is sent as an InputStream so that the jersey web service framework can send and receive the file in chunks. It is specially important when big images are to be sent.

Table 3.2: Web service post operations done by the AidedMemory mobile application

Other settings

The mobile application is configurable allowing to set what sensors are running and which are not at a given time. Also, it is sending data as soon as it is available to allow for the inference motor and knowledge gathering unit to process it more accurately. However this is the desired behaviour, it is possible to have a bigger interval between data sending. All this aims at being more battery friendly.

Figure 3.5: Settings screen for the selection of on and off sensors

Chapter 4

Applications

In this chapter we grasp the possibilities for visualisation tools for content presentation that our prototype system allows. Two visualisation tools are presented. One for visualisation of daily data gathered from the AidedMemory mobile application and another visualisation tool called friendcrafting memories that retrieves data from the user Facebook profile package and presents it in a more suitable interface.

4.1 Daily data visualisation

Visualisation tool to provide daily data remembering and reassurance.

4.1.1 Concept

We develop a front end to allow a user to review his daily dos. Daily data visualistion focus in specific routes, pictures taken and publicly available popular photos of the locations. Contrary to visualisation tools that focus on long term memory, this one focus on allowing the patients to keep functioning by reinforcing activities and day to day memory. People establish routines in their daily lives that are usually very similar through time. This means that although we are enabling viewing routes recorded yesterday, it is highly likely that the route has been made several times before and is deeply rooted into the person's day to day living.

The interaction is made in a map life interface where the routes are highlighted in red and the places where most time was spent are signaled with a red marker. When clicked the marker expands into an info window were the photos of that day are presented, the ones taken by the user and the publicly available online. Pictures from both types can also be seen as a slideshow for the day. The slideshow can be started, paused and stopped, giving time for the person to see every individual image.

4.1.2 Objectives

The goals of this visualisation tool is to start conversation and improve the patient's ability to perform activities by reviewing activities. Daily data visualisation contributes to the PD with the following improvements:

- Acts as a conversation trigger aiming at improving patient communication skills and improve comprehension and provide support.
- Through the reviewing of daily routines improve the patient's ability to perform activities of daily living.
- Reduce cognitive decline speed by improving memory.

4.1.3 Design and Implementation

Our user interface can be found in Figure 4.1. Being the target users PD we favour interface simplicity. Also, we take into consideration that PD have different influencing factors in several categories that have consequences in data visualisation:

- in terms of cognitive process: short and long term memory, learning, attention and time perception disabilities.
- perceptual and motor performance: low capacity for high mental load; suffer from monotony and boredom; sensory deprivation; experience anxiety and fear; isolation and ageing.

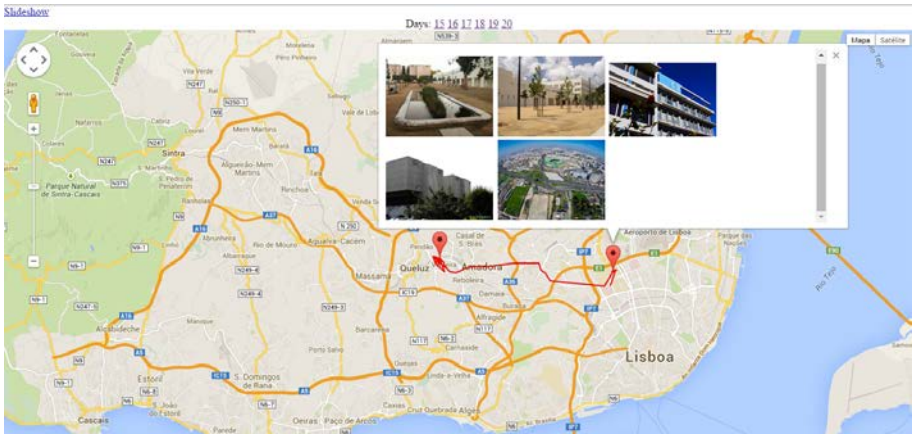


Figure 4.1: UI for daily data visualisation

The necessary information to build our user interface comes directly from the AidedMemory mobile application, then it is sent to the web server and made available to clients by web services. Information that comes from the web service is represented in Appendix C. In order to provide clues about the places visited we include pictures publicly available from Panoramio API.

Figure 4.2: Pictures slideshow

4.2 Friendcrafting Memories

Visualisation tool to improve QoL and remembering life events.

4.2.1 Concept

Reviewing and talking about past memories as a way for reminiscence is progressively becoming popular in nursing homes with older people. Sharing memories with other people can aid communication and increase self-esteem [27]. Friendcrafting memories user interface allows users to reflect on their past as well as share their memories, which in itself is a way to facilitate and improve communication skills. The memories gathered and displayed in our visualisation tool are supported and provided by what we call the patients support network. This support network is composed by different types and number of members, such as: kin, caregivers, and friends that actively contribute to the patient's reminiscence process. The patient support network and the number of unmet needs patient's complain about have a direct relationship [17]. These support networks can be classified accordingly to the Practitioner Assessment of Network Topology framework (PANT) [42]. This framework describes three main features where the support networks usually fit: 1) availability of local close kin; 2) level of involvement of family, friends and neighbours; 3) level of interaction with the community and voluntary groups. It not only focus on the type of people that are part of the patient support network but also the spatial distribution and availability.

With our online support network we complement the "on the spot" network by allowing for a more active involvement of all the members, regardless of proximity and type, in every patient support network provided mediation of a caregiver or family member. The mediator manages the patient Facebook page, in this case the media added in the life events. The mediator also has the power to create life events and manage others created by someone from the patient support network.

4.2.2 Objectives

Friendcrafting memories contributes to the PD with the following improvements:

- Provide enjoyable daytime activities and reduce psychological distress: reduce depression, anxiety and bad mood.
- Improve memory related issues: reduce cognitive decline speed.
- Improve communication: improve comprehension, provide support and assistance.
- Provide different, more accurate information: through time, patient's support network tend to decrease in number of members, this happens due to the difficulty others feel, specially close friends, in seeing someone once close deteriorate so fast. The usual coffee invitations and such are more frequently turned down until all communication is cut off. With this, people that may have valuable information are no longer contributing to help the PD, with our support network there is yet a chance to help their friend providing relevant information that he may still recall.

4.2.3 Design and Implementation

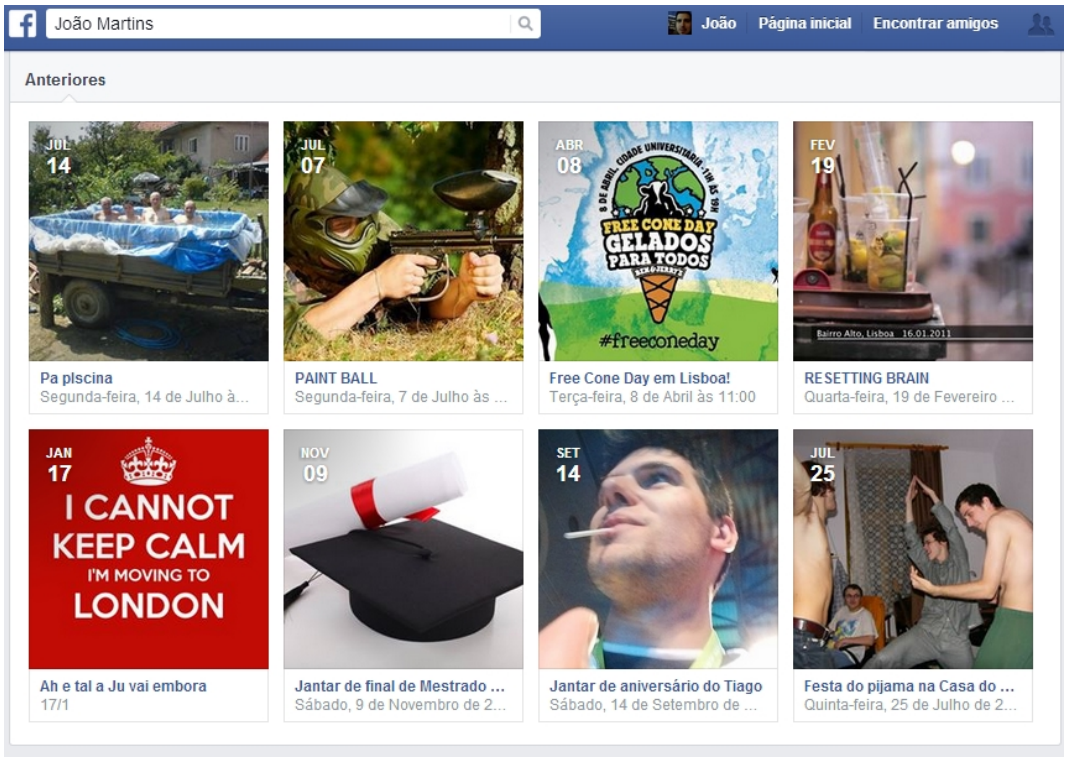


Figure 4.3: User's Facebook account with attended events

The main area of unmet user needs still is the one of remembering as seen in Section 2.1.2. PD may seem to live in a different reality in the distant past, making past

memories easier to remember. With our web interface we display past memories that are friendcrafted by family and friends in Facebook events. Anyone with Facebook account can register in our application and from that time on we have access to the user Facebook profile information. We can understand what they like and have access to the Facebook events like the ones presented in Picture 4.2.3. After, we get events where the person was in, participants in those events, associated media and interests.

Friendcrafted memories front-end works as a metaphor for a bookshelf where several books are stored. Each book focus on a specific visualisation: photo album; interests; people and places. From which, each page presents a specific event, person, interest or place while providing other media associated to that event, person, interest or place. The number of events, persons, interests or places per page is customisable, i.e, several page configurations are available from five events per two pages to one event per two pages.

An example of our interface is presented in Figure 4.4. Although the interface is designed to adapt to the screen size of the viewers device it was optimised for tablets. To build our front-end we use jquery to make all the asynchronous requests to the web-services and populate the user interface. We also use CSS 3D transforms and javascript for the book pages flip effects and to guarantee that the web browser will respond to tablet touch events.

Figure 4.4: Friencrafting Memories user interface

In order to build our interface, we first request to the server what type of information it is possible to show in this interface. To do so, we request for all events for a specific user. Example of get events request and associated XML response:

```
function getEvents(){
    return $.ajax({
            type:"GET",
            url:"http://"+
```

```
            server+":"+port+
            "/remember-me/rest/events?user="+user,
            dataType : "xml"
    });
}
```

When the request is successful an XML response with the following characteristics will be returned:

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<page>
  <events>
    <id>36</id>
    <name>Infancia</name>
    <description>Nascimento / Infancia</description>
    <startDate>1990-12-15T00:00:00Z</startDate>
    <endDate>1990-12-15T00:00:00Z</endDate>
  </events>
  ...
</page>
```

Since we are using restful web services we need to respect its pattern where each url represents a specific entity. In this case the operation *events* will only provide us the id, name, description, start and end date. To get more information about a specific event we need to go through the event id field and request for media, participants and places associated to that event id. All this is needed in order to decide how many, which books to create and what content will be on them. The same goes for user specific interests. Next, we have an example of the information retrieved about the user so far:

variable	**value**
id	26
name	Fotografia: Que cumplicidade! xd
description	Que cumplicidade! xd
bdate	2014-01-16T17:38:07Z
edate	2014-01-16T17:38:07Z
participants	’id’ : 2; ’name’ : ”João Martins”; ’birthDate’ : 1990-12-15T00:00:00Z; ’pictureUrl’ : https://...
media	’id’ : 64; ’url’ : https://...; ’content’ : https://...
places	’id’ : 2; ’latitude’ : 38.7119; ’longitude’ : -9.14085

Table 4.1: Life event example of information retrieved from web service

variable	**value**

id	19
name	Bon Jovi

Table 4.2: Interest example of information retrieved from web service

Next, we present all the books created in our friendcrafting memories visualisation tool in more detail. Not only the functions they provide but also the interface itself.

Photo Album

Photo album presents all the events as if they are an enriched photo album, it contains a title, a time for that event, a description, associate pictures, places and people that attended that event. In Picture 4.5 we can see how the events are presented in the book, those events are then selectable. The result of that selection can be seen in Picture 4.6. When clicking a certain event, the information provided about that event is more complete, showing the pictures and the names of the people that attended the said event as well as information about the place.

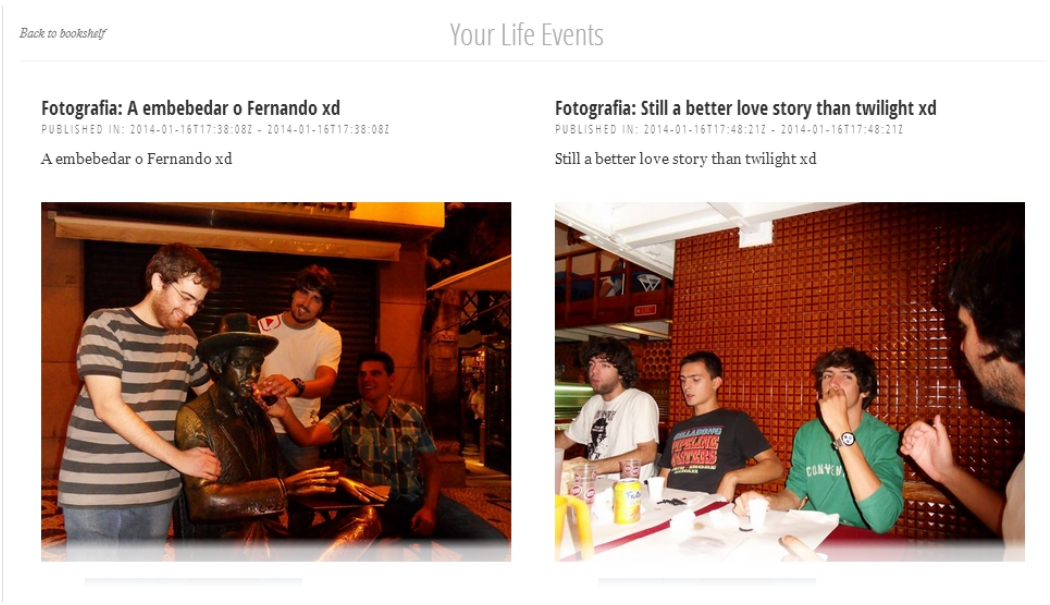


Figure 4.5: Life event book

Interests

Interests book focus in the likes of the Facebook profile, in our case the only information we know about a given interest is its name. From that name we then make requests to the Wikipedia API to fetch information about those entities. In Figure 4.7 we can see an example of information we can fetch from Wikipedia services about a specific interest of

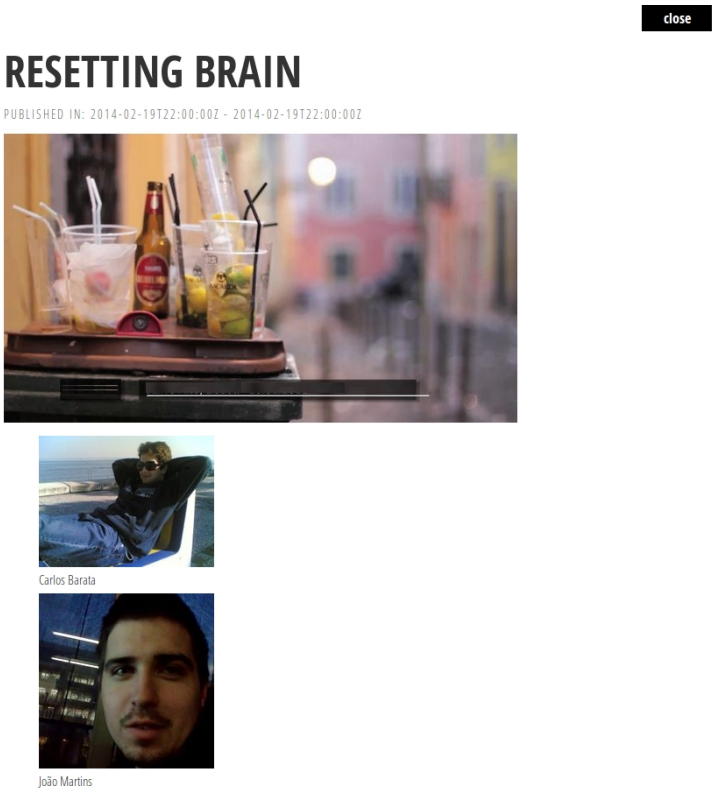


Figure 4.6: Life event details

the user and correspondent representation in our UI. The information are two singers that the user liked in Facebook with complete background information.

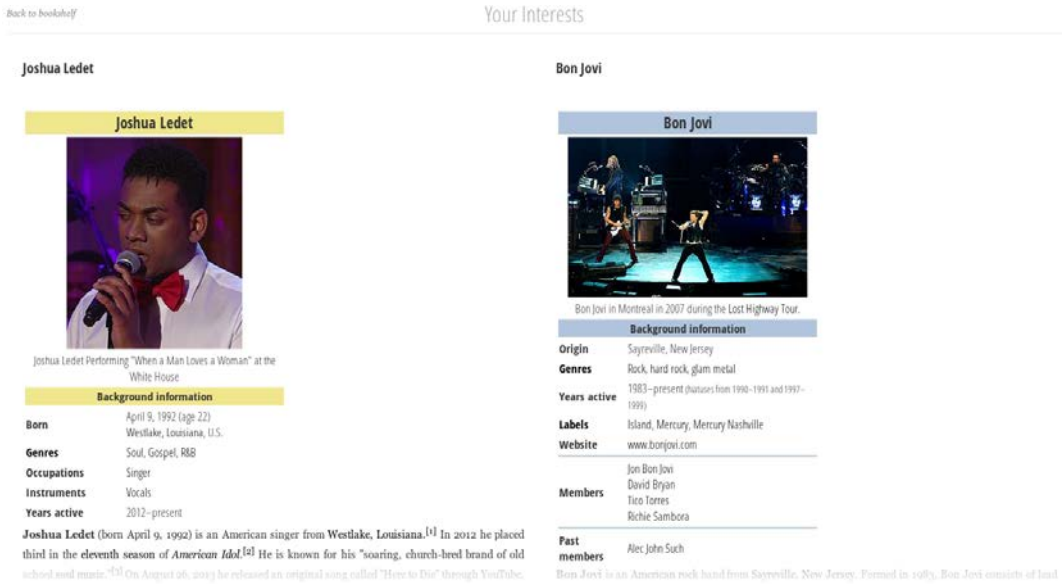


Figure 4.7: Interest page

People

People book focus on the relevant people within Facebook events of the person. We fetch their basic information and display it in this book. This visualisation mode includes all the events where that person was present.

Due to several restrictions with Facebook API there isn't more information we can get about a person besides the profile photo and the name. Although, to overcome this, there is the possibility to retrieve more information about someone if that given person logs in with his/her Facebook account into the same application as the PD, i.e, the system can then provide information like birth date, interests of that person and display it for the PD in his books. An example of this visualisation can be found in Figure 4.8.

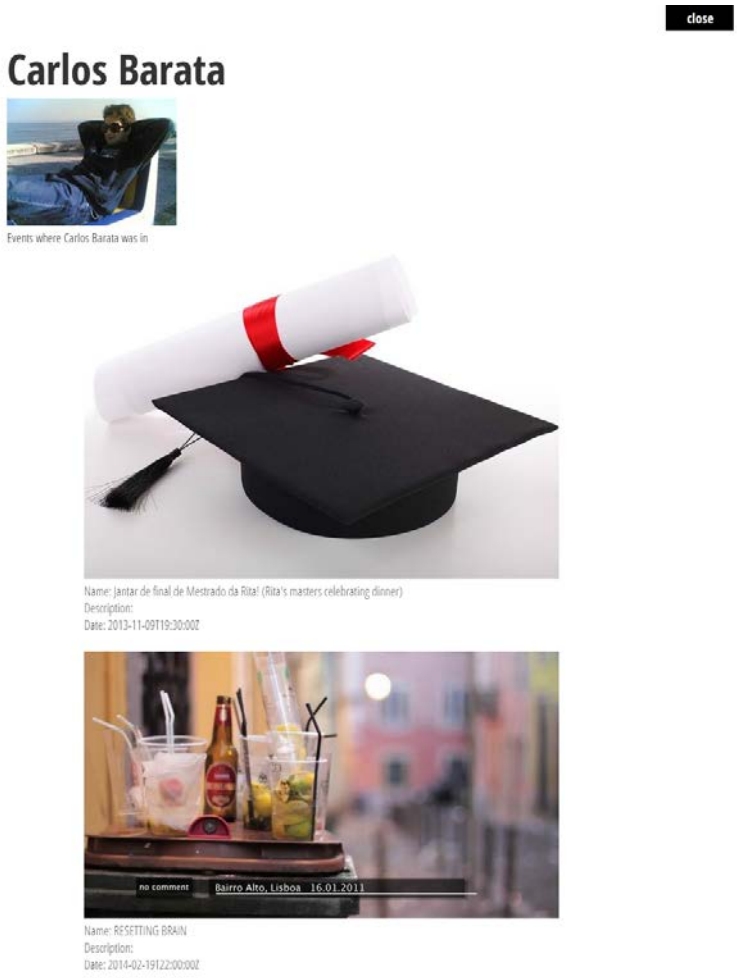


Figure 4.8: Friend page

Places

Places book is based on the places present in the person Facebook profile. Besides the location, we provide public photos taken on those places by other people. To do so, we use

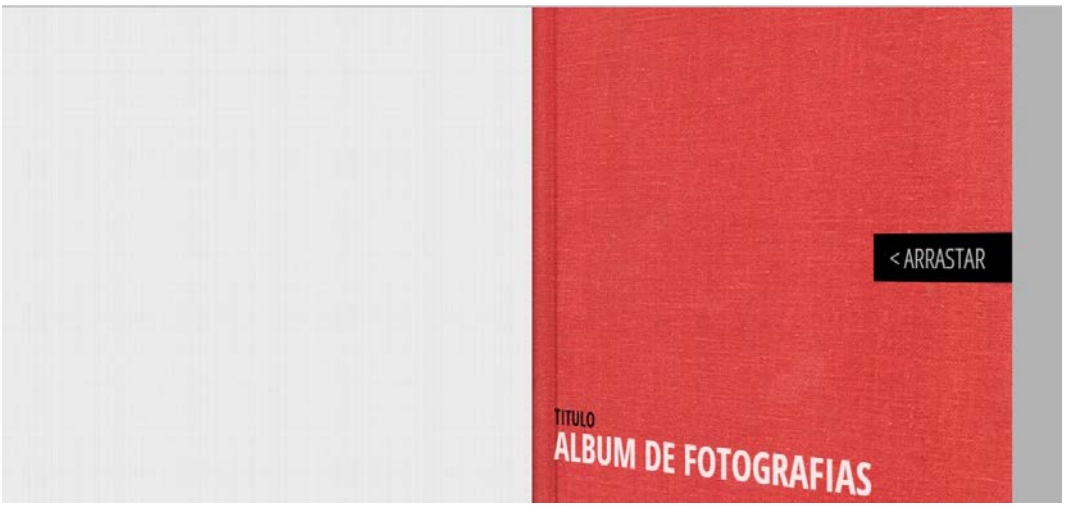


Figure 4.9: Friencrafting Memories user interface flip effect

google geocoder in order to obtain location coordinates from addresses and names. From the location latitude and longitude we set a radius from which we want to fetch public photos. The location and radius are then passed into the Panoramio API. The Panoramio API then gives us photos spread in that area. An example of this visualisation can be found in Figure 4.10 where we present a swipeable slideshow from the place.

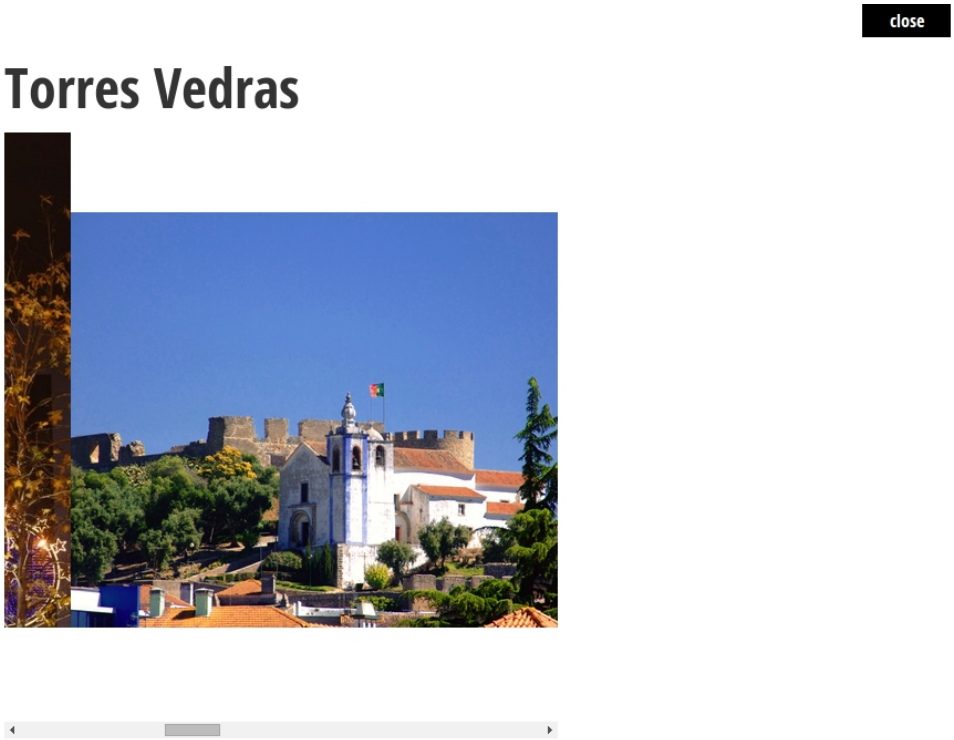


Figure 4.10: Place page

Chapter 5

Evaluation

In this chapter we present all the evaluations we performed on our system. From a preliminary assessment based on literature reviews and one interview with an expert to user tests for the two visualisation tools.

5.1 Preliminary assessment

In order to validate our concept, an interview was performed with the responsible for the psychology and formation body of Alzheimer Portugal. This department not only specialises in patients that suffer from Alzheimer's Disease, but also helps caregivers and family members to cope with the burden and responsibility of caring for someone with this disease.

In order to provide a better explanation and understanding of the overall system, during this interview, we presented it through several usage scenarios. These scenarios improve the system comprehension by providing information about the people and information involved in our system. Next, we deepen what was spoken and understood during this interview.

Tools availability and adequacy to patient needs

Cognitive prosthetics as a way to facilitate reminiscence and monitoring of the patient were not new to the interviewee. Nonetheless, no real success examples were provided when asked. Existent tools or systems either prove themselves too cumbersome for the caregivers or inadequate when trying to fulfil patient needs.

The progression of the disease requires tools that are customisable through time in order to easily adapt to their users. Although, in the beginning the user might have full control of the tool, eventually that will no longer be the case and the main caregiver might have to step in and help the care receiver. The interviewee acknowledge the potentials of our tool in order to do so.

Patient support network

Usually as time goes by, social contact with patients that suffer from dementia related illnesses rapidly decreases. Although, at first, people tend to be very understanding and helpful, with time people once close start to move away.

A system, like ours, where one of the main contributions is the relief of the burden set upon one or two main caregivers by increasing the size of the support network was subject of concern from part of the interviewee. The interviewee stated that, quickly our system would be reduced to the same caregivers as before and, as such the burden relief would prove itself insignificant. Although, with more insight on the subject, the interviewee stated that the virtual world would be a way of keeping in touch and still provide some help to the patient. As the saying goes, out of sight, away from the heart. With our system we try to change that.

Privacy concerns

Several concerns in the field of privacy were raised during the interview. The two areas were: what type of information to monitor and when; and information sharing with different users that are part of the support network. Several solutions have to be in place so that this issues are dealt with. With the monitoring component there is the need to consciously say when the user wants to be monitored and what type of information he is willing to record. On the other hand, levels of privacy need to be set. Social networks that favour different privacy settings for different users are the ones to use since patients might not be willing to share all information about themselves to everybody in their support network. Also, the capacity to provide information to PD's smartphone we avoid unnecessary disclosure of information.

The challenge of presenting contents

With the help of the support network and with the automatically gathered data, the contents presented to the PD will become more and more complete over time. Although, with the PD disabilities and disease progression it is important to take into consideration what to present to the patient. Presenting everything can have a prejudicial effect when the patient can't remember information. Instead of motivating PD to communicate there is the possibility that the opposite effect occurs increasing anxiety and become a cause of depression. Typically, Reminiscence Therapy needs to be carefully planned and executed in order to afford comfort and enjoyment as well as improve communication.

5.2 Data Gathering

To evaluate our mobile and crowd-powered memory prosthesis we conducted a study to assess what data is collected when used by real users in day to day activities for a period of one week. The data collected was only concerning location and pictures taken through time. This study was made with 6 users that carried android smartphones with the following characteristics:

Model	Operative System
Samsung Galaxy S2 Plus	4.2.2 Jelly Bean
HDC H7100	4.1.1 Jelly Bean
Samsung Galaxy S3	4.4.4 KitKat
Nexus 4	4.4.4 KitKat
Nexus 5	4.4.4 KitKat
Samsung Galaxy Young	4.1.2 Jelly Bean

Table 5.1: Smartphone models and Operative Systems used

Appendix C presents samples of the data gathered and provided by web services, further results will be based on a set of the those samples for the six users.

The average location accuracy of the six users was of 142.21 meters, although different users used different location strategies. From the six users, four allowed the usage of GPS location through the entire time with an average location accuracy of 91.78 meters. One user did not allowed for GPS location using only Wi-Fi, as such the average location accuracy was 420.35 meters. Also, one user switched from GPS location to Wi-Fi location accordingly to what suits him best, this user got an average location accuracy of 140.45 meters. These results are consistent to what google location APIs say, when a Wi-Fi location is available the location is less accurate due to triangulation made to assess someones position. The best the wireless connection can make is say that the user is in a specific area making it less accurate.

Also, during the one week period, the six users took an average of 4.67 pictures and travelled an average of 33.8 kilometres per day and an average of 203.6 kilometres during the one week period. Significant differences in distance travelled a day were observed from user to user, the user who travels the least everyday travelled in average 14.4 kilometres a day and the user who travels the most everyday in average traveled 100.2 kilometres a day.

5.3 Daily life visualisation tool

We have made a study to evaluate the daily life visualisation tool in two separate ways. One to measure usability with the System Usability Scale (SUS) [3] and through obser-

vation of the interaction and how users react to the visualisation understand positive and negative aspects of this tool.

First, we placed the users accessing the UI and viewing what they did from July 15 to July 22. This information, represented in the UI to build routes and show pictures, is the one gathered and used to evaluate the AidedMemory mobile application. As the data was gathered two months before the display to the users, we can now understand with a better degree of certainty whether the tool allows users to remember not only where they went but how their day was or not.

Next, we created several task to be executed by them in it. These tasks were specifically designed taking into consideration the several features of the system, all of them aim at trying to understand if the way the system was built allows users to enjoy all its features as easy as possible. The tasks were the following:

1. watch the path travelled in a day of your choice. What different places you visited accordingly to the information displayed?

2. in the day you selected in the previous task, explain as detailed as possible your itinerary. Since places you visited that might not be represented in the tool to details you might have considered interesting during the routes.

3. watch images that concern a specific day.

4. watch images of a specific day at a specific place or event of your choice.

Since the data we gathered with the mobile application is the data we use to present the users day, the number of users is also six. From the observation and comments from the users, several problems and advantages arise. All users had trouble finding the slideshow functionality, just noticing it in the end of the tasks. It was suggested that it should be bigger, in a more visible place and while showing the pictures it should contain information about the day and the place. Also, it wasn't clear what the slideshow would show them. Another problem users complained about was the lack of details in some paths. The paths were sometimes poorly outlined due to the accuracy in certain portions of the travel. Users that kept the GPS location on have better outlined paths.

Although, not all was bad. From the six users, only one said that ***near his house the photos were too far*** although at the same time he also stated that in ***another location they were also very near the desired spot***. Four said that, although the photos weren't in the exact place, it were ***close enough to be relevant in providing clues of the area***. One even said that the mechanism to fetch photos automatically from places near the locations was ***so accurate that it even showed a photo where his house appeared***.

When reviewing a desired day, three users clearly stated ***let me see what I did this day!***. These users just actively remembered what they did when they saw it outlined in the map, one user even said ***I was riding my bike and in this spot I had a flat tire and***

called my girlfriend to pick me up. The others didn't seem sure about what they did in the days they selected but the presented information was enough for them to acknowledge that they did not left home that day or they just went to college or work and back to home.

One user asked if he could ***see the travelling sequence***. The user that stated this, was also the one that had the most visited places and longer travelling routes. Sometimes it was not clear where he started travelling, the next and previous stops as well as where and when his journey ended. Two users complained about the fact that ***balloons containing images didn't automatically close and resize to better fit the screen***.

One user reported that ***at one point no longer knew which days were already visited, asking for a feature that would distinguish visited days from unvisited days***. Also, another user ***didn't found the slideshow intuitive enough, stating that he wasn't sure of what he was going to see***.

After using the daily visualisation tool, we asked the users to fulfil a questionnaire in order to evaluate the tool usability. For that, we used the System Usability Scale (SUS) [3] a questionnaire found in Appendix D, that as the name says, aims at measuring the perceived ease of use of software, hardware, cell phones and websites.

Results differed from user to user sometimes with significance and we can see it in Table 5.2.

user	**result**
1	77,5
2	72,5
3	70
4	92,5
5	57,5
6	82,5

Table 5.2: Results obtained from SUS questionnaire

The average result was 75,42 which in the SUS scale corresponds to a B and a standard deviation of 11,88. As we can see in Figure 5.1, B is the second highest usability score.

5.4 Friendcrafting Memories

To assess our friendcrafting memories visualisation tool, we conducted a study that aimed at understanding how the support network for the final user actually behaves and how the person using the tool reacted to it.

The study was conducted with 82 years old person, that does not suffer from dementia, and his thirteen people support network, in an attempt to better recreate the end purpose

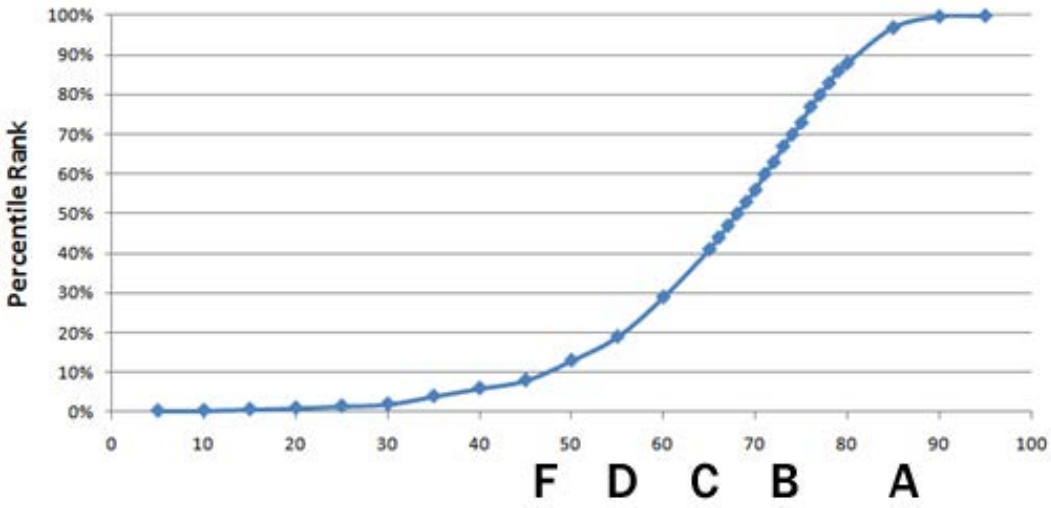
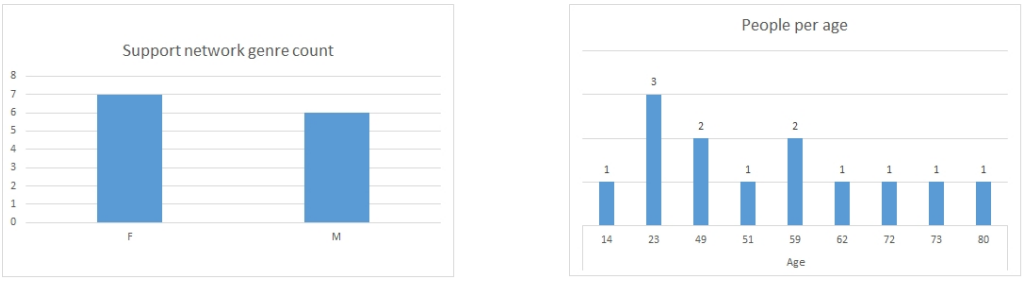


Figure 5.1: SUS usability score curve

of our application where we develop an interface that is suitable for PD. The people that compose the support network range from 14 years of age to 81 years of age. We presented a characterisation of the support network in Picture 5.2.



(a) Genre distribution in the support network (b) Age of the people in the support network

Figure 5.2: Support network characterization

Prior to the observation of the user with the visualisation tool and interviews with support network members several actions needed to be taken. First, we created a Facebook profile page for the targeted subject. The Facebook profile page was created by a person in the support network responsible for the management of it. People in the support network were contacted with the pretext of creating a life history book about the subject's life in a chronological order and can be seen in Picture 5.3.

Five people out of twelve had to create a Facebook account because they didn't own one. Although, only one user didn't know what Facebook was and wasn't able to use it. That person was the spouse of the target subject and the oldest person in the support network. All others knew what Facebook was and understood the result we wanted to achieve. All the others that had Facebook accounts, use it at least two times a day. Those that use Facebook on a regular base stated that the main consumption they do is looking into photos of friends and family or subjects they have a special interest in.

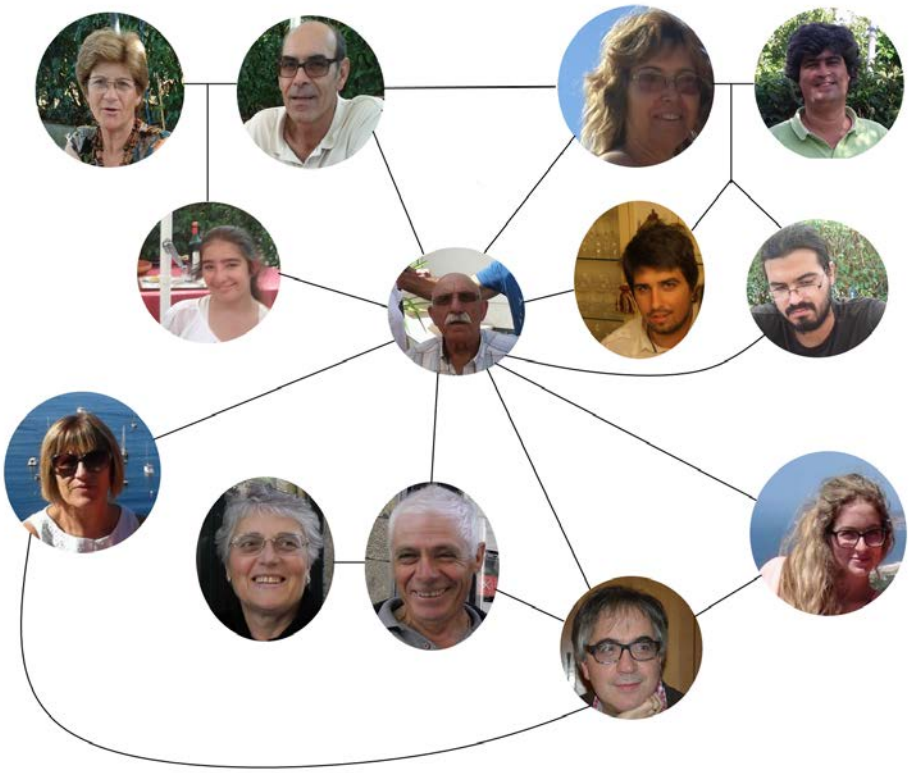


Figure 5.3: Person's support network

Motivation

Different people in the support network reported different motivations in order to conduct such an enterprise. Overall, users willingly participated in this study, offering not only their time but also their personal information in order to help someone they care about. All users stated this as the main motivation in using such a system. Out of the thirteen, three users said that ***would create events and enrich them in order for them to build their own events as well***. By helping someone they are also helping themselves.

When asked to think about alternative ways of helping someone, by presenting items that would help a person they care about, remembering several participants answered that ***would use photo albums in order to try to achieve the same result***. The reason being that mainly they used photos as the media that describes an event the best. When asked if they would prefer that method instead of enriching events in Facebook, users highlighted several advantages and setbacks for both alternatives.

These advantages and setbacks vary greatly accordingly to the background, experience and knowledge about technology of the interviewee. Two users stated that by ***placing the information in a digital format that would help them manage the repository***. These two and a third user also pointed out that by ***placing a lot of information in a social network, privacy will be lost***. It wasn't as much the sharing with information with other people

they know but placing it where the control of information depends on the social network managers will.

All users but one, the spouse which lives with the subject and doesn't want to use technology, stated that the ***distance would make them use the system due to the difficulty in being with the person they try to help***. Besides the spouse, two more users evoke the ***lack of knowledge they have when it comes to use technology in general and with tools such as our system***. These users highlighted that they ***depended on someone close like the husband or a daughter to interact with the social network becoming passive users***. Passive users contribute to the creation of events and with ideas, they do not perform the work itself. One user also said that one disadvantage of using Facebook is the ***loss of proximity but on the other hand said that having the information in a digital format would enable to perform several functions like zooming in***.

Events and observation

The support network provided several events that are shown in Table 5.3, with an interesting time frame. The events that are closely related to family are in its essence evenly distributed through time, but the less relevant events are more present in the recent past and not in the early life of the user.

Also, it is interesting to notice that there aren't any bad events, like someone died. Deaths are a relevant and unavoidable part of life but still no one even though or mentioned these events, although, the mere mention of someone that is no longer present, brought back emotions of sadness.

Event	Date	Nº of photos
Grandfather's birth	1932	0
Marriage	1953	0
Son's birth	1956	0
Police	1957	0
Olivais	1959	0
Granddaughter birth	1965	5
Caldas da Rainha	1989	2
Grandsons birthday	1990	4
Grandsons baptism	1991	4
Family's party	1996	3
Son's marriage	1998	5
Granddaughter birth	2000	4
Visiting sister in the nursing home	2012	0

Back to Aldeia do Souto	2013	8
Visiting nephew	2013	1
Easter in Torres Vedras	2014	3
Birthday	2014	4
Visiting Leiria	2014	7

Table 5.3: Events created by the support network

The support network provided an average of 2.77 pictures per event with a standard deviation of 2.55 during a period of four days. Next, we proceeded with the observation in order to evaluate the friendcrafting memories user interface with the older person.

The user didn't have any previous experience with computers or even with a tablet. Although, when presented with the tablet and how to interact with it, it showed to be relatively fast. First, we demonstrated how to interact with the tablet by touching in things and sliding across screens. Even understanding and wanting to perform the clicking and the swiping, it wasn't clear for how long the user had to click. Specially in how long to press and in what part of the screen start the swiping. In the beginning the user pressed items in the screen for too long, initiating an unwanted behaviour from the tablet. Also, the user started swiping from the margins of the tablet where the screen doesn't detect touch events.

After the initial training the user was presented with our interface. The first interest of the user was reading what was written in the books. The book the user visited first was the people's book, where besides someones name and photo there is also all the events those two people shared with a caption with description of the event and the photo for it. The user first saw user photos on the book pages and although he navigated in the book pages he didn't seem sure he could click in the page of a user to see more detailed information. When told, the user eventually touched the pages and was able to identify several events for a person. Some people in the event photos weren't recognised but they weren't relevant.

Next, the user selected the interest book. Interest book presented several entities that were selected by the support network manager based on what he knows the older person likes. The manager selected Benfica, Eusébio, Maria do Céu Guerra, PSP and several agricultural pages as the older person interests. The information provided was accurate enough and interesting to the user. This book revealed itself as the book where the mood was more outgoing and relaxed starting a conversation about the weekly soccer results.

The place's book wasn't very interesting for the user, although the user proved to be knowledgeable about the location names and recognised some pictures, they were poor in trying to trigger conversation.

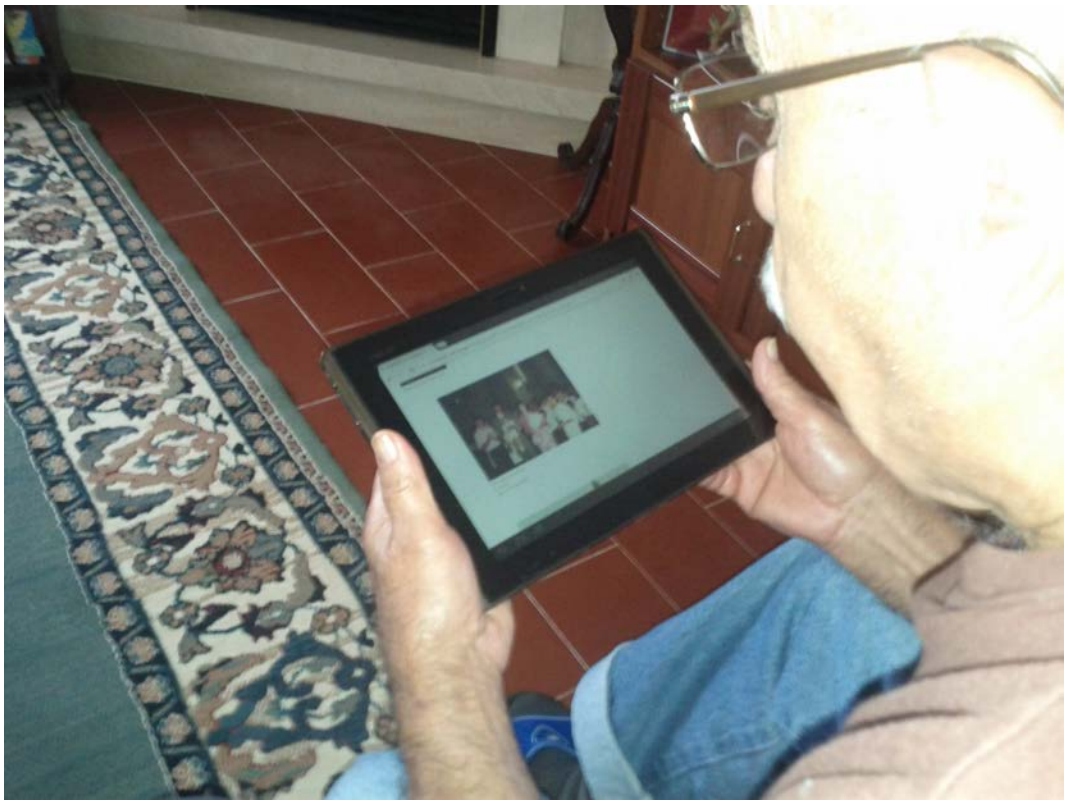


Figure 5.4: User accessing friendcrafting memories visualisation tool

When selecting the photo album the user quickly found events he was interested in, one of the events that the user started talking was when he saw an old photo from his sister that is no longer around. The viewing of his sister made him comment of how much they work in the village where they were born and the poor conditions but always with excitement. This book was the last one picked despite being the first because of its name. Album wasn't explicit enough and didn't awaken the user interest in selecting it. A change in the name of this book must be considered for future evaluations.

The interface showed to be adequate when it comes to the chosen metaphor for the bookshelf that was easily identified. Furthermore, the book swiping was coherent to the user through out the several books being able to navigate in them when understood the mechanism. The swipe label helped the user by showing up in the cover of each book.

Nonetheless, in depth navigation wasn't so clear to the user. Specially when it comes to select pages to view more detailed information as well as to get back to the bookshelf to select and view other books. It would also be interesting to conduct this study during a larger period of time, which would increase the number of members and events presented by the support network.

Discussion

The overall opinion about our system was that it is feasible. Feedback provided by users of the mobile application and consequently users of the daily visualisation tool was positive. Event though they pointed out a lot of examples of improvements to be made, they were motivated and actively remembered their daily activities.

With respect to the friendcrafting memories visualisation tool, initial results show a higher acceptance rate of the person's support network in providing events and media. Nonetheless, due to the short time period of the study it is not possible to assert that the support network would show this level of engagement through time. One clue we have that this engagement might continue is the need to help someone they care about and the statement some users made that by creating events for others they create events for themselves as well.

Chapter 6

Conclusion

In the beginning, at the Introduction chapter, we expressed that our work was a prototype aiming towards a general purpose context aware system. In this chapter, we will describe the progress made towards this goal in terms of framework development and applications as well as several issues in a range of domains. Furthermore, we also suggest several future research directions that could provide the next steps along the path to a complete system.

We developed a cognitive prosthesis capable of automatically gather contextual data from a user's smartphone, its support network and supplementary information available in online APIs. Two tools were created to provide different visualisations from the data gathered and processed. The first tool targets the visualisation of daily life with a special focus on routines. Routines are deeply linked to what users like to do or what they have to do. This tool tries to provide safety and reassurance to the user by reviewing its routines. The second tool focus on events created by the user support network on Facebook and associated media. Due to the wide spread of social networks, we use them as our lifelog interface to build someones life events in a chronological order with the biggest degree of certainty possible. Facebook was chosen as the best social network for such a system due to the number of users, different privacy settings and stable APIs.

Despite some necessary changes in our prototype, our three evaluations displayed positive outcomes from the users. The mobile application only drawback was some battery consumption, although it accurately gathered contextual data from all the test users. To avoid battery consumption problems we allow for several customisations like turning on/off sensors and increasing update intervals of data. Our daily visualisation tool refreshed the users memory by presenting routes and pictures of places they no longer accessed for quite some time. Most problems reported concerned information availability.

6.1 Benefits

In general, our system proves it feasibility in terms of the ability to gather a larger support network. Not only that support network is capable of enriching events by itself but several smaller networks are created inside of it. Users with low experience rates with computers and social networks still contributed to the network by resorting to the closer people that lives in their house.

The work developed was effective in obtaining data from the mobile phone, support network and online APIs and presenting contents to a PD. The system also proved to work when splitting some of the work that would normally lie on top of the main caregiver to a wider support network.

6.2 Limitations

The friendcrafting memories is highly dependent on the capability of motivating a wider support network that is capable of providing good and relevant information. There is the possibility that users are motivated enough to provide enough information or start creating irrelevant events for the people they are trying to help.

When performing the evaluation of this visualisation tool and although it would be with someone without cognitive disabilities there was the need to be there supporting the usage and providing instructions. Sometimes even when with a lot of training if an unwanted behaviour occurs the person using the tablet would just stop its interaction. This is also valid for the daily life visualisation tool.

6.3 Future work

A few problems must be solved to improve the development of a contextual mobile application. These problems suggest a variety of research directions that need to be pursued to make such a system usable by PwD:

- improve security through the system: One of the problems that is not addressed in our thesis is the one of security in data transmission. To succeed, there is the need to add encryption and authentication through digital signing of data transmission from the mobile application to the web server as well as from the visualisation tools to the web server and vice versa.

- extend existent evaluations of the system to PD: The next step would be, taking into consideration the learning from the evaluation of the several visualisation tools, improve them and then conduct an evaluation of both tools with PD and their support networks.

- understand and create statistical information about content usage and visualisation to build systems that auto tune information: some content is usually accessed more often and therefore has bigger relevance to the user. It is a good addition to have mechanisms capable of understanding and create statistics about content usage and visualisation.

- use raw data to derive locomotion and activity patterns has a way to detect unwanted behaviours and later assessment of acitivity information by therapists.

Assistive technology systems still have a large margin for improvement. With devices getting smaller by the day, worldwide network access and with the exponential increase of photographs taken everyday, it is expected that lifelogging systems specially those that aim at aiding memory will continue to evolve and wow us.

Appendix A

Frameworks

A.1 Synchronisation Mechanism

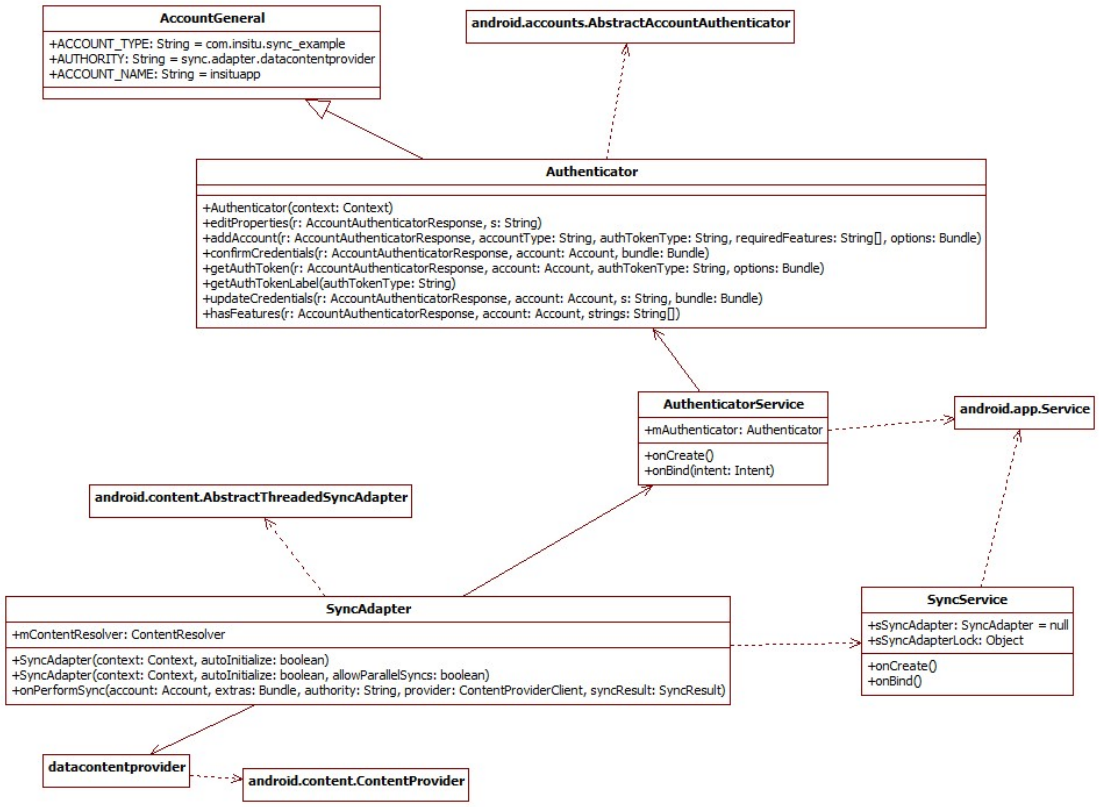


Figure A.1: Synchronisation mechanism

A.2 Sensor Framework

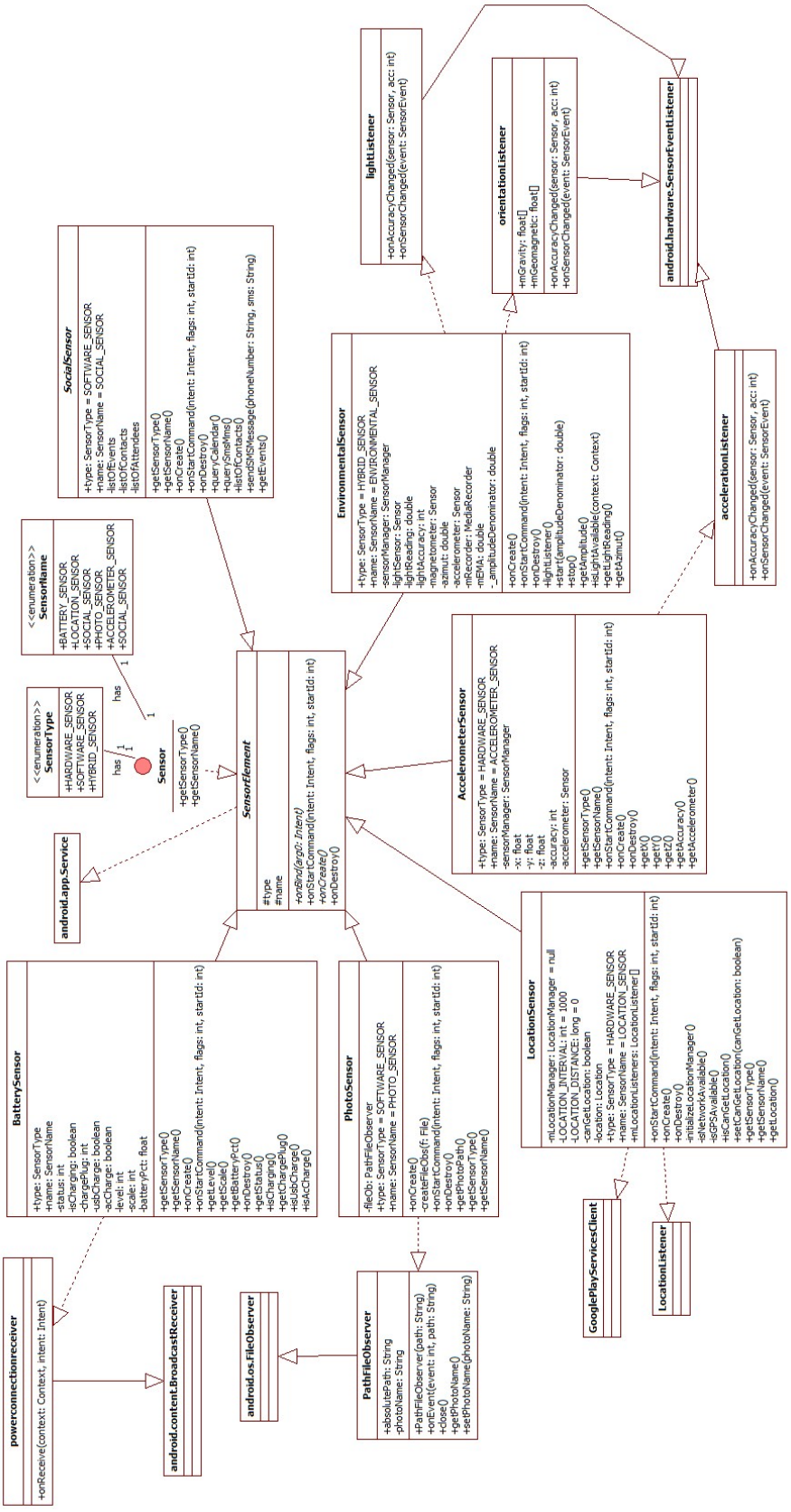


Figure A.2: Sensor framework

Appendix B

Google scheduled event

B.1 User google calendar

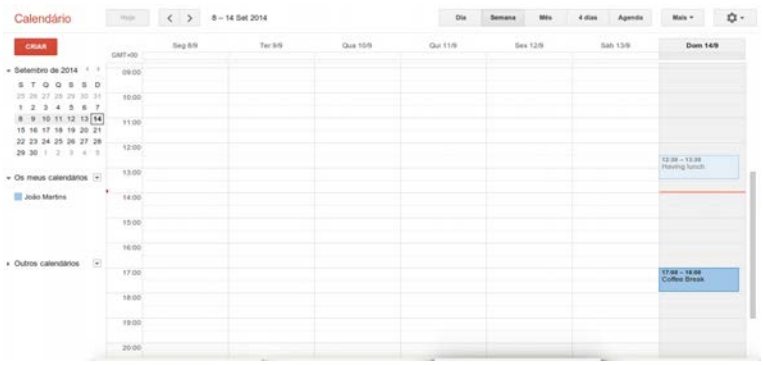


Figure B.1: User's google account with scheduled events

B.2 Scheduled event details

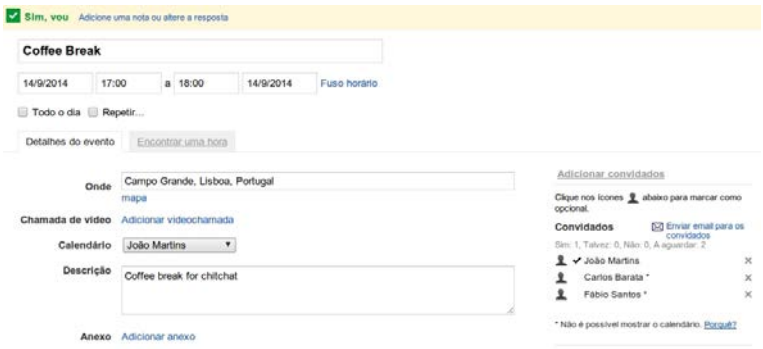


Figure B.2: Scheduled event detailed information

Appendix C

Mobile information provided by services

id	accuracy	latitude	longitude	provider	time
1	44.184	38.7558051	-9.1577604	fused	1405429315479

Table C.1: Location information sample from AidedMemory

id	accuracy	latitude	longitude	picname	time
1	23.063	38.7934104	-9.11955734	20140720_135502	1405860935504

Table C.2: Picture information sample from AidedMemory

Appendix D

SUS questionnaire answers and calculations

Question	u1	u2	u3	u4	u5	u6
1. I think that I would like to use this system frequently.	4	4	3	4	2	3
2. I found the system unnecessarily complex.	2	2	1	1	2	1
3. I thought the system was easy to use.	4	4	4	5	4	4
4. I think that I would need the support of a technical person to be able to use this system.	1	2	1	1	1	1
5. I found the various functions in this system were well integrated.	4	4	3	3	3	3
6. I thought there was too much inconsistency in this system.	2	4	4	1	4	1
7. I would imagine that most people would learn to use this system very quickly.	5	3	4	5	4	5
8. I found the system very cumbersome to use.	4	1	1	1	5	1
9. I felt very confident using the system.	4	4	3	5	3	3
10. I needed to learn a lot of things before I could get going with this system.	1	1	2	1	1	1

Table D.1: Questions asked to users for the evaluation of the daily visualisation UI

Acronyms

AD Alzheimer's Disease. 1, 43

ADL automation for daily life. 4

API Application Programming Interface. vii, ix, 3, 34, 39, 41, 45, 55, 56

CDN Cogknow Day Navigator. 9

CPU Central Processor Unit. 25

CSS Cascading Style Sheets. 37

GPS Global Positioning System. 10, 23, 25, 45, 46

GSM Global System for Mobile Communications. 4, 18, 28

MMS Multimedia Messaging Service. vii, 2, 4, 23, 26, 28

PANT Practitioner Assessment of Network Topology framework. 35

PD People with Dementia. ix, 1, 2, 3, 4, 7, 8, 9, 10, 12, 13, 18, 21, 33, 34, 35, 36, 41, 44, 47, 56

QoL Quality of Life. 2, 19, 34

RT Reminiscence Therapy. 1, 12, 19, 44

SMS Short Messaging Service. vii, 2, 4, 14, 23, 26, 28

SUS System Usability Scale. xii, xiii, 45, 47, 65

UI User Interface. ix, xiii, 2, 28, 34, 39, 46

UM unaided memory. 14, 16

XML eXtensible Markup Language. 23, 37, 38

Glossary

cognitive prosthetics is any computer-based system that has been designed for a specific individual to accomplish one or more designed tasks related to activities of daily living, including work. 7, 8, 18, 43

crowdsourcing is a way to retrieve information we need, ideas, or content by asking it to a large set of people, usually an online community instead of traditional employees or suppliers. 2, 10, 11, 18

lifelogging is the construction of a digital archive of our lives, and it gathers information ranging from personal information such as conversations, calls, emails and sms to environmental as well as biometric information like temperature, ambiance light and heart rate measures.Its goal is the creation of an e-memory that surpasses humans capability to remember things and use it to augment our own memory. 3, 4, 14, 16, 17, 18, 21

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