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A Mobile Phone Navigator For Older Adults and Persons with Dementia

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Abstract

We live in an aging society where, for the first time, the senior population is close to outnumber the younger population worldwide. This leads to a growth in the amount of age-related difficulties and health conditions, overwhelming health and social care services. Due to these facts, many nations turned their attention to technology in order to create solutions that could assist this older population into a more autonomous living style, providing greater quality of life and promoting aging in place.

Dementia is one of the conditions that older people are more susceptible of contracting, with a new case developing every 7 seconds worldwide. It is actually not a condition *per se* but a syndrome, a group of signs and symptoms, associated with a progressive loss of cognitive ability. Its most common form is Alzheimer's disease which, by itself, accounts for 50 to 80 percent of all dementia cases.

Alzheimer's most common symptom pattern begins with a gradually worsening difficulty in remembering new information. Right from its early stages, the disease may lead to a person becoming confused, lost in familiar places, misplacing things or even having trouble with language. Later on, one of the most concerning symptoms of the disease may occur, wandering. Wandering consists of an aimless and disoriented walk which can become dangerous by increasing the possibility of accidents, getting lost, serious injuries or even death. Being a progressive disease, the need for care becomes more assiduous as the disease progresses and although the majority of caregivers live close to their patient, some are considered long-distance caregivers, living over an hour away making the task of constantly monitoring the actions of the patient extremely difficult.

In this project, a functional prototype that provides older adults and persons with dementia, as well as their caregivers, with a greater sense of safety whenever they go outdoors, was developed. It achieves this goal by monitoring their location and making sure that they remain within a safe perimeter. Whenever they stray from their safe zone, they are alerted to this circumstance and can choose to call for help or be navigated back to a safe place. Caregivers are also automatically alerted of the situation, and of their cared-for's location, so that they can take action if necessary.

For this application to be useful it needed to be usable, so interfaces and work flows of the prototype were designed with the target group's specific needs and limitations in mind, and according to the existent guidelines on the subject. A real time navigational interface was also developed specifically for this user group, and promising results were obtained.

Resumo

Vivemos numa sociedade em envelhecimento onde, pela primeira vez, a população sénior se encontra próxima de ultrapassar a população mais jovem a nível mundial. Isto leva a um crescimento do número de doenças e complicações relacionadas com a idade, sobrecarregando os serviços de saúde e acção social. Por este motivo, várias nações viraram a sua atenção para o desenvolvimento de soluções tecnológicas que permitam a esta população sénior viver com uma maior autonomia, providenciando-lhes simultaneamente uma maior qualidade de vida e promovendo o envelhecimento em casa.

A demência é uma das complicações que as pessoas de idade são mais susceptíveis de contrair, com um novo caso a ocorrer a cada 7 segundos. Na realidade, a demência é uma síndrome, ou seja, um conjunto de sinais e sintomas, associados a uma progressiva perda de capacidade cognitiva. A doença de Alzheimer é a forma mais comum de demência, sendo responsável por 50 a 80 por cento de todos os casos da mesma. O padrão sintomático mais comum da doença começa com um gradual aumento da dificuldade em relembrar informação recente. Desde a sua fase inicial a doença pode provocar desorientação, podendo levar a que as pessoas se sintam perdidas em locais que lhes deviam ser familiares. Com o avanço da doença, aumenta a possibilidade de ocorrência de um dos sintomas que causam maior preocupação às pessoas responsáveis por estes doentes, denominado vulgarmente de *wandering* (vaguear, em português). Este sintoma consiste numa caminhada desorientada que pode tornar-se perigosa ao aumentar a probabilidade de ocorrência de acidentes, de o paciente se perder, de sofrer ferimentos graves, ou até, de morte. Sendo uma doença progressiva, a necessidade de cuidados torna-se mais relevante com o passar do tempo e apesar da maior parte das pessoas responsáveis por cuidarem destes pacientes viverem perto dos mesmos, existem situações em que tal não se verifica, tornando-se extremamente difícil a sua monitorização.

Neste projecto, um protótipo funcional que fornece a idosos e pessoas com demência, assim como às pessoas responsáveis por estes, uma maior sensação de segurança quando saem de casa, foi desenvolvido. Atinge-se este objectivo através da monitorização da sua localização e ao garantir que estas pessoas se mantêm dentro de um perímetro de segurança. Caso o idoso abandone o mesmo, é alertado para esta circunstância e pode optar por ligar a pedir ajuda ou por ser navegado pela aplicação de volta para um lugar seguro. A pessoa responsável pelo idoso também será avisada da situação, assim como da sua localização, para que possa agir caso seja necessário.

Para que esta aplicação seja útil necessita de ser utilizável pelo seu público-alvo, e por esse motivo as interfaces e o próprio *work flow* da aplicação foram desenhados com as necessidades e limitações do mesmo em mente, tendo sido seguidas as *guidelines* existentes sobre esta matéria. Foi também desenvolvida a pensar neste público-alvo, uma interface para navegação em tempo real, cujos resultados obtidos foram promissores.

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Ricardo Moutinho

"Our society must make it right and possible for old people not to fear the young or be deserted by them, for the test of a civilization is the way that it cares for its helpless members."

Pearl S. Buck

Contents

1 Introduction **1**
1.1 Problem Description . . . 2
1.2 Objectives and Motivation . . . 2
1.3 Document Structure . . . 3

2 The Older Adult and Dementia **5**
2.1 Dementia . . . 6
2.1.1 Alzheimer's Disease . . . 6
2.1.2 Caregivers . . . 9

3 The Relation with Technology **11**
3.1 Assistive Technology . . . 12
3.2 Mobile Phones . . . 13
3.2.1 Smartphone Technology . . . 13

4 Existing Products and Related Work **19**
4.1 Commercial Products . . . 19
4.1.1 Tracking Devices . . . 19
4.1.2 Monitoring Services . . . 21
4.1.3 GPS Navigation . . . 22
4.1.4 Mobile Applications . . . 24
4.2 Research Projects . . . 26
4.2.1 Route-Finding Assistances for Community Travelers with Cognitive Impairments: A Comparison of Four Prompt Modes (2007) . 26
4.2.2 Auditory Navigation for Persons with Mild Dementia (2008) . . . 27
4.2.3 iWander (2010) . . . 28
4.2.4 Electronic Tracking of Patients with Dementia and Wandering Using Mobile Phone Technology (2005) . . . 29
4.2.5 Training Early Alzheimer Patients to use a Mobile Phone (2002) . 30
4.2.6 European Research Project COGKNOW (2006-2009) . . . 30
4.2.7 The Escort System (2010) . . . 31
4.2.8 The ENABLE Project (2001-2004) . . . 33

5 AlzNav: Project Specification **41**
5.1 The Approach . . . 41
5.2 Methodologies . . . 42
5.3 Requirements Specification . . . 43

5.3.1 Functional Requirements . . . 43
5.3.2 Non-Functional Requirements . . . 45
5.4 Use Case Model . . . 46
5.4.1 Actors . . . 46
5.4.2 Caregiver . . . 47
5.4.3 Patient . . . 49
5.5 System Architecture . . . 49
5.5.1 AlzNav Modules . . . 49

6 Implementation **53**
6.1 Requirements . . . 53
6.1.1 Operating System . . . 53
6.1.2 Hardware . . . 53
6.1.3 Languages . . . 54
6.2 Interface Considerations . . . 54
6.2.1 Brightness . . . 54
6.2.2 Text Color . . . 55
6.2.3 Keep Awake . . . 55
6.2.4 Color Codes . . . 55
6.2.5 Labels . . . 55
6.2.6 Icons . . . 55
6.2.7 Buttons . . . 56
6.2.8 Dialogs . . . 57
6.2.9 Advanced Options . . . 57
6.3 Functionalities . . . 57
6.3.1 Main Menu . . . 58
6.3.2 Contacts . . . 59
6.3.3 Navigation . . . 63
6.3.4 Taxi . . . 65
6.3.5 Settings . . . 65
6.3.6 Safezone . . . 66
6.4 Processes and Algorithms . . . 68
6.4.1 Calls . . . 68
6.4.2 Location Management . . . 69
6.4.3 Alerts and Location Requests . . . 72
6.4.4 Navigation . . . 73
6.4.5 Safezone . . . 76
6.4.6 Phone State Management . . . 77

7 Evaluation and Results Discussion **79**
7.1 Questionnaire . . . 79
7.2 Functionality Tests . . . 80
7.2.1 Location Management . . . 80
7.2.2 Navigation . . . 82
7.3 Usability Tests . . . 82
7.3.1 Test Description . . . 82
7.3.2 Setup . . . 83

7.3.3 Process . . . 84
7.3.4 Demographics . . . 84
7.3.5 Results . . . 85
7.4 Results Discussion . . . 91

8 Conclusions and Future Work **93**
8.1 Objectives Fulfillment . . . 93
8.2 Contribution . . . 94
8.3 Future Work . . . 94

References **97**

A Initial Design Prototypes **103**
A.1 Main Menu . . . 103
A.2 Contacts . . . 104
A.3 Configuration . . . 104
A.4 Navigation . . . 105

B Power Management **107**

C Example JSON Response **109**

D Questionnaire Results **111**
D.1 Demographics . . . 111
D.2 Questions . . . 111

E Usability Tests **115**
E.1 Script . . . 115
E.2 Results . . . 118
E.2.1 Caregivers . . . 118
E.2.2 Patients . . . 120
E.3 Participants Satisfaction . . . 122
E.3.1 Caregivers . . . 122
E.3.2 Patients . . . 123

List of Figures

2.1 Symptoms of AD throughout each stage [ANMF10] 8

3.1 U.S. smartphone market penetration (Adult consumers, Jun - Nov 2010) [Com11a] 14
3.2 Composition of smartphone users by age segment [Com11b] 14

4.1 i-traks™ Lite – An example of a compact GPS tracking device 19
4.2 GPS shoes, vest and bracelet examples 20
4.3 EmSeeQ™ watch – An example of a cellular network tracking device . . 21
4.4 Comfort Zone's interface 21
4.5 Examples of turn-by-turn navigation devices by two of the top GPS makers 22
4.6 Examples of turn-by-turn navigation applications on a smartphone 23
4.7 Google Navigation screenshots 23
4.8 Alz-Locate application 24
4.9 Tell My Geo™ application 25
4.10 Four navigation prompt modes tested on persons with CI 26
4.11 Examples of the adapted TomTom application and device 28
4.12 COGKNOW's prototype (including touch screen and mobile device) . . . 31
4.13 The Escort System's overview 32

5.1 System overview 42
5.2 User Centered Design Process 43
5.3 System's actors 47
5.4 The caregiver's use cases 48
5.5 The patient's use cases 49

6.1 Buttons' states final design prototypes 56
6.2 Main menu's interface according to user type 58
6.3 Quick contacts functionality interface 59
6.4 Quick contacts interface with over 4 contacts 60
6.5 On-click/long click actions for each user type 61
6.6 Example of the contacts' phone type overlays 61
6.7 Interfaces used for picking and editing contacts 62
6.8 Navigation interface 63
6.9 Static instructions possibilities 64
6.10 Destination screen using streetview 64
6.11 Call a taxi feature interface 65
6.12 Settings interface 66

6.13 Safezone definition process 67
6.14 Call process when the network is unavailable 69
6.15 Status bar notifications that the application is running 70
6.16 Influence of the emergency state on the location update frequency 71
6.17 Example of the automatic alert messages 73
6.18 Static instructions calculation example 75

7.1 Compass calibration process 82
7.2 Outdoor test route 89
7.3 Contradictory instruction situation 90
7.4 Google Maps' graphical instruction for the decision point on which the navigational errors occurred 91

A.1 Initial main menu prototypes with an emergency number call button instead of the caregiver's quick call button 103
A.2 Initial arrowed scroll view prototype with disabled buttons 104
A.3 Initial configuration screen which was removed entirely after the feedback received from the usability tests 104
A.4 Some of the alternative prototypes for the navigational interface 105

B.1 Log of a travel before the power management implementation 107
B.2 Log of a similar travel after the power management implementation . . . 107

E.1 Caregivers' general satisfaction per task 122
E.2 Patients' general satisfaction per task 123

List of Tables

3.1 Possible relation between common smartphone applications and typical dementia victims' needs [ea08] . . . 15
3.2 Design guidelines for MAT aimed at people with CI [BPPG09] . . . 16

4.1 Summary of ranking for most and least helpful modes of prompts [FYSH07] 27
4.2 Guidelines regarding the design of a navigation system for PwDs [dB08] 29
4.3 Principle 1: Equitable Use [Bjo04] . . . 35
4.4 Principle 2: Flexibility in Use [Bjo04] . . . 36
4.5 Principle 3: Simple and Intuitive Use [Bjo04] . . . 37
4.6 Principle 4: Perceivable Information [Bjo04] . . . 38
4.7 Principle 5: Tolerance for Error [Bjo04] . . . 39
4.8 Principle 6: Low Physical Effort [Bjo04] . . . 40
4.9 Principle 7: Size and Space for Approach and Use [Bjo04] . . . 40

E.1 Safezone Definition: Results . . . 118
E.2 Safezone Definition: Notes and Suggestions . . . 119
E.3 Settings: Results . . . 119
E.4 Settings: Notes and Suggestions . . . 119
E.5 Quick Contacts: Results . . . 120
E.6 Quick Contacts: Notes and Suggestions . . . 120
E.7 Calling: Results . . . 120
E.8 Calling: Notes and Suggestions . . . 121
E.9 Taxi: Results . . . 121
E.10 Taxi: Notes and Suggestions . . . 121
E.11 Navigation: Results . . . 121
E.12 Navigation: Notes and Suggestions . . . 122

LIST OF TABLES

Abbreviations and Acronyms

AD	Alzheimer’s Disease
AT	Assistive Technology
CI	Cognitive Impairements
FhP	Fraunhofer Portugal
GPS	Global Positioning System
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
MAT	Mobile Assistive Technologies
MMSE	Mini Mental State Examination
OS	Operating System
PDA	Personal Digital Assistant
PwD	Person with dementia
PwDs	Persons with dementia
SMS	Short Message Service
UCD	User-centered design
UI	User Interface
US	United States of America
XML	eXtensible Markup Language

Chapter 1

Introduction

With the steady increase of the worldwide average life expectancy, projections indicate that the number of older or senior people (aged 65 years or older) is expected to outnumber the world's younger population (aged 5 years or younger), for the first time in history, during the first half of the current decade. These same projections forecast that over the next 30 years the number of older people is expected to almost double, from 506 million (in 2008) to 1.3 billion, which would correspond to a leap from 7 to 14 percent of the world's population. Europe is the most affected continent with 23 of the 25 oldest countries and the prediction that by 2040 over one in four Europeans are expected to be at least 65 years old, and one in seven at least 75. [KH09]

As the ratio of senior citizens in today's society increases, so does the number of people with age-related impairments and difficulties, both physical and cognitive. This, alongside the fact that there will be fewer young people to look after them and provide informal care, will lead to new demands for health and social care services. Older people also have a higher risk of suffering from chronic diseases (which are also associated with high use of health care services) being estimated that almost 75% of them have at least one, and that 50% have at least two [fHQ02]. Chronic diseases such as heart disease, strokes, Alzheimer's and other dementia related diseases, cancer, chronic respiratory diseases and diabetes, are illnesses that are prolonged, do not often resolve spontaneously and are rarely cured completely [oHW02]. They are also by far the leading cause of mortality worldwide (responsible for 60% of all deaths) [Org05] and their prevalence is increasing.

The use of technology in the home environment in order to enable this senior population to live as autonomously as possible is the focus of many nations' strategies to address these concerns. Whether it would be by supporting people to be socially active, by assisting them in the management of chronic diseases, by monitoring for specific events like falls or wandering, or by any other action that could provide further independence, technology is seen as an enabler for a more autonomous living. [PR09]

1.1 Problem Description

The increase of the average life expectancy leads to the formation of an older society and, therefore, to an increase of age-related impairments, like dementia. Older adults' time and spacial orientation are already often disrupted, even if momentarily, but this becomes particularly noticeable if they suffer from any type of dementia. These factors lead to a significant decrease in these persons' navigation skills – the skills a person needs to find their way to a specific location – which are fundamental for community access, personal independence and community integration [FYSH07]. These limitations make these people feel less secure when going out on their own, making them more dependent on their caregivers. Further, one of the most concerning symptoms of the most common form of dementia, Alzheimer's Disease (AD), is a wandering behavior in which patients wander past their caregiver's supervision and begin an aimless and disoriented walk. Such behavior can become extremely dangerous if undetected. [VPS+08]

1.2 Objectives and Motivation

The main focus of this project are older adults and persons with dementia (PwDs), mainly in early stages. AD victims are given special attention, due to the fact that AD is, by far, the most common form of dementia and that this project's features can be particularly helpful to deal with some of its most worrying symptoms, namely: wandering. However, by no means is this project's usefulness limited to AD victims, as its main goals are to give older adults, and PwDs in general, some of their independence back by providing them, as well as their caregivers, with a greater sense of safety when going outdoors.

This project aims to accomplish these objectives by developing a smartphone application that fundamentally can:

- Keep track of the user's location;
- Facilitate the process of calling for help;
- Autonomously assess if the user is lost and straying from a safe location, possibly due to a dementia induced wandering state, and respond accordingly;
- Try to navigate the user back to a safe location, if he wishes to;
- Inform caregivers of the user's situation and location, when necessary;

- Allow caregivers to request and receive information regarding their cared-for's whereabouts.

Last, but not least, the developed application needs to be easy and intuitive enough to be used by older adults and PwDs.

1.3 Document Structure

Apart from this introduction, this document contains seven other chapters.

In this first chapter, a description of the problem, as well as its context, were presented. The motivation and objectives behind this dissertation project were also declared. In chapter 2 it is presented the state of the art, as well as pertinent information, regarding older adults, dementia, Alzheimer's disease and respective caregivers. In chapter 3 it is shown the state of the art regarding the usage of technology by older adults, the concept of assistive technology and the possibilities of mobile technologies like mobile phones in this field. In chapter 4, related work and existing products on this field are presented, including common commercial applications as well as research projects with similar goals. In chapter 5, the specification of this dissertation's resulting prototype can be found, including the chosen approach to the problem, its requirements, and a description of its architecture. In chapter 6 implementation details are presented, including design choices and detailed descriptions of the implemented functionalities. Then, in chapter 7, the conducted functionality and usability tests are presented, as are their results and corresponding discussion. Finally, chapter 8 provides a summary of the developed work, its conclusions and directions for further research and development.

Chapter 2

The Older Adult and Dementia

There is no precise age to determine when someone becomes an older adult. As far back as 1875, in Britain, the Friendly Societies Act enacted the definition of old age as any age after 50, yet pension schemes mostly used ages of 60 or 65 years for eligibility and, to this day, these remain the most common ages associated with the start of old age (60/65 years).

It is acknowledged that normal aging factors pose as potential barriers to the use of technology [CFS+09, BK04], so in order to design an easy and intuitive interface, it must be first understood the impact of these factors on an older adult. Regarding handheld technology these factors include: vision, hearing, cognition and motor skills. Each of these factors are now briefly described:

- **Vision:** The aging eye has a reduced ability to focus on close objects. A decline in visual acuity affects the ability to see objects clearly as well as the perception of their colors. Depth perception is reduced as well, making it more difficult to judge the distance to an object. [ftB]

- **Hearing:** There are several changes in hearing that are age-related thus impacting the ability to hear sounds, especially those with high frequencies. [XD07]

- **Cognition:** An older adult's performance on working memory tasks declines with age, which leads to a reduced ability to discern details in the presence of distracting information. [HM01]

- **Motor Skills:** Older adults have decreased motor coordination. Since their movements tend to be less smooth and coordinated, they find it difficult to perform what would appear to be simple tasks, like moving or clicking on a screen. [SS96]

Other factors like technological skills could also be important. In [EDG+03], Eisma et al. state that for many seniors, computer related technologies are not part of their everyday life and despite their growing popularity within this user group [OPN05], many of them still have had limited exposure to new technologies like handheld devices. Nevertheless, studies have shown that they are motivated to learn and apply new technology skills [IDW02].

2.1 Dementia

As previously mentioned, older adults are more susceptible to contract certain conditions. Dementia is one of them. Although it can occur in anyone, at any age, resulting from injury or disease, it is most commonly associated with old age. Actually, dementia is not a specific disorder or disease, but a syndrome (a group of signs and symptoms) associated with a progressive loss of cognitive ability. [oMH95, oA08] To be classified as dementia the following criteria must be met [Ass10]:

- It must include decline in memory and in at least one of the following cognitive abilities:
    1. Ability to generate coherent speech or understand spoken or written language;
    2. Ability to recognize or identify objects, assuming intact sensory function;
    3. Ability to execute motor activities, assuming intact motor abilities, sensory function and comprehension of the required task;
    4. Ability to think abstractly, make sound judgments and plan and carry out complex tasks.
- The decline in cognitive abilities must be severe enough to interfere with daily life.

It is estimated that 35.6 million people worldwide have dementia, with a new case occurring every 7 seconds. Estimates released by the Kings College of London[1] predict that by 2030 over 65.7 million people worldwide will have dementia, and this number is expected to surpass 115 million by 2050. [Int09]

The most common form of dementia is Alzheimer's Disease accounting for 50 to 80 percent of all dementia cases [Ass11b, Ass10].

2.1.1 Alzheimer's Disease

Alzheimer's Disease (AD) is an incurable, degenerative and terminal disease that was first described by the German neurologist Alois Alzheimer back in 1906 and, as such,

[1] www.kcl.ac.uk

was named after him. The 2009 Alzheimer's Disease Facts and Figures [Ass09], from the Alzheimer's Association, claims that every 70 seconds, a new case of Alzheimer's occurs in the United States of America (USA). Furthermore, the latest report [Ass10] estimates the existence of a total of 5.3 million victims in the USA only, and Brookmeyer et al. [BJZGA07] point to the existence of over 26 million victims worldwide. Also, the cost of care for people with AD is greater than the cost of care for those with cancer, stroke, and heart disease combined [ANMF10].

AD is a physical disease that affects the brain, leading to the death of brain cells. Although the evolution of AD can affect different people in different ways, there are common symptoms. The most common symptom pattern begins with a gradually worsening difficulty in remembering new information. This is due to the fact that the disruption of brain cells tends to begin in regions related to the forming of new memories. As the damage spreads across the brain, so do the difficulties, and individuals start showing other symptoms. The following are considered warning signs for AD [Ass10]:

- Memory loss that disrupts daily life;
- Challenges in planning or solving problems;
- Difficulty completing familiar tasks at home, at work or at leisure;
- Time and spatial disorientation and confusion;
- Trouble understanding visual images and spatial relationships;
- New problems with words in speaking or writing;
- Misplacing things and losing the ability to retrace steps;
- Decreased or poor judgment;
- Withdrawal from work or social activities;
- Changes in mood and personality.

Being a progressive disease it is commonly divided into three main stages: early (or mild), moderate and advanced (or severe). The main symptoms for each of this stages can be seen on Figure 2.1.

The mean life expectancy following diagnosis is of approximately seven years and fewer than three percent of individuals live more than fourteen years after diagnosed [MMR86, MMR95]. In an advanced stage of the disease, people need help with everyday activities like eating, bathing, dressing or using the bathroom. Those in the final stages also lose their ability to communicate, fail to recognize loved ones and become bed-bound and reliant on 24/7 care. In fact, as the symptoms evolve, AD victims require a growing

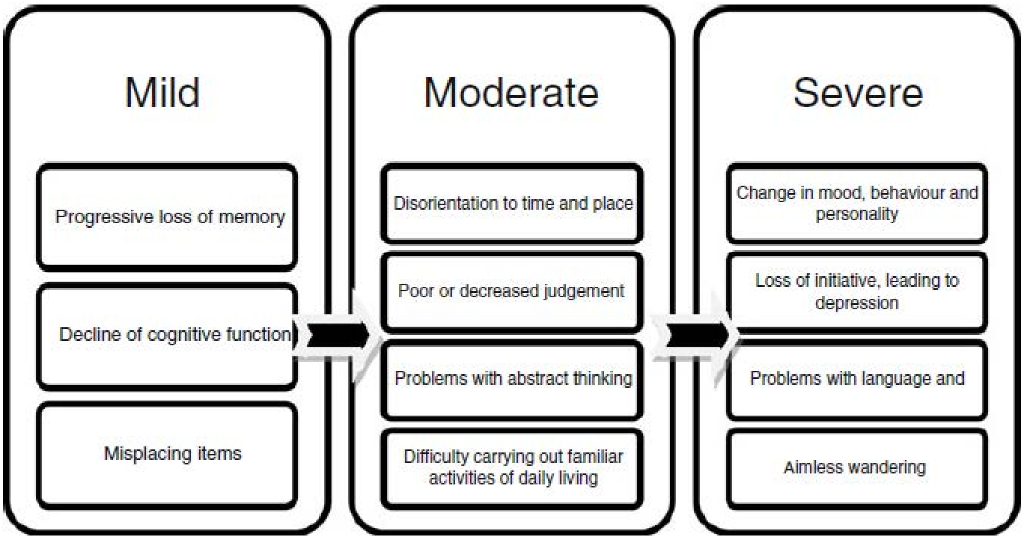


Figure 2.1: Symptoms of AD throughout each stage [ANMF10]

assistance in order to be able to maintain their everyday lives. This assistance is often provided by family and friends, who generally prefer to keep them at home for as long as possible, despite the increasing burden on their part. From the early stages of mild memory loss and decline in cognitive abilities, to help in carrying out everyday activities in the moderate stage, and to support in almost all aspects of daily functioning in the final stage [HGK+03]. However, due to the difficulty of providing the required constant attention during the most advanced stages, people with the disease tend to eventually move into a nursing home or another residence where professional care is available, in spite of the significant cost associated with such a decision. [Ass10]

One of the main concerns of caregivers regarding Alzheimer's patients is their wandering behavior [OYM+04], an aimless and disoriented walk which can become dangerous [VPS+08] by increasing the possibility of accidents, getting lost, serious injuries or even death. Furthermore, according to Vassalo et al. [VPS+08], it is actually an excellent (78% accurate) predictor of fall risk. Wandering occurs when a patient with decreased cognitive ability wanders away from supervised care [dR] and 60% of AD victims exhibit this behavior. [KM08]

Workers in the field differentiate non-goal and goal-directed wandering. In the former, the subject moves about aimlessly with no apparent goal while in the latter the subjects moves toward some type of goal [dR]. Common goals include the search for something or someone, trying to find something to eat or going to the bathroom.

Currently, there are two common ways to deal with dementia wandering:

- To detect the patient as soon as he/she leaves the safe zone and take him/her back;
- To find or monitor the location of the patient who has left the safe zone.

Assistive technologies and devices can be used to manage, support and relieve the symptoms associated with AD [LRR+10]. By doing so they can assist caregivers in their task, by relieving them of some of the associated pressure and required availability. Also, by increasing the patient's autonomy, the need for professional care can be delayed, allowing the patient to remain in its home environment for as long as possible which is a common desire for AD patients and family [Ass10].

2.1.2 Caregivers

All over the world, family remains the cornerstone of care for older people who have lost the capacity for independent living. In the USA alone, figures point to the existence of 10.9 million unpaid caregivers [Ass10]. Although all people with dementia experience some degree of functional disability this does not mean that they should all be regarding as needing care. Despite values varying according to location, in most cases, 50 to 70 percent of those with AD and other dementias were rated as needing care, and most of those are rated as needing "much care". These needs also vary by level of dementia, with 30% of those with mild dementia, 69% of those with moderate dementia, and 88% of those with severe dementia needing much care. [Int09]

Caregivers of people with AD and other dementias spend an average of 1.6 hours daily assisting with core personal activities (including washing, dressing, toileting, eating). When including the time spent assisting with instrumental activities of daily living (such as cooking, shopping, laundry, household finances) this value increases to 3.7 hours, and when general supervision is also taken into account the average care input reaches 7.4 hours per day. [SMBM99] People with AD or another dementia also often have other serious medical conditions, such as heart disease, diabetes and cancer. Family and other unpaid caregivers commonly help to manage these medical conditions as well. This could explain why caregivers of people with AD and other dementias provide more hours of help, on average, than caregivers of other older people. [Ass10]

Most family and friends who provide informal care take pride in their role and perceive many positive advents like companionship, fulfilment, enjoyment and meaningfulness. Nevertheless, these caregivers also experience high levels of strain, psychological morbidity and even impaired physical health, with effects caused by caring being the major health problem of many caregivers. In the USA, over 40% of unpaid caregivers of people with dementia rate the emotional stress of caregiving as high or very high. This leads to very high levels of psychological morbidity among these specific caregivers with studies showing a 2.8 to 38.7 times higher prevalence of major depression in this group when compared to a control sample. Caregiving also has a negative impact on employment, income and the financial security of many caregivers. [Int09, Ass10]

As mentioned, some families and other unpaid caregivers who live with a person who has AD or other dementia provide supervision and help 24 hours a day, 7 days a week, assisting with all daily activities. This around-the-clock care is needed, in good part, due to the risk of wandering, getting lost and other unsafe activities. Although the majority of caregivers live with – or close – to their patient, about 15% are considered long-distance caregivers (they live over an hour away). [Ass10] This makes constant monitoring of patients extremely difficult for these remote caregivers. The use of technologies could assist in the reduction of these factors, increasing quality of life not only for patients but for caregivers as well.

Chapter 3

The Relation with Technology

Due to all the factors mentioned earlier, an application interface that is considered perfectly usable by a younger adult may be difficult, if not impossible, to use by an older adult. Unfortunately, interfaces for most technologies, excluding special devices, have been designed for younger users. [GNZ02] For an older adult with dementia, the situation is even more challenging. To try to make up for this problem and keep this user group involved in the market, Cook [Coo09] suggests two approaches:

1. To make conventional technology approachable and manageable to those with disabilities;

2. To design technologies expressly for this target group.

The first method is known as universal design, and its goal is to include all users regardless of disadvantage. The second focuses mainly on User-centered design (UCD). UCD, or human-centered design, as it is also called, focuses on the end users' needs, wants and limitations, and extensive attention is given to these during each stage of the design process. In UCD *"all development proceeds with the user as the center of focus"*. [Rub84] This is typically the choice for the development of assistive technologies (AT) [UT99] although even its makers still often argue that universal design is preferable to the need for AT, and that universal design projects should be continuously expanded.

Studies have revealed that older adults wish to use new technologies but are mainly deterred by difficulties experienced during the learning steps. They have also revealed that this deterrence can be subdued through direct experience and familiarity. This shows that although older adults may struggle at first, with the right coaching and motivation, they can in fact become competent new technology users. [IDW02, US03]

3.1 Assistive Technology

Assistive technology or adaptive technology includes assistive, adaptive, and rehabilitative devices for people with disabilities. It promotes greater independence by enabling people to perform tasks that they were formerly unable to accomplish, or had great difficulty accomplishing, by providing enhancements to – or changed methods of interacting with – the technology needed to accomplish such tasks. According to the U.S. Administration on Aging [oA], it is *"any service or tool that helps the elderly or disabled do the activities they have always done but must now do differently"*. A more formal and complete description, by Marshall [Mar07], describes it as being *"any item, piece of equipment, product or system, whether acquired commercially, off-the-shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with cognitive, physical or communication disabilities"*. Examples of this kind of technologies range from something as simple as walking canes or magnifying glasses to highly advanced technical solutions, like sensor technology within smart living environments which are able to detect doors being opened and cooking appliances being left on [NHH+08]. These technologies can help both patients and caregivers, by allowing a more independent lifestyle for patients and promoting aging in place (according to AIPatHome[1], the ability to live in one's own home for as long as confidently and comfortably possible), while keeping costs stable [KH09, TLH+10].

Other projects (Technology, Ethics, and Dementia Report [BTH99]; ASTRID Report [Mar07]; At Home with AT [Cas04]; ENABLE Project [Ena]) have listed the following requirements regarding the design of technology for people with dementia [PMM+09]:

- Support the user's sense of autonomy;
- Support decision-making;
- Be a positive influence on the user's quality of life;
- Support intact abilities while de-emphasizing a loss of function;
- Support the end user's image of themselves as a person with abilities (do not reinforce a disabled mentality);
- Provide effective information;
- Provide autonomous systems that require a minimum of learning and interaction with new information;
- Use of audio/visual multimedia;
- Simple language;

[1] Age In Place at Home

- Large font to balance macular degeneration;
- Choose colors that prevent glare.

Studies have shown that over 75% of disabled older adults use or have used some form of AT [AF03]. A large amount of assistive technologies are available within the market place for AD patients in particular. Common examples include memory aids (post-it notes, diaries, voice recorders, medication reminders) and monitoring or safety aids devices [Lor06]. AT can also assist patients in calendar management, using the telephone, enhancing their feeling of safety via intercoms or wandering monitoring devices, helping them locate misplaced items, among others [ATD11].

3.2 Mobile Phones

Mobile technologies have transformed the way people communicate, work and interact. Mobile phone subscriptions increased rapidly since the 1980s, with the overall number of subscriptions overtaking the number of fixed landlines worldwide by 2002 [Fel03]. Despite the influence of this kind of technology in our everyday lives, there have been only a relatively limited of studies that have used mobile phone technologies to assist patients suffering from AD [ANMF10]. With a growing range of technologies and services being offered by these devices, they pose as a potential solution for the management of some of the problems associated with this condition.

3.2.1 Smartphone Technology

First generation mobile phones were large in size and permanently installed within a vehicle. Only in 1973 was the first ever call using a truly portable wireless phone made, ten years prior to the release of the final product onto the market. At the time this device had only one functionality: two-way communication. [Cor07]

Nowadays, mobile technologies have evolved in such a way that not only are mobile phones small, light, easy to carry and relatively inexpensive, but are also loaded with a wide variety of features and functionalities. These include capabilities such as motion sensing, voice recognition, video calls, wireless communications (such as Bluetooth, WiFi, 3G or infrared), GPS tracking, and others. Mobile phones who offer such functionalities are commonly labeled as smartphones.

By definition, smartphones are mobile phones that offer more advanced computing and connectivity abilities than a contemporary feature phone (lower-end mobile phones that feature basic functionalities and usually have proprietary operating systems (OS) with limited third-party software support). In other words, smartphones are devices which integrate typical mobile phone capabilities with common features of handheld computers or PDAs (Personal Digital Assistant). Another of their main features is their typically large, comfortable touchscreen interface.

According to Gartner, in their report dated November 2010, smartphone sales worldwide have doubled in the last year (from 41093.3 thousand to 80532.6 thousand) which means that smartphones now represent over 19.3 percent of the overall mobile phone sales [Jud10].

The growing popularity of smartphones like Apple's iPhone, RIM's Blackberry devices and a variety of Google Android-based models on the market, has accelerated the adoption rate. As can be seen on Figure 3.1, in November 2010, 45% of recent US purchasers chose a smartphone over a low end phone. This number also shows a significant increase from the initial 34% in June, confirming the predicted rise in demand.

Figure 3.1: U.S. smartphone market penetration (Adult consumers, Jun - Nov 2010) [Com11a]

More importantly, the most recent numbers show that in the EU5 (UK, France, Germany, Italy and Spain) users aged 55 or older represent 18.1% of the composition of the whole smartphone market, surpassing the 18-to-24 bracket with its 14.5% (Figure 3.2).

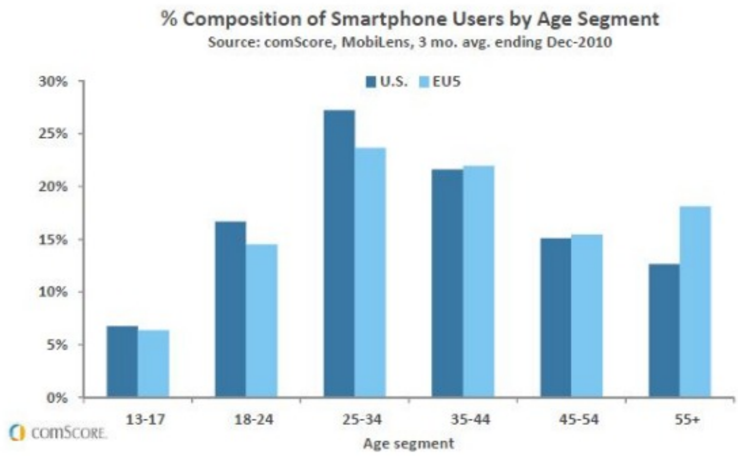


Figure 3.2: Composition of smartphone users by age segment [Com11b]

As previously mentioned, these new functionality packed mobile phones could prove useful for PwDs, in particular to those still in the early stages. In Table 3.1, an example of possible relation between smartphone common stock applications and typical older adults and PwDs needs is shown. If we take into account the possibility of using software designed specifically to tackle any or several of these needs, the possibilities as well as their usefulness improve greatly.

Table 3.1: Possible relation between common smartphone applications and typical dementia victims' needs [ea08]

User needs	**Smartphone application**
Memory aid	SMS/MMS/voicecalls/time management software
Reminiscence	Pictures/videos/music
Exercise diary	Pedometer/personal diary
Directions/patient wandering	GPS/SMS
Medication reminders	Voice call/SMS/alarm
Relaxation aid	Music/video
Activity monitoring	Accelerometer/GPS
Social networking	Internet/e-mail/chat
Personal Organizer	Calendar

With the increase of market share and popularity of smartphones, studies as well as academic and commercial projects started to be developed aiming at this platform (examples will be presented on Chapter 4). One study in particular [BPPG09] resulted in a set of design guidelines targeting specifically the development of mobile assistive technologies (MAT) aimed at people with cognitive impairments (CI). These guidelines can be seen on Table 3.2.

In a study conducted to determine problems older people (in this case aged 60 and above) experience when using regular mobile phones, the following problems were identified [Kur08, ANMF10]:

- **Size and location of buttons:** Users felt that the button's size was too small and rubbery and did not provide sufficient feedback when pressed;
- **Menus:** Users felt that the menu systems were too complex, with too many unnecessary menus and with menus too difficult to understand;
- **Device:** Users felt that the devices were too small, making it difficult to hold them comfortably;
- **Text size:** Users felt that the text size was too small to be easily read.

Smartphones have the potential ability to solve these issues. Smartphones are available in various sizes, from small to large, that can be chosen by the target user according to its

Table 3.2: Design guidelines for MAT aimed at people with CI [BPPG09]

	Objectives/Description	**Features**
Customization	- Develop sense of belonging - Automatic adaptation to the specific needs of the user	- Adapt to the context - Functionalities selection according to the user's needs and abilities
Feedback	- Reassure user regarding its actions - Give perceivable feedback depending on CI and context - Give consistent feedback	- Use audio, visual and haptic feedback - Give feedback after every action
Modalities	- Use various modalities to increase the chances of comprehension - Adapt modalities to the context - Do not overcrowd the interface - Use clear, concise and consistent messages	- Use audio, visual and haptic messages - Use images or sound when the user can not read easily - Use short and smart sentences - Use images prudently
Error Prevention	- Minimize situations that could generate errors - Consider error possibilities due to smallness of screen - Use consistent interfaces	- Ask for confirmation before critical actions - Do a cognitive walkthrough adapted to the users
Inputs	- Use automatic inputs if possible - Maintain minimum input possibilities - Keep input consistent, similar actions ask for similar inputs	- Minimize cognitive load on inputs - Use words choice instead of text input
Connectivity	- Manage variable connectivity - Manage GPS reception	- Offer constant assistance even in poor coverage areas - Offer alternatives when unable to lock a GPS signal

preference. They are equipped with touchscreens which make possible the readjustment of button location and size according to these older adults specific needs, and they also allow visual, audio and haptic feedback to be given on button press or any other situation. Menus and text size can also be tailored to meet these users specific needs with simpler and clearer interfaces that take full advantage of the typically large screen size.

3.2.1.1 Android

Android is an open source mobile operating system, based upon a modified version of the Linux kernel, which was developed by Google and the Open Handset Alliance. It is currently the most popular mobile operating system, with predictions pointing to a growth of more than twice the rate of its major competitors in 2011 [Com10, ftHTI11].

Some of the main advantages of this operating system regarding the needs of this project are:

- Fully customizable application interfaces;
- The ability to easily thread background running processes;
- Customizable home screens which can keep active widgets, always accessible and always visible;
- Wide range of devices with different shapes, size, weight, hardware and price (while maintaining OS compatibility);
- Polished Google Maps and Directions API;
- Open source;
- Open application market which makes the deployment of applications easier.

Some of these points are of vital importance to the success of the project and not all of them are available on other operating systems. The ability to fully customize an application's interface without constraints, for example, is one example of those points. This could compromise the end-result's usability and usefulness since this application is aimed at a very specific target group.

After careful comparison with other operating systems, and keeping in mind this list of advantages, this was the chosen operating system to develop the project's resulting prototype.

Chapter 4

Existing Products and Related Work

4.1 Commercial Products

4.1.1 Tracking Devices

The most common commercial solution for the problem targeted by this project is the use of tracking devices (mostly GPS devices) to monitor the location of the older adult. These devices exist in all shapes and sizes, with some of them being designed specifically for this type of users. These devices usually have very simple displays (if any) and some of them allow the user to request assistance by pressing a *panic button*. The main advantage of these devices is that they are, most of the times, able to provide an accurate location of their user. This allows caregivers to find out their patient's location in case of an emergency.

Figure 4.1: i-traks™ Lite – An example of a compact GPS tracking device

More information about this device can be found at:
http://www.bluetreeservices.co.uk/i-traks/lite.htm

4.1.1.1 Shoes/Vests/Bracelets/etc.

These devices are designed so that the user does not easily forget them and/or have a hard time taking them off. This can be important since AD/dementia victims will more likely forget to take their common GPS device when going out, than their shoes for example (remember that newly acquired memories – like the instructions to take the device with them before they leave – are usually the first to be affected). Permanent bracelets can also be a way to make sure the patient is always carrying its tracking device, though they may not be very comfortable to wear at all times.

(a) GTXC GPS Shoes (b) TrackerPAL System (c) Vega GPS Bracelet

Figure 4.2: GPS shoes, vest and bracelet examples

More information about the presented devices can be found at:
GTXC GPS Shoes: www.gpsshoe.com/
TrackerPAL System: www.questguard.com/TrackerPal-System_.html
Vega GPS Bracelet: www.medicalmobile.com/en/products/hardwares/vega/

4.1.1.2 Cellular Network Tracking Devices

These products are similar in looks to the ones that use a GPS location system, but instead of using GPS to pinpoint their location, they use the cellular network to try to triangulate the user's position. The main advantage of using this method is that GPS signal is not always available (like for example while indoors), while the cellular network is usually still available since its signal is not hindered by buildings or bad weather. The precision of this method, however, is heavily dependent on the number and geographical distribution of the available cell towers and even on ideal conditions it does not provide a location as precise as GPS-based systems.

Some devices also provide both options, switching to cellular network tracking when it is not possible to obtain a GPS lock. These systems are better than the ones that only offer one of the options since they can provide a location more often, and under a wider range of conditions.

Figure 4.3: EmSeeQ™ watch – An example of a cellular network tracking device

More information about this device can be found at:
www.emfinders.com

4.1.2 Monitoring Services

In the preceding sections the devices that provide the means to locate a user were presented. However, that is just a part of the typical commercial solution for this problem. Apart from this, there is also the monitoring side. According to a determined monthly fee, the location of the user will be monitored with a given frequency, and a number of services are provided. An example of this kind of service, that was designed specifically with Alzheimer's in mind, is the US national Alzheimer's Association Comfort Zone™ [Ass11a], which is a Web-based GPS location management service where family members can monitor a person's location.

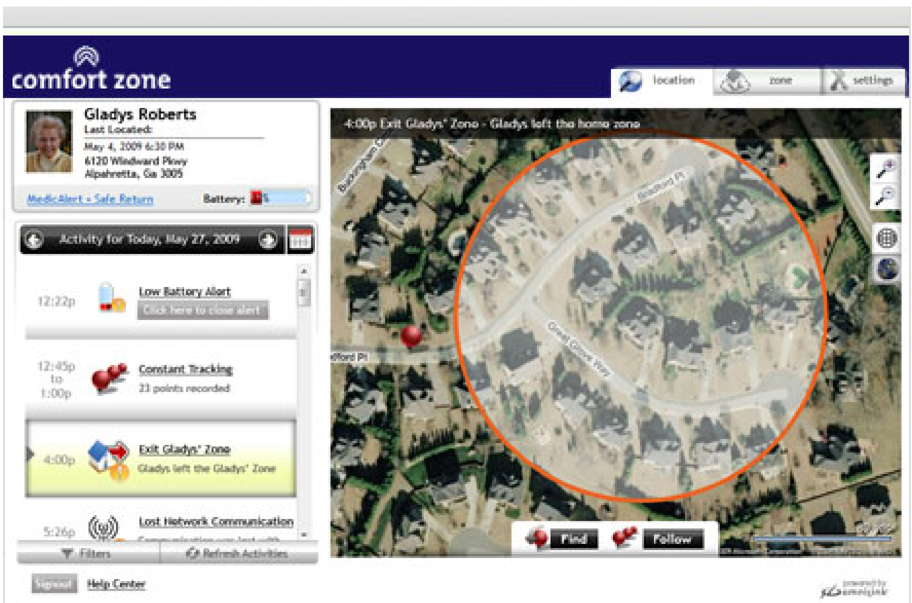


Figure 4.4: Comfort Zone's interface

These services usually feature:

- Determined safe zones;
- Alerts via SMS or e-mail;
- Zone exiting and entering alerts;
- Location history;
- 24/7 location assistance and consultation;
- Other services (fall detection, for example) depending on the used device's capabilities.

More information about this product can be found at:
www.alz.org/comfortzone/

4.1.3 GPS Navigation

There is currently a wide range of products when it comes to GPS navigation devices. As the name suggests, these use GPS signals to determine the device's current location and then provide navigational instructions to a specified destination using the built-in road/paths database to calculate the best route in real time. There are devices which are oriented at specific types of routes, for example, driving routes or biking routes, but it is common for devices to be able to provide both walking, driving or biking routes. In recent years, turn-by-turn navigation devices have become particularly common. In these devices, the directions are continually presented to the user in the form of visual instructions, and are usually complemented by spoken instructions. These tend to occur at, or near, decision points, in order to inform the user of the next instruction without forcing him to take his eyes off the road. Examples of this type of device can be seen on Figure 4.5.

(a) Example of a TomTom device   (b) Example of a Garmin device

Figure 4.5: Examples of turn-by-turn navigation devices by two of the top GPS makers

With the growth of the smartphone market, these applications also became widely available for mobile devices. In spite of the, usually, smaller screen, these applications' interface remains pretty similar to that of their original counterparts as can be seen on Figure 4.6.

(a) Example of TomTom running on an iPhone (b) Example of Garmin running on an iPhone

Figure 4.6: Examples of turn-by-turn navigation applications on a smartphone

Another application worth mentioning is Google Navigation for Android. This application, unlike most, is free and requires only a data connection to perform the routing since it does not contain a roads database offline (map graphics also need to be downloaded but can then be cached for offline use). One of the main advantages of this is that the online service that calculates the routes – the Google Directions service – is always using the most recent road information available. But the most interesting feature of this application is the fact that it takes advantage of Google Street View, whenever possible, to show actual photos of intersections before you reach them, placing arrows that point the way on top of them. It also shows an actual photo of the destination once the user closes down on it. What is so interesting about this feature is the fact that it closely resembles the second best rated prompt mode of the study conducted by Fickas et al. [FYSH07]. Both this features can be seen on Figure 4.7 (the last two screenshots are Street View images).

Figure 4.7: Google Navigation screenshots

Unfortunately, even Google Navigation uses the aerial/perspective map representation for most of the route, which is too complex to be understood by persons with cognitive impairments [dB08, FYSH07]. Therefore, in spite of several interesting features that could be useful, these products and applications are still too complex to be a usable solution for this project's target group.

4.1.4 Mobile Applications

4.1.4.1 ALZ-Locate

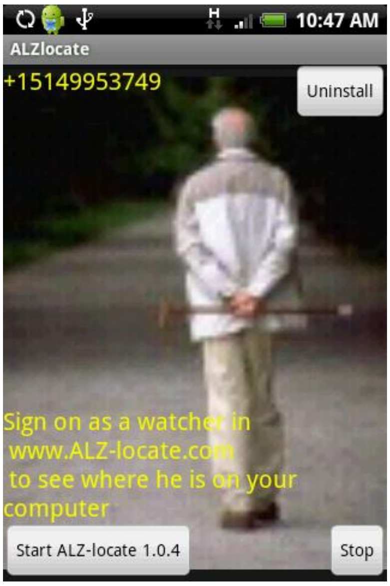


Figure 4.8: Alz-Locate application

This is a very simple Android application that turns a smartphone into a tracking device pretty much like the ones already mentioned. The application itself is free but the online service that allows the caretaker to check the user's location requires a fee to be accessed.

The main advantage of this product, when compared to the ones presented earlier, is that the user does not need to buy a dedicated GPS device, making it a cheaper solution. The provided service is, however, very feature limited when compared to the full scale commercial monitoring products already mentioned, being that it only allows caretakers to request their cared-for's current and recent locations.

More information about this application can be found at:
`www.alz-locate.com/web/ALZhome.php`

4.1.4.2 Tell My Geo™

Figure 4.9: Tell My Geo™ application

This is the other and most recent smartphone application which is aimed at Alzheimer's victims. Unlike ALZ-Locate, this application provides more features other than the simple location of users and it actually aims to be helpful and usable by its target users. Also, unlike most services, it does not offer a Web-based location manager, using two Android phones instead (one for the caretaker and another for the cared-for). Besides acting as a tracking devices Tell My Geo™ has the following advantages:

- Allows the user to find out where he is located;
- Allows the user to send its own location when needed or on a time basis;
- Facilitates calling for help;
- Stores the user's medical information.

Unfortunately, this application's interface is not "older adult friendly", with current location being displayed in very small letters, a bad choice of colors for the buttons' text (low contrast colors) and a complex patterned background which could prove confusing for an older adult.

More information about this application can be found at:
`www.iconosys.com/product.php`

4.2 Research Projects

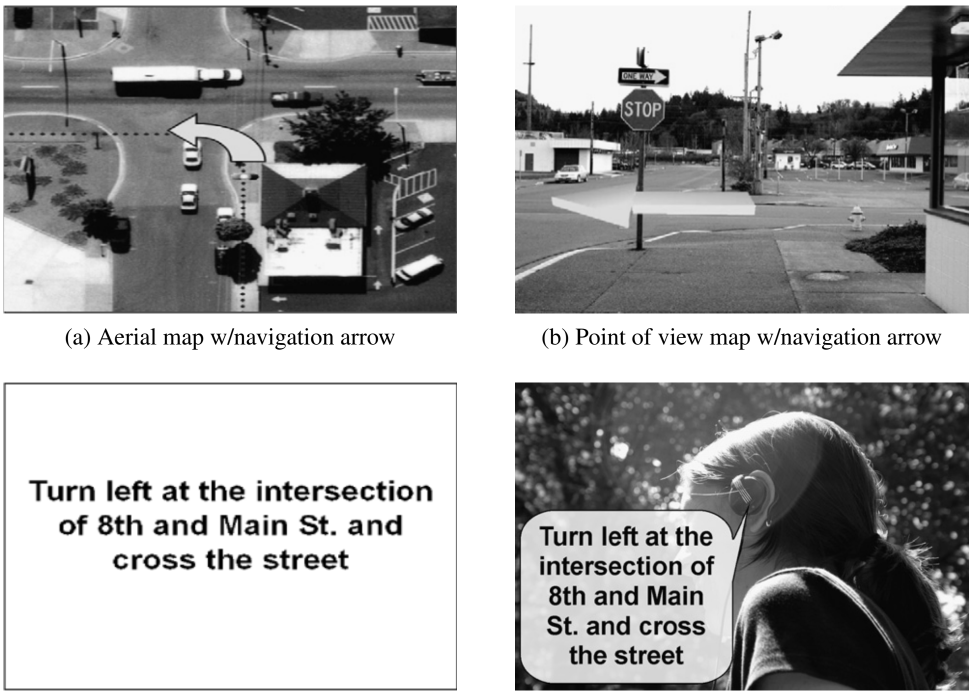
4.2.1 Route-Finding Assistances for Community Travelers with Cognitive Impairments: A Comparison of Four Prompt Modes (2007)

Fickas et al. [FYSH07], studied what would be the best way to navigate a person with cognitive impairments through a prespecified route. To do so, they compared four different prompt modes: an aerial map with a navigation indication arrow (an approximation of the typical commercial solution), a point of view map with a navigation indicator arrow, text based step-by-step instructions and auditory only step-by-step instructions. An example of each of these prompt modes can be seen on figure 4.10.

In this study, 60% of the participants (16 out of 20), chose the audio prompt mode as the most helpful. According to their feedback, there were three main reasons for this:

1. Audio instructions were easier to follow;
2. This mode was more straight forward;
3. It did not require them to keep looking at the screen.

The last point is of vital importance since the person being navigated has to be able to keep at least some of its attention on its surroundings, so that it can reach its destination safely.



(a) Aerial map w/navigation arrow (b) Point of view map w/navigation arrow

(c) Text based instructions (d) Auditory instructions

Figure 4.10: Four navigation prompt modes tested on persons with CI

On the other hand, 45% of the participants (9 out of 20), reported that the aerial map was the least helpful mode. The main reasons pointed out for this were:

1. It was hard to comprehend where the arrow was pointing;

2. It was hard to identify how the pictures related to what they where seeing and where they were walking.

This result confirmed the difficulties that people with cognitive impairments have on taking advantage of standard commercial navigation products. The point of view image with a navigation arrow however was still considered usable by many participants with 20% of them considering it to be the most helpful prompt mode while only 10% found it the least useful. A complete results summary for this study can be seen on table 4.1.

Table 4.1: Summary of ranking for most and least helpful modes of prompts [FYSH07]

Mode	**Most Helpful(%)**	**Least Helpful(%)**
Aerial view w/navigation arrow	20	45
POV Image w/navigation arrow	20	10
Text	0	30
Audio	60	15

One of the main issues regarding this study was that participants were not able to orient themselves independently in any prompt mode in order to receive the first instruction. This meant that a researcher was required to tell them what direction they should face prior to the beginning of the experiment. The authors themselves considered that for a navigational device prompt system to be useful, it would be critical to be able to orient the traveler as they begin a route and to be able to reorient them in case they became confused and stray off route.

4.2.2 Auditory Navigation for Persons with Mild Dementia (2008)

In this study [dB08], Windows mobile-based PDAs with TomTom's (a leading GPS navigation devices manufacturer) navigation software were used in field trials. The devices and software were adapted so that the interface had no menus, and all functions and status bars were removed from the screen, with the exception of the remaining distance to the next decision point. The TomTom interface allowed for three types of navigation: 2D aerial-map navigation, 3D map navigation, and arrow navigation. Due to the fact that maps were, according to the existing literature, very difficult to use for people with cognitive impairments, arrow navigation was selected. Examples of the screens participants saw can be found in figure 4.11.

Figure 4.11: Examples of the adapted TomTom application and device

During these trials, researchers noticed that participants almost never looked at the device, with almost all participants only looking at the screen when a message was not understood or heard. This study also concluded that the use of familiar voices for guidance contributed to the efficiency of this type of system for people with mild dementia, but their satisfaction did not differ however. Further, during these trials the use of warning sounds before each instruction were tested, and although they did seem to improve the attention of the participant, the final results indicate that using warning sounds may have a negative effect on the quality of way finding for people with mild dementia. As a result of this study, the set of guidelines present on Table 4.2 regarding the design of a navigation system for PwDs was presented.

4.2.3 iWander (2010)

iWander [SDT10] is a mobile application that runs in the background and collects data from the device's sensors, such as GPS, and from user feedback. This data is then evaluated using Bayesian network techniques to determine the probability of the person being wandering. Depending on the probability, iWander takes actions that could range from navigating the patient to a safe location (using Google's Navigation), notifying caregivers, providing the current location of the patient or calling an emergency number. One of the issues with the current application was the inexistence of a baseline model that could be used to detect wandering behavior with a good accuracy. This led to the generation of many false positives, which in turn, could deter the usage of this application by the older adults.

Unlike the existing applications, in this project special attention was paid to the design so that it would meet the needs of older adults. It would also only alert caregivers if no autonomous progress was made, trying to increase its user's independence by doing so.

Table 4.2: Guidelines regarding the design of a navigation system for PwDs [dB08]

Familiar Voice	- Use own jargon; caregivers should make their own natural sentences. The use of predefined sentences prevents recognition by PwDs. - Exercise: let caregivers exercise their sentences. They need to be crystal-clear and clean of mispronunciations. - Short: sentences should be short and in natural language. Prevent use of too many verbs. - Commanding: sentences should get the PwD started, forcing them a little does not hurt them.
Warning Sounds	- Use structured sound: make sure there is a tune, melody, or other recognizable pattern in the used warning sounds. - Pre-test usable sounds: only use sounds that are pre-tested by the target-group. - Neutral: make sure sounds do not trigger already existing memories.
System	- No pre-warning: while walking a pre-warning of what is to come is not strictly necessary. PwDs do act when necessary. Giving them a warning in advance does distract them from their task. - Super solid: only the key functionalities should be available. Additional screens, warnings, buttons and information does only distract PwDs from their task. - Primary focus on audio: PwDs mainly use the audio component of the navigation system. The visual interface is needed, but only as a backup when the audio message is not understood.
Experiment	- Test: The developed system should be pre-tested extensively. There is no room for flaws in the system. It only leads to interruptions, distraction and confusion. - Informed consent: PwDs and their caregivers should sign for using audio, video, and photos for your use. - Advantages: tell PwDs and caregivers that they can gain from using this system. In the future it is likely that such a navigation system for PwDs will become available for them.

4.2.4 Electronic Tracking of Patients with Dementia and Wandering Using Mobile Phone Technology (2005)

Within this study [Mis05], 11 participants were given mobile phone handsets with built-in GPSs for a total of 84 patient-weeks. Each participant had a relative or caretaker who was taught how to use the phone and given a manual. The relative or caretaker was responsible for ensuring that the phone was set up correctly and that the participant wore it correctly every day. Each relative/caretaker was interviewed and daily/weekly activities of the patients were recorded, so that the tracking could be tested when the participant was active. The level of successful tracking was examined and the relative/caretakers were interviewed to determine feedback about the general usability of the phones. To study the overall performance of the GPS integrated phone as a tracking device, participants were sent out to walk randomly with GPS phones in a shoulder bag or waist bag in an attempt to simulate the walk of a lost elderly person. These random trials consisted of random combinations of built-up, open field, indoor and confined transportation environments. Results from the trials showed that these devices can, in fact, determine a person's location to within 5 meters.

It is also important to highlight that from the original 11 participants, five of them stopped participating due to usability or comfort issues. The majority of the participants (9/11) also revealed to have issues with the weight of the handset and 27% of them found the handset physically too demanding to carry.

4.2.5 Training Early Alzheimer Patients to use a Mobile Phone (2002)

Within this study [LWLS02], Lekeu et al. described a training program developed to teach patients with mild Alzheimer's disease how to use a mobile phone. Each training session was divided into two parts. In the first part, the spaced retrieval technique was used to promote the consultation of a card pasted on the back of the phone. The card detailed each stage of phone utilization and which keys had to be pressed to call somebody. In the second part, the patients received repetitive exercises of calling based upon the errorless learning principle, where a patient interacts with the mobile device with support and slowly this support is taken away. The patients within the study received individual training lessons that consisted of 45 minutes sessions, two days a week. Results from the study indicate that one of the two patients needed more spaced-retrieval sessions in comparison with the other. Also, by the repetition of calling exercises, both patients showed a decrease of instruction card consultation, whereas they were still able to correctly call somebody. This learning ability is hypothesized to be a consequence of a relatively preserved procedural memory in both patients.

Despite their differences, after three months, both patients reached the criteria for success: 100% correct responses without any cueing during two consecutive sessions. This highlights the effectiveness and usefulness of the combination of both methods when teaching AD patients how to use mobile phones.

4.2.6 European Research Project COGKNOW (2006-2009)

The COGKNOW project [Tea] was a specifically targeted research European project aimed at people with mild dementia. The project started in September 2006 and ended in August 2009. It was supported by the European Commission and eleven participating organizations from eight countries. The project's final prototype, the COGKNOW Day Navigator, gives persons with dementia increased independence, while relieving their caregivers from always having to be around to support them. Their vision was that persons with mild dementia should be able to take part in society without being seen as very

Figure 4.12: COGKNOW's prototype (including touch screen and mobile device)

different, just using a bit more cognitive support than the rest of us who use calendars and other memory aids.

This prototype's main functionalities are:

- Time Indication;
- Remotely configurable reminders;
- Music and Radio;
- Picture Dialing;
- House Alerts for safety;
- Mobile Navigation for going home.

This was the first project to conduct exploratory studies regarding the best way to navigate persons with mild dementia, leading to the creation of important guidelines on this subject (like those presented on Table 4.2, for example). Its mobile prototype was also the first mobile device to offer navigation designed specifically for this user group.

This project is now over, and the commercialization of the COGKNOW Day Navigator is scheduled to occur later this year. [Lim]

4.2.7 The Escort System (2010)

This project [TLL+10] presents a system to help caregivers ensure the safety of residents who wander in assisted living environments. The Escort™ System uses Talking Lights®, location-transmitting light beacons, and a ZigBee® wireless network to monitor the presence of residents in potentially dangerous areas. When the system finds out that the patient is in a potentially dangerous area, it sends a pager or cellphone-based alert to on-duty caregivers. During the trial stage, a modulated non-flickering illumination-based system was used for location purposes. Users wore small badges with capability for location determination and automatic communication with a central server that was responsible for alerting caregivers if necessary. For this communication ZigBee-compliant devices designed by Talking Lights LLC were used.

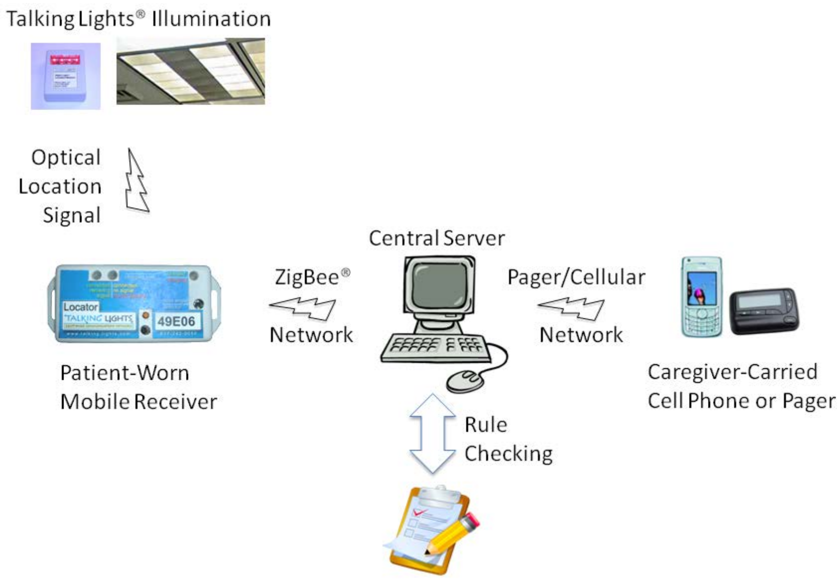


Figure 4.13: The Escort System's overview

One of the advantages of this system is the location device used by the patients: light, wearable badges. During the trial stage, residents not only did not object to wearing them but, in fact, some were uncomfortable when the badges were removed for charging. This work has demonstrated that an optical, illumination-based locating system can provide accurate real-time indoor location information. This system could then be used in conjunction with a GPS-based system for outdoor monitoring, in the same way that some tracking devices switch between GPS and cellular network signals to obtain a location, upon availability. In comparison to the last, this combination would have the advantage of being able to maintain accurate locations, with small error margins, while both outdoors and indoors. This would, however, only apply to specific indoor location like the user's residence or nursing home.

4.2.8 The ENABLE Project (2001-2004)

The European Commission funded Enable [Ena], a three year longitudinal study involving five countries to examine the feasibility of devices, and to assess the socio economic costs of providing technology, to enhance the quality of life of people with dementia and their caregivers. People with dementia have traditionally not been considered potential users of new technological products, except for products to ensure safety. This project aimed to show that such products can in fact be designed and adapted to benefit this rapidly growing user group as well as their caregivers. The findings of this project suggest that people with dementia and their caregivers have a great deal to benefit from devices that can facilitate independent living at home, while at the same time presenting recommendations and challenges for the development of technology to be used by these particular user group. [Jon04]

Several useful design guidelines were developed during the ENABLE project. Like all guidelines they are generalizations, but although there are probably many exceptions, they felt useful to list some of the most important that were experienced and defined by the Bath Institute of Medical Engineering[1] [Bjo04]:

- No learning should be needed on the part of the user. Devices such as the locator that do require some limited learning were useful for people in the early stages of dementia and for caregivers, but could not be easily used by people in the later stages of dementia.

- Support equipment should seem familiar. For people with dementia a new device has to operate and feel just like similar equipment they have always been used to. The supportive features need to be incorporated in an invisible way. The cooker monitor for example used the same cooker that the user had always been using but just added replacement knobs that had the ability to turn themselves off in the event of danger.

- Control should not be taken away from the user. The cooker monitor did not just shut down the gas to the cooker and leave the user confused about what had happened. It turned off the knobs in a similar manner to a caregiver faced with the same situation, and the user could just carry on using the cooker subsequently without having to rely on someone to come in and reset everything.

- The user should be reassured by the device. Support technology should not be threatening or alarming. The automatic night light, for example, does not just suddenly turn on when the user gets out of bed at night, it gently fades up in a reassuring manner.

[1] http://www.bath.ac.uk/bime/

- Devices that make judgements about user behavior must deal with errors. Equipment like the cooker monitor has to make judgements about user behavior. Such judgements are by definition probabilistic and will inevitably on occasion be in error. Any errors should be false positives, i.e. the cooker turns off when it does not need to, rather than stay on when it should not.

- For devices that are providing backup and support to ensure safety it is preferable that the user should not have to interact directly with the device. In these cases the best support device is one that can detect when it has to support the user and do so automatically without their intervention.

- Safety critical devices must have a backup that can call for help. If the cooker monitor sensed danger that persisted after it had acted, it would shut off the main gas supply to the cooker and call for help via mobile phone.

When designing and trying products for people with dementia, three aspects of the product must be assessed and respected: usability, usefulness and acceptance. The usability of a product defines if a person is able to use the product and what the user quality of the product is. The usefulness of a product, on the other hand, can be defined by observing if the product is being used and how the users express their opinion of whether they use and need the product or not. A product can have a high usability, i.e. be easy to use, but still the user does not find that the product is useful, meaning that they do not need it in their life. Last, acceptance: a product can be both usable and useful, but still the user may not accept it for a number of reasons. For example, the price of the device may be prohibitive, or even the aesthetic and design aspects of the product may not be appealing. Older people are often more skeptical to technology, therefore familiar design is important. The products must also be acceptable to family members. [Bjo04]

A particularly interesting fact about this project is that the requirements were organized based on the principles for universal design[2], and then, under each principle, the specific needs and requirements of people with dementia were listed and taken into special consideration. In the following tables (4.3-4.9), these needs and requirements regarding each principle are presented [Bjo04].

4.2.8.1 Universal Design Principles and PwDs Specific Needs

The principles described in this section are quoted from North Carolina State University's guidelines [CJM+97].

[2] http://www.design.ncsu.edu/cud/

Principle 1: Equitable Use

The design is useful and marketable to any group of users. Guidelines:

- Provide the same means of use for all users: identical when possible, equivalent when not;
- Avoid segregating or stigmatizing any users;
- Provision for privacy, security and safety should be equally available to all users;
- Make the design appealing to all users.

Table 4.3: Principle 1: Equitable Use [Bjo04]

PwDs needs	Requirements
- Prevent stigmatization	- High quality products for adults
- Maintain social contact	- If using pictograms, make sure they are logical and self-explanatory to this age group
- Safety	- Emphasize interactive aspects
- Ethical considerations	- Intrinsic safety
- Medication reminders	- Consent procedures in case of monitoring
- Age relevance and familiarity	- Familiar and attractive design, the way they are used to. Adapting a product they are already used to.
- Enough time to carry out tasks	- Aesthetically pleasing
- Support empowering and reassurance	- Avoid childishness, use familiar concepts, avoid "funny", special and decorative fonts for information
- Low cost or available financing	- Design to fit in with environment
	- Sufficient reaction time before timeout
	- Cost issues to be dealt with

Principle 2: Flexibility in Use

The design accommodates a wide range of individual preferences and abilities. Guidelines:

- Provide choice in methods of use;
- Accommodate right- and left-handed access and use;
- Facilitate the user's accuracy and precision;
- Provide adaptability to user's pace.

Table 4.4: Principle 2: Flexibility in Use [Bjo04]

PwDs needs	Requirements
- Adaptability to individual needs and changing conditions	- Pre-programmable choices (invisible to PwD)
- "Happy helpers", do not annoy care-givers	- User friendliness for the caregivers: no extra work, integration of product in daily activities
- Right as well as left-handed mode of use	- Preferably not for one OR the other
- Adaptability to pace and coordination problems	- Ensure enough time to carry out an activity and enough time between activities. - Individual settings if possible

Principle 3: Simple and Intuitive Use

Use of the design is easy to understand, regardless of the user's knowledge, experience, language skills or current concentration level. Guidelines:

- Eliminate unnecessary complexity;
- Be consistent with user expectations and intuition;
- Accommodate a wide range of literacy and language skills;
- Arrange information consistent with its importance;
- Provide effective prompting and feedback during and after task completion.

Table 4.5: Principle 3: Simple and Intuitive Use [Bjo04]

PwDs needs	Requirements
- Solve common problems easily, increase independence	- Link with long term memory
- Minimal need for learning	- Intrinsic logic
- Experience of success	- Few functions, operations and choices in one product
- Avoid stress, produce stimulation	- Recognizable product/function
- Avoid confusion	- Avoid too much information at one time
- Maintaining of familiar situations	- Remove irrelevant and confusing information and decoration
- Using long term memory	- Restrict number of actions necessary
- Pleasurable to use products, aesthetics, touch, dignity	- If several steps; logical, visual and clear
- Not to have to reason	- Product and control must be close together
- Feeling of enabling	- Preferably no remote control (except TV)
- Feeling of security	- Switch should give traditional feedback, by feeling the turn or a click
- No need to search for product, easy to find	- Easy to see it
- Feeling of familiarity and a natural solution to a problem	- Pushbutton controls with click provide good tactile cues
- Assistance in time orientation	- Do not mix different types of operation, like turning, pushing, pulling
- Respect for normal age related changes	- Automatic functions must not be confusing
	- Add aids to already existing and used technology, e.g. place an automatic calendar next to a clock or an aid that shows the time of day

Principle 4: Perceivable Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. Guidelines:

- Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information;
- Provide adequate contrast between essential information and its surroundings;
- Maximize legibility of essential information in all sensory modalities;
- Differentiate elements in ways that can be described (i.e. make it easy to give instructions or directions);
- Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

Table 4.6: Principle 4: Perceivable Information [Bjo04]

PwDs needs	Requirements
- Meet the needs associated with normal aging changes in vision - Meet the needs associated with common age related cognitive problems - Meet the needs associated with normal age related hearing changes	- No glare or reflexes, provide large letters and numbers and good contrast between text and background - Sufficient lighting - Consistent color coding - Put the most important information in the middle of the visual field - Make certain that text has the size and dimensions in relation to reading distance and light - Good fonts are Helvetica, Arial and Verdana - Information must be clearly visible, in simple, plain words, in understandable language - Isolate individual messages - Reduce speed of spoken messages - More functions in one product can be confusing - Form, color and materials must support the recognizability and/or function of the product - Put the product in a logical place - Avoid unnecessary decoration (for example background decoration) - Give analogue instead of digital numbers, for example for a clock - Use letters rather than symbols /pictograms - If using graphical illustration (pictograms) for information, make sure it is logical and familiar, and combine with text - Use more signals to attract the attention to the same function, e.g. image, sound and color - Do not rely on auditory cues or warnings only - Make volume control logical and easy to operate - Keep auditory messages in the range between 500 and 1500 Hz - Reduce or remove confusing background noise - If auditory message is given, use a sound first to get the attention - Sound pitch: choose intermittent or continuous

Principle 5: Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions. Guidelines:

- Arrange elements to minimize hazards and errors: most used elements most accessible; hazardous elements eliminated, isolated or shielded;

- Provide warnings about hazards or errors;
- Provide fail safe features;
- Discourage unconscious action in tasks that require attentiveness/vigilance.

Table 4.7: Principle 5: Tolerance for Error [Bjo04]

PwDs needs	Requirements
- Reliable products, these users have lower tolerance for errors	- The product must work immediately, no waiting time, because of short concentration span
- Experience of failure is distressing to people with dementia, and lead to not wanting to use the product	- Prototypes must be fail safe to be tried with this user group
- Feeling of safety and security is depending on stable functionality	- Fail safe backup
- Supporting safe taking of medication	- No possibility to injure oneself
	- Spoken messages of danger must be clearly distinguishable from background noise
	- Emphasize good diction and pronunciation in spoken messages. Some consonants are difficult to distinguish from each others in auditory messages
	- Fireproof
	- No loose parts
	- Safe to put in the mouth, not contain hazardous materials or colors.
	- As few plugs or electric flexes as possible
	- Domestic appliances must switch off automatically if failure
	- Give clear messages of what is wrong if errors
	- Do not expect reasoning in error corrections
	- Not breakable, stable, solid, good quality products
	- In signalling, red is danger, green is safe
	- Alerting the person of dangers is not enough, it is often necessary to alert the caregiver also

Principle 6: Low Physical Effort

The design can be used efficiently and comfortably and with a minimum of fatigue. Guidelines:

- Allow user to maintain neutral body position;
- Use reasonable operating forces;
- Minimize repetitive actions;
- Minimize sustained physical effort.

Table 4.8: Principle 6: Low Physical Effort [Bjo04]

PwDs needs	Requirements
- Meet the needs associated with lower physical strength, poorer fine co-ordination	- Large controls, suitable to the hand's optimal, functional position - Avoid fine manipulation - As few manual operations and little hand strength as possible - Sometimes it is easier to control a product with both hands

Principle 7: Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation and use, regardless of the user's body size, posture or mobility. Guidelines:

- Provide a clear line of sight to important elements for any seated or standing user;
- Make reach to all components comfortable for any seated or standing user;
- Accommodate variations in hand and grip size;
- Provide adequate space for the use of assistive devices or personal assistance.

Table 4.9: Principle 7: Size and Space for Approach and Use [Bjo04]

PwDs needs	Requirements
- Relevant in relation to where the product is positioned	- Do not require unfamiliar movements or locations - Place all controls within comfortable reach of where the user normally is for each activity - Use mechanical principles to ease movements

Although not all of these requirements apply to the current project, many of them can still be applied to the development of a mobile application and, as such, should be taken into consideration.

Chapter 5

AlzNav: Project Specification

5.1 The Approach

This project's approach to the problem at hand was the creation of a mobile application, AlzNav, whose main goal is to reduce the unease, risk and concern that affects both the cared-for and its caregiver, when the cared-for leaves its safe place. To do so, it primarily allows caregivers to:

- Specify a safety radius and receive alerts whenever their cared-for enters or exits it;
- Request the cared-for's current location when worried (an initial consent from the cared-for is required);
- Set a list of "quick dial" contacts that the cared-for can easily call if necessary.

Regarding the cared-for, the application primarily helps by:

- Providing an easy process for calling a set of contacts (its caregiver in particular);
- Warning him if he's leaving its safezone, providing immediate options to get help if needed, and taking action automatically if necessary;
- Giving the option to be navigated back home.

Figure 5.1 shows a simplified overview of the system's functionalities.

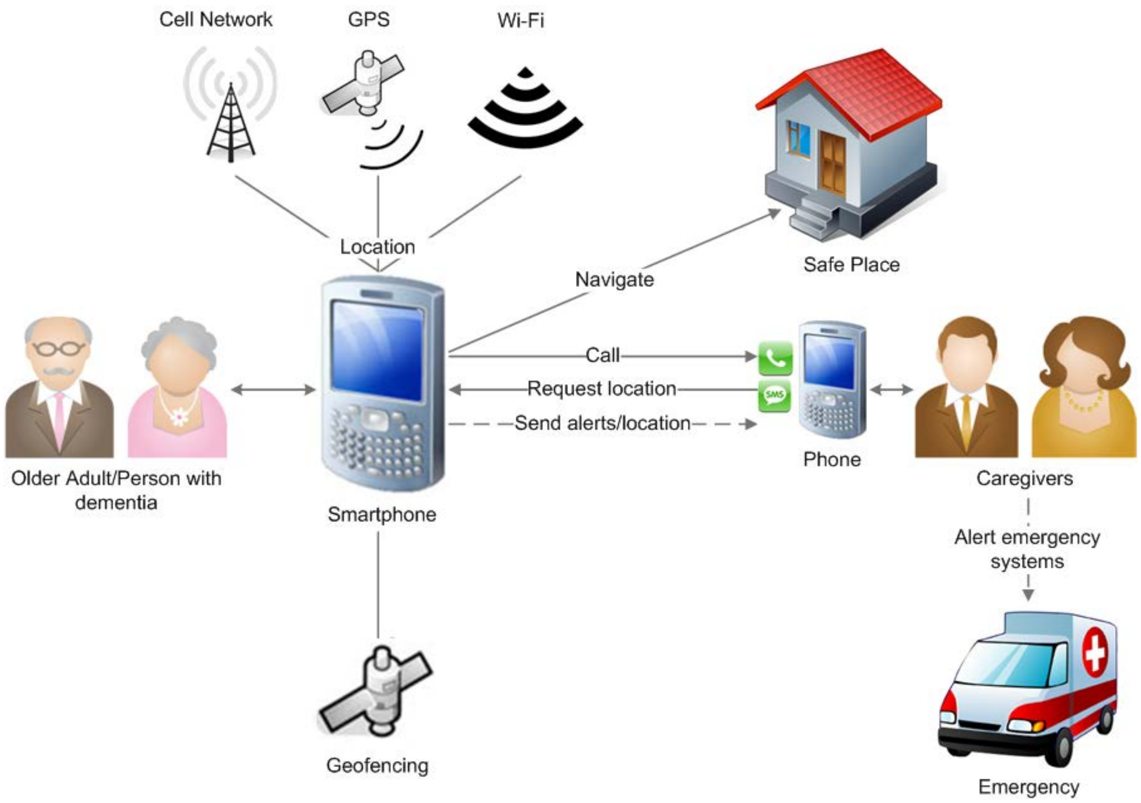


Figure 5.1: System overview

5.2 Methodologies

User-centric design methodologies were used. A thorough investigation of the end user's needs and limitations was made in order to fully understand their difficulties as well as their influence in practical applications. Interfaces were created paying close attention to the existing design guidelines for (mobile) applications aimed at both older adults and people with cognitive impairments, and a lot of attention was given to small details that could make a difference. Although regular design validation by the target user was hard to obtain, the application's design evolved through an iterative process until the mentioned goals were fulfilled. A representation of the UCD design process can be seen on Figure 5.2.

Apart from the design, the application's functional modules themselves were also implemented through an iterative module-based process.

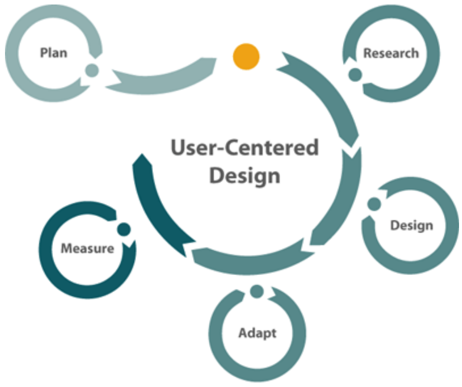


Figure 5.2: User Centered Design Process

5.3 Requirements Specification

In this section, both functional and non-functional requirements of the system are specified.

5.3.1 Functional Requirements

5.3.1.1 System

The system must be able to:

- Obtain the phone's current location using GPS, WiFi location or cell towers trilateration;
- Know the precision associated with each location;
- Assess if that location is, or is not, within a certain safe radius, and by what margin;
- Send alert messages to caregivers when necessary;
- Make calls to pre-determined contacts;
- Receive remote location requests (by SMS) and respond accordingly;
- Get walking directions between the current location and the safe place;
- Navigate in real time, presenting instructions on a current situation basis;
- Speak instructions out loud;
- Assess if a navigation mistake has been made and seamlessly reroute;
- Be able to orient the traveller in the right direction as they begin a route.

5.3.1.2 Caregiver

Regarding to **contacts**, the caregiver can:

- Add, edit and remove contacts from the list of important contacts ("quick dial" functionality);
- Clear the contacts list easily.

Regarding the **safety area**, the caregiver can:

- Search for a location by its address or directly on a map;
- Set a location as home;
- Set a safety radius and a home radius separately;
- See the current safezone on a map, including the currently set radii and home location.

Regarding the **settings**, the caregiver can:

- Set/change the patient's dementia level;
- Set another person as caregiver (changing the one currently set);
- Enable/disable the location request and alerts features, since the patient must approve the enabling of these features;
- Set calls to be made using loudspeaker by default;
- Enable/disable the overriding of the contacts' default button size in order to occupy as much of the screen as possible;
- Enable/disable spoken instructions (text-to-speech) when the user is being navigated back home;
- Enable/disable the overriding of the current system sound volume to maximum when navigating;
- Set/change the taxi service number to be used in the *Call a taxi* feature.

5.3.1.3 Patient

A **person with moderate dementia** can:

- Be navigated back home;
- Call the caregiver;

On top of that, a **person with mild dementia** can also:

- Call a set of contacts previously chosen by the caregiver;

Finally, an **older adult** can do all the previous, plus:

- Call a taxi (being informed of its current location).

5.3.2 Non-Functional Requirements

5.3.2.1 Usability

Usability is a key point for the system. The system should follow the existing design guidelines for its target user group and take advantage of existing knowledge on the subject whenever possible, e.g. the system should adapt its interface, workflow and functionalities according to the dementia level of its current user. The interface should be clean, disposed of unnecessary options and consistent across screens. It should also take advantage of all the possible smartphone's capabilities to make the experience as user-friendly as possible, e.g. make sure the screen brightness is always set to the maximum value when the application is running.

5.3.2.2 Reliability

Since the purpose of the system is to provide reassurance and help in emergency situations, it is very important for the system to be reliable. The system should, within its possibilities, not send erroneous information to the caregiver (e.g. send an alert saying the patient has left its safety area when in fact it has not), but most importantly, it should be able to act accordingly when emergency situations do, in fact, occur.

5.3.2.3 Robustness

In case some of the requirements to achieve a certain operation chosen by the user are temporarily unavailable, the system should inform the user of the situation, instead of failing silently, and try to achieve the desired operation's outcome as soon as possible, without the need for new user interaction. For example, if the user tries to call a contact when its mobile network is currently unavailable, the system should alert that contact, as soon as the mobile network returns, that the user has tried to call him. It should also inform the user that it has done this, in order to try to diminish the potential stress caused by this unexpected situation.

5.3.2.4 Error Recovery

In case an error occurs, the system should recover in a way as transparent to the user as possible. In case an unforeseen error actually forces the system to terminate, the system itself should try to restart and proceed with its functions.

5.4 Use Case Model

The use case model helps to describe the proposed functionalities, by presenting a graphical overview of the functionality provided by the system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases.

5.4.1 Actors

The system has two main actors: the caregiver and the patient (representing its cared-for). However, patients are divided into three possible categories:

Older adult: An older adult user who has not been diagnosed with any kind of dementia;

Person w/mild dementia: An user who has been diagnosed with mild dementia;

Person w/moderate dementia: An user who has reached a state of moderate dementia.

As can be seen on Figure 5.3, the person w/moderate dementia is the most limited of the patients with only the bare minimum of options available leading to a decrease in the cognitive workload required to operate the application. A person w/mild dementia will inherit its capabilities and add its own. Finally, the same goes for the older adult, the patient with the most options, inheriting all the previous' capabilities, plus its own.

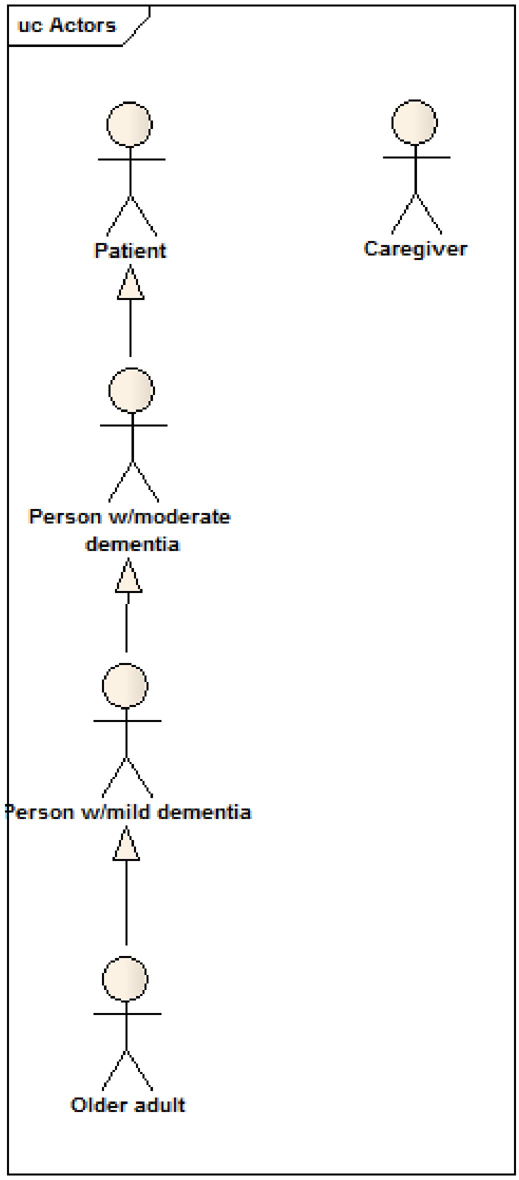


Figure 5.3: System's actors

5.4.2 Caregiver

The caregiver is the person responsible for the configuration of the application. In an ideal situation this should happen only once, when the application is first launched. In Figure 5.4, the caregiver's use cases are presented.

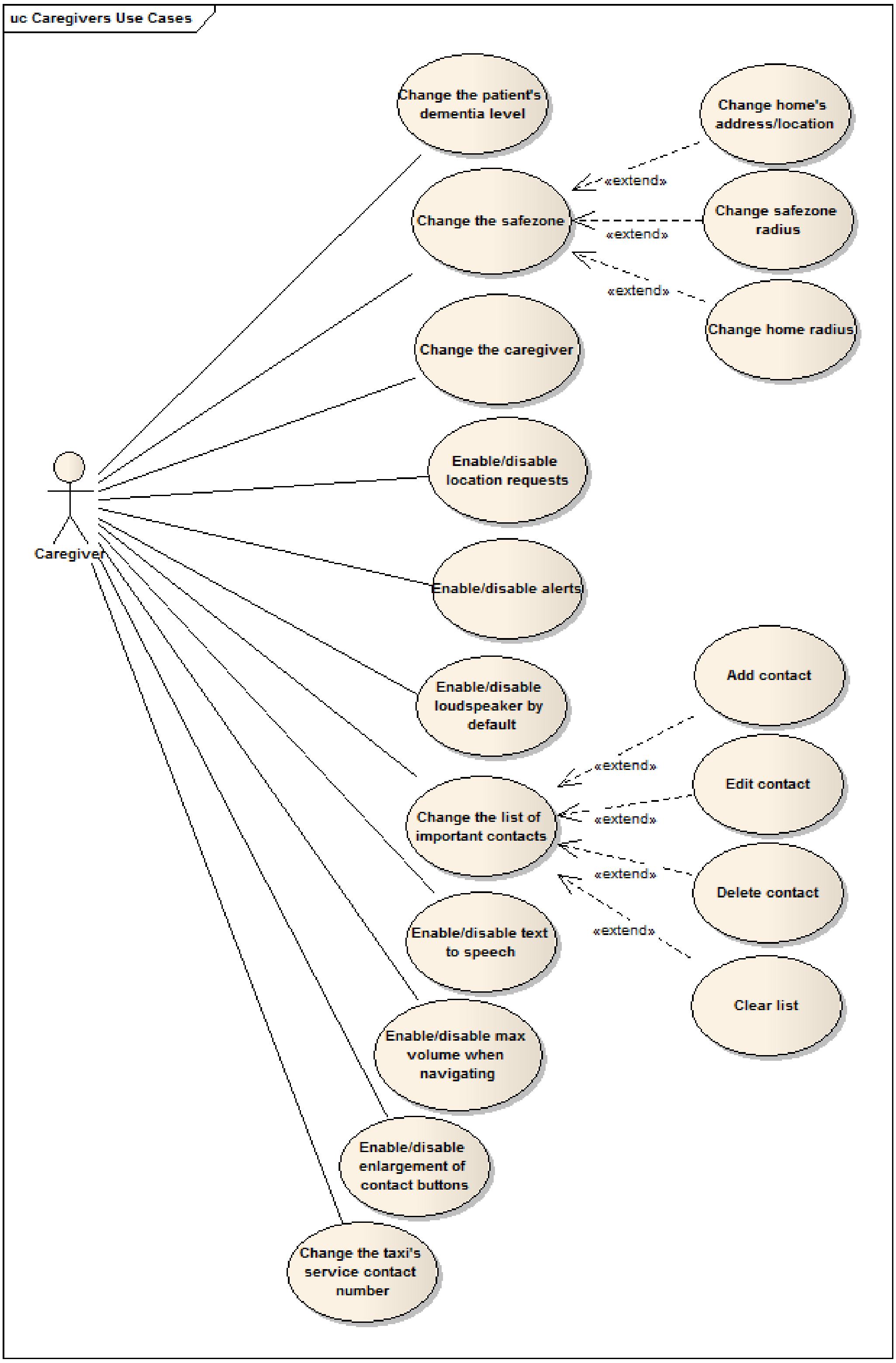


Figure 5.4: The caregiver's use cases

5.4.3 Patient

The patient represents the cared-for, meaning, the application's final user. Figure 5.5 presents its use cases according to dementia level.

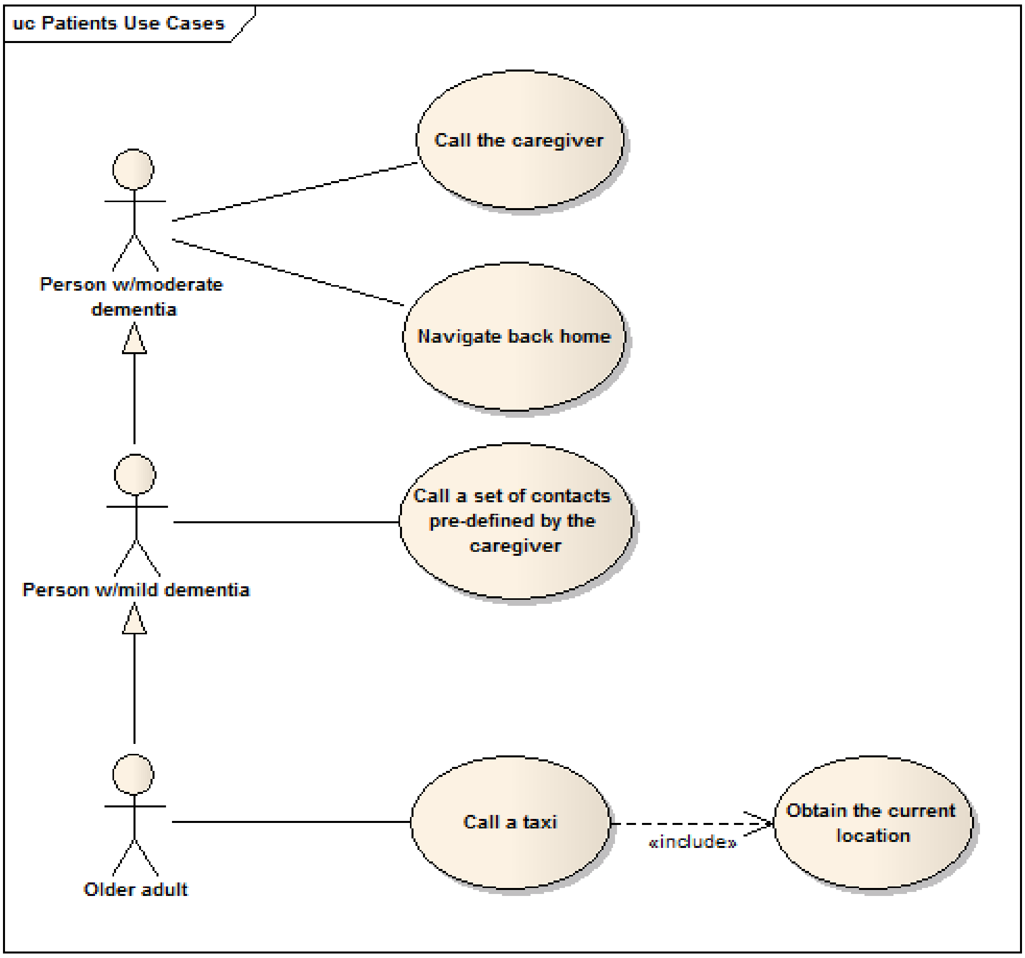


Figure 5.5: The patient's use cases

5.5 System Architecture

5.5.1 AlzNav Modules

5.5.1.1 Calls

This module is responsible for the calling processes of the the application. It handles the network verification before calling, the actual process of initiating a call (and subsequent action if necessary), and the process of bringing the user back to the application once the call has ended.

5.5.1.2 Contacts

This module is responsible for everything that is related to the contacts data. It acts as a bridge between the OS contacts database and the application, by obtaining the contacts' info and passing it onto the application's internal data structure. It is also responsible for the contacts list persistent storage and loading.

5.5.1.3 Directions

This module is responsible for obtaining, parsing and storing navigational directions. It is responsible for all the process of generating the request – creating a request asking for walking directions, in the current language, from the current location to the location specified as home – as well as the parsing of the JSON file that is received in response.

5.5.1.4 Location

This is the most important module of the application. It is responsible for:

- Obtaining location updates;
- Accepting or declining location updates (assessing if a new location is better than the current);
- Updating the level of emergency according to the location distance to home, in relation to the defined radii;
- Choosing the location providers from which to request updates from, accounting for availability and the current level of emergency;
- Optimizing battery consumptions by changing the frequency with which updates are requested, according to factors like the current level of emergency and the current battery level;
- Detecting when a user enters or leaves its safezone;
- Reverse geocoding (transforming a coordinate into a street address);
- Logging locations.

5.5.1.5 Navigation

This module is mostly responsible for combining all the information gathered by other modules and turning it into actual real time navigation. It combines data from the smartphone's magnetic sensor with GPS locations, to provide real time directions to the user. It is also responsible for detecting mistakes and rerouting in response.

5.5.1.6 Phone State

This module is responsible for receiving updates from all across the system. It gathers information regarding:

- Battery level;
- Mobile network connectivity (whether mobile network is available);
- Data connection (whether there is a data connection available, and if it is on WiFi or through the mobile network);
- SD card (whether it is mounted or not).

5.5.1.7 Safezone

This module is responsible for the safezone definition functionality. It is responsible for presenting a graphical representation of the current safezone on top of a map view, and for the whole geocoding process (turning an address input from the user into a coordinate that can be shown on the map).

5.5.1.8 SMS

This module is responsible for anything related to text messages. Its purpose is to send messages (such as alerts) and to check received SMS for remote requests, executing them and answering back if that is the case.

Chapter 6

Implementation

6.1 Requirements

In this section, the minimum requirements to run the developed prototype are presented.

6.1.1 Operating System

The prototype was developed and tested on devices running versions 2.2 (Froyo) or newer of the Android operation system. Compatibility code was produced in order to support version 2.1 as well, but this has not been thoroughly tested. According to Google's data, 74.4% of the currently active Android devices are running version 2.2 or newer. If we take into account version 2.1 as well, this figure increases to 95.6%. [Goo11c]

The device must also have Google Apps installed. These are a set of standard applications written and maintained by Google (GMaps, Gmail, Gtalk, etc.) which can be found in pretty much every official device. However, since they are closed-source, custom rom developers are asked not to include them in their roms, so a manual installation may be required in seldom cases.

6.1.2 Hardware

The prototype was developed to support screens with HVGA (480x320) or higher resolutions. As of June, 2011 this corresponded to 96.7% of all active devices [Goo11d]. It is, however, recommended the use of a screen with WVGA (800x480) resolution or higher. The device must be equipped with a GPS receiver, or else it would not be capable of providing locations accurate enough for real time navigation. Finally, an active data connection (3G or WiFi) is necessary. The application needs a data connection in order to do four main things:

- Get location updates from both WiFi and cell trilateration;
- Get directions for the navigation feature from Google's Directions service;
- Load map graphics for the visual definition and representation of a safezone;
- Turning coordinates into addresses and vice-versa.

This means that without a data connection, the application is unable to provide its navigational feature (although after the initial directions are received, a data connection would only be required if a reroute is necessary) and is also unable to provide the patient's current location in a readable textual manner. But most alarmingly, it would only be capable of using GPS (which does not work while indoors) to obtain location updates.

6.1.3 Languages

The prototype supports the English and Portuguese languages out of the box. The language used is chosen automatically according to the device's current preferences. Languages were implemented taking advantage of Android's capabilities, so these are easily expandable. All it is required is an extra XML file with the translations of each string to add a new language. If the application is launched from a device using a language that it does not have a translation to, English is used by default. Android's default text-to-speech engine also supports English, French, German, Italian and Spanish out of the box, but other languages can be obtained by using custom speech engines and voices available from the Android Market (e.g. Portuguese). Navigational instructions are available in the languages provided by Google's Directions API, which include over 50 languages (including accents)[1].

6.2 Interface Considerations

Given the target user of this application, several design choices that should be present throughout the entire application were made right from the start, in order to try to adapt it to its special needs. These are presented next.

6.2.1 Brightness

Whenever the application is brought to the foreground, the screen's default brightness level is overridden to its maximum. This makes sure that the screen is always as bright as it can be, increasing color contrast, and making it easier to be seen. This feature tries to compensate for the older adult's decreased visual acuity.

[1] http://goo.gl/aJtsQ

6.2.2 Text Color

On the Android OS, the default text color is a shaded white, resembling a light grey. In order to provide as much contrast as possible between information and the background, text in the application is presented in pure white, as bright as it can be. Once again, this feature tries to diminish the amount of visual effort required by the user to perceive the information presented on screen.

6.2.3 Keep Awake

By default, smartphones turn their screen off and lock themselves after a certain amount of time. This behavior could be extremely confusing for an older adult, specially if in a dementia state, because the concept of keeping a screen from going idle is neither straightforward nor intuitive enough. Further, after the screen had gone idle, the user would have to know that to turn it back on, the power button had to be pressed and the default unlock slide had to be performed, which again is something that the user might not be able to achieve if in a state of anxiety and emergency. To try to attenuate this issue, on the most important parts of the application (the ones used by the patient), the screen is automatically kept awake. For example, during navigation, the screen will never dim or turn off unless the actual power button is pressed.

6.2.4 Color Codes

Throughout the literature, color codes are mentioned as facilitators for certain actions. In the developed prototype a simple color code was employed in dialog buttons, where green stands for positive/safe actions and red stands for negative/risky actions.

Also, interfaces developed with the caregiver in mind have a different background color from the ones intended to the patient user, making them more easily distinguishable.

6.2.5 Labels

An effort was made to use labels for buttons or titles, that would represent actions to which the user could relate when reading, instead of the generic functionality label. For example, the main screen's navigation button label is "Guide me home" instead of the generic "Navigation".

6.2.6 Icons

Although prototype icons are not final, they should have strong colors and, on each screen, they should be easy to distinguish from one another.

6.2.7 Buttons

One of the first things that had to be defined, regarding the application's interface, was the visual aspect and the functional behavior of buttons. Regarding buttons' visual aspect, three states had to be defined: the default state, a focused state, and a pressed state. The first corresponds to the default state of a button, in which it is not focused nor pressed. The focused state can not be achieved through touch, but if the user has a device that is equipped with a physical keyboard or a trackball, it can run through the buttons this way and it will receive feedback on what button is currently selected. Finally, the pressed state is presented as soon as person actually presses or clicks the button, whether through touch or key. An additional state was considered, the disabled state, for when a button was visible but could not be pressed. However, from the iterative tests that were conducted throughout the development of the prototype, it was concluded that this type of button was not easily understood, and as such, whenever such a state would occur, the button was instead completely removed from the interface.

Apart from the states a button should have, there was also the need to define what types of buttons would be required across the application. Three types of buttons were chosen: text only buttons, image buttons, and mixed (both text and image) buttons. The design prototypes for these buttons can be seen on Figure 6.1. According to the literature, the usage of pictures helps the older adult to recognize a certain action, but these should always be accompanied by a text label as well, so even in the case where a picture occupies the whole button (an image button) is displayed, a text label that mimics its behavior was added on top.

(a) Text buttons' states (b) Mixed buttons' states (c) Image buttons' states

Figure 6.1: Buttons' states final design prototypes

Regarding behavior, in order to minimize the acquaintance needed with the application and the operating system's standard way of doing certain tasks, buttons were designed in a way that both single tap clicks and long button presses both led to the same outcome. Long presses consist of a continuous press, of about a second, which usually leads to a different outcome than a regular single tap click. Examples of this functionality will be presented in the following sections. Further, in order to maximize the feedback on button clicks, as soon as the user presses a button, haptic feedback (through vibration) is provided. The intention of this functionality is to reassure the user of when an actual press on a button was detected and when it was not. A complementary sound feedback should also be given, but this was not implemented due to the fact that the main testing device used during development already provided this functionality out of the box.

6.2.8 Dialogs

A custom dialog style was developed in order to keep the interface consistent. Android's default dialog theme was replaced by a custom theme with a completely opaque background, custom buttons and straight corners (so that it does not resemble a button by itself). The backgrounded view was also set to dim as much as possible (more than by default), making sure that the dialog gets the user's full attention.

6.2.9 Advanced Options

It was determined that options that only the caregiver should have access to, would be placed within the options menu, and that all the options in these menus should only be directed at the caregiver. This means that no functionality expected to be used by the patient can be delegated to the options menu. This choice was taken because this menu is by default hidden, and only pops up at the bottom of the screen when the physical *menu* key is pressed, meaning that it would be hard to make the patient user even aware of its existence.

6.3 Functionalities

In this section, the implemented functionalities will be presented, through their activities. On Android, an activity represents a single screen with a user interface, so each functionality's interface will be presented and justified, and relevant implementation details will also be explained.

6.3.1 Main Menu

The main menu's interface changes according to the user's dementia level. The higher the dementia level, the fewer the options, so a user with no diagnosed dementia will have four choices, while a user with moderate dementia will only have two. This behavior can be seen on Figure 6.2.

(a) No dementia (b) Mild dementia (c) Moderate dementia

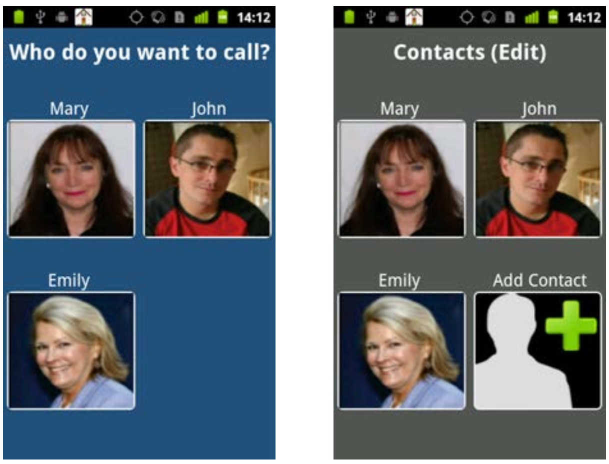
Figure 6.2: Main menu's interface according to user type

In all the alternatives, there is a quick one-click way to establish a call with the caregiver. At first, the idea was to have an emergency button, that would dial the national emergency number on all the screens, while the caregiver would be the first contact within the *make a call* functionality – an initial prototype of this interface can be seen on Appendix A, Figure A.1. However, Android does not allow an application to start an emergency call by itself. The best it can do is launch the call dialer with the emergency number in place, and then wait for the user to start the call, which is not the best solution in this specific situation. Due to this unforeseen circumstance, the caregiver became the emergency contact. This way, dementia victims are also more likely to ask for help if they need to, since they can easily see and recognize their caregiver's picture on the main screen. Still, if the caregiver believes the first option to be the best, he can set a contact with the national emergency number, and by setting that contact as *caregiver* in the application settings, the described behavior will be obtained (if the caregiver does not set a picture to the contact, the emergency icon presented on Figure A.1 is used).

6.3.2 Contacts

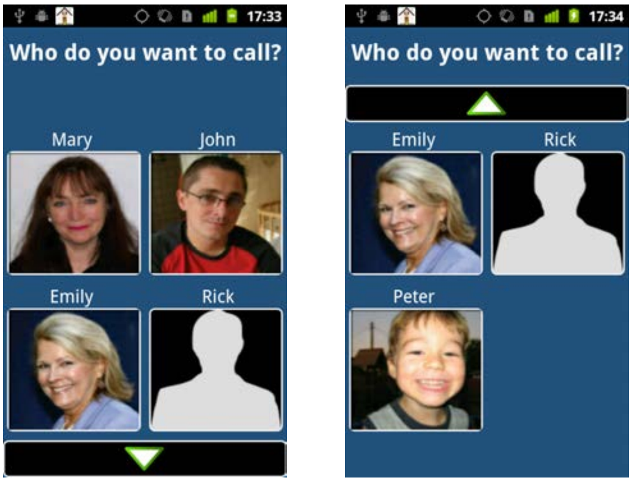
In this activity, the patient can select a contact to call to from a list. The caregiver can set an unlimited number of contacts, but if the patient suffers from any form of dementia, it is recommended that this list does not contain over four contacts since that would require the patient to scroll in order to see the full list. Android's default way of informing the user that there's more information than that currently being displayed on screen is by adding a small fading effect to the edge of the screen to which the user can scroll over to. This is very easy to go unnoticed unless the user is used to it, so a simpler, easier to spot solution was required. Furthermore, older adults may have more difficulty in performing the screen swipe required to scroll due to their decreased motor coordination. To deal with these issues, a custom view was implemented: the arrowed scroll view. This view extends Android's default scroll view implementation, disabling the swipe gesture based scroll and adding two buttons to it, a top arrow and a bottom arrow. These will be responsible for scrolling the view up or down, respectively, by a line. Whenever the top or bottom are reached, the corresponding button is disabled. Initially, this would change the button onto a disabled state, but this was later changed to the complete removal of the button from the interface, minimizing the chance for mistakes. The original interface prototype, with the disabled buttons, can be seen on Appendix A, Figure A.2.

Older adults' decreased motor coordination occasionally also leads to unintentional double clicks on buttons. If these were to occur on the arrow buttons, the user could skip a line in the contacts list without noticing it. To deal with this event, a small timeout of a quarter of a second was introduced on these buttons. This timeout is long enough to prevent the mentioned occasional situations, but small enough to go unnoticed during ordinary scrolling.



(a) Patient view (b) Caregiver view

Figure 6.3: Quick contacts functionality interface



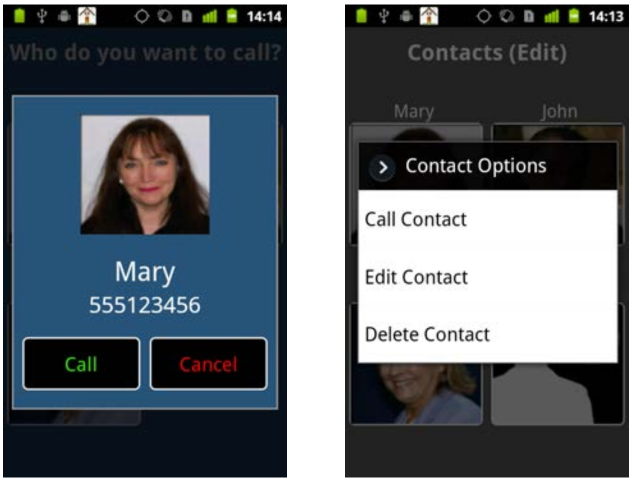
(a) Patient view (top) (b) Patient view (bottom)

Figure 6.4: Quick contacts interface with over 4 contacts

Figure 6.3 shows the interface for both the patient as well as the caregiver with a contacts list constituted by three contacts, while Figure 6.4 showcases how the implemented arrowed scroll view manages arrow visibility on a list with five contacts. The patient's interface was inspired by a study's results [ANMF10] that suggest this picture dialing interface as the best option for PwDs.

The patient and the caregiver view are visually similar, with the only differences being the title, the fact that the last button of the list in the caregiver's view always allows the addition of a new contact and the different color in the background. One other thing that sets them apart is their behavior. If a patient clicks or long clicks on a contact, it will immediately be presented with a call confirmation dialog (Figure 6.5a). In the caregiver's view however, a click or a long click on a contact, opens up a contextual menu, allowing the user to choose whether he wants to call, edit or delete that contact (Figure 6.5b). The idea behind similar actions for both click and long click is simple: an inexperienced user may easily perform a long click to execute an action, unaware that it is commonly used to access contextual information or options. On the other hand, a caregiver may also not be aware of the long click's common use of accessing contextual options, so he may very well perform a single click. Hence by limiting the number of options in each scenario, the number of possible errors is also limited, and both advanced and unfamiliarized users can achieve the desired outcome.

Hidden in the options menu of the caregiver's interface, there is also an extra option to clear the entire list.



(a) Patient view (b) Caregiver view

Figure 6.5: On-click/long click actions for each user type

Each button on this interface is associated with a contact's phone number. By default, only the contact's picture shows up on the button, but if the caregiver wants to set two different numbers for the same contact (e.g. the home and the work number) two similar buttons are created and a small overlay image is added to the bottom right corner of each to indicate the phone number's type (home, mobile, work, etc.). On the call confirmation dialog, the full phone number is also displayed, however, this method enables the user to know to which type of number he is going to call before clicking any contact at all. Figure 6.6 showcases this feature, with three different numbers from the same contact being presented on the list. It can also be seen that the three overlay icons selected have very distinct colors, so that they can be easily distinguishable.

Figure 6.6: Example of the contacts' phone type overlays

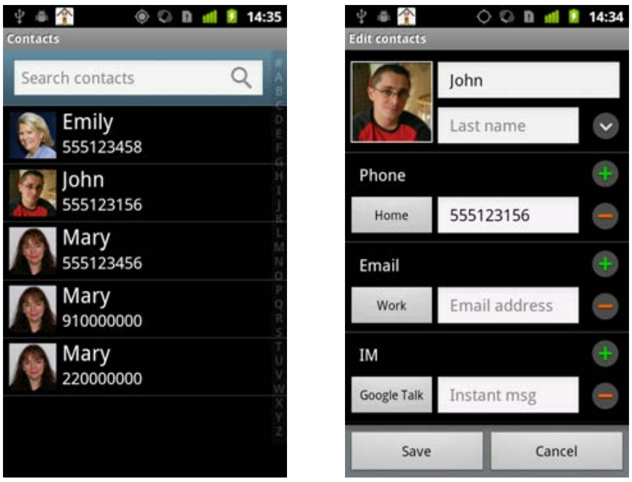
The functionalities of adding a new contact and editing the information of existing ones, are achieved taking advantage of Android's default contact activities. To select which contact to add to the list, the following intent was used:

```
//intent to pick a contact from the OS's contacts list
Intent pickContactIntent = new Intent(
    Intent.ACTION_PICK,
    ContactsContract.Contacts.CONTENT_LOOKUP_URI);
//we want to pick a specific phone number
//not only a contact (who may have several), this splits them
pickContactIntent.setType(ContactsContract.CommonDataKinds.Phone.CONTENT_TYPE);
startActivityForResult(pickContactIntent, ADD_CONTACT);
```

After defining the intent, the `startActivityForResult` method is called with it. Once the user selects a contact, the `onActivityResult` method is called, and the information of the selected contact is passed back to the application through the Intent's data. The process is similar for editing an existing contact:

```
Intent editContactIntent = new Intent(
                Intent.ACTION_EDIT);
//we want to edit a contact, with the id: contactID
editContactIntent.setData(
    ContentUris.withAppendedId(ContactsContract.Contacts.CONTENT_URI,
                               contactID));
startActivityForResult(editContactIntent, EDIT_CONTACT);
```

Figure 6.7 shows the interfaces for when adding/picking a contact and for editing a contact.



(a) Selecting the contact to add

(b) Editing an existing contact

Figure 6.7: Interfaces used for picking and editing contacts

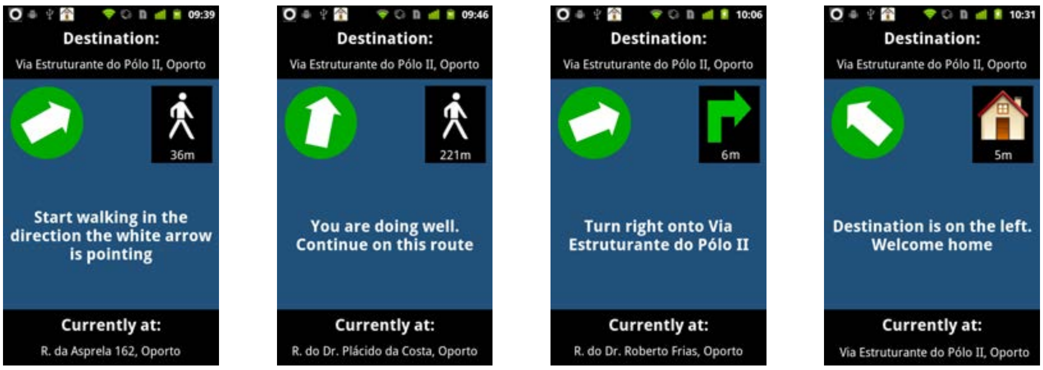
6.3.3 Navigation

This activity's interface (Figure 6.8) was particularly difficult to define since a lot of information is required to provide real time navigation. The first thing that separates it from the previous interfaces is the fact that it is mainly divided into three sections:

Destination: the header section that contains the destination (home) address. This section is important since the patient can constantly know, and remember, where he is being navigated to. It can also be useful to ask for help.

Navigational Instructions: this section is where all the information regarding navigation is displayed. It combines text instructions with both dynamic (white arrow) and static instructions.

Current location: the footer section that informs the patient of its current location street address. This is helpful for both navigation (reassurance that the patient made a right turn) and for orientation (the patient may recognize the street name and regain its orientation).



(a) Initial instruction (b) Reassurance message (c) Turn instruction (d) Final instruction

Figure 6.8: Navigation interface

Each of these sections is also clickable, and upon click, the main information on each will be read out loud to the user using text-to-speech. Although these clickable views diverge from the specified button design, it was very important that audio could play a big role in the navigation process since it is a process sure to be executed while outdoors. This way, the user does not have to pay as much attention to the screen and can focus on its surrounding environment. Still, the pressed state of these views mimics that of the other buttons in the application to try to keep as much consistency as possible.

When a navigation process is initiated, the first instruction needs to get the patient moving in the correct direction. To do this, the first instruction always tells the patient to start walking in the direction pointed out by the white arrow, as can be seen on Figure 6.8a. This arrow always points to the current waypoint, no matter where the user is headed or how he is holding the device. From this point onwards, audio should become the main guiding interface. The visual interface remains on screen for when an instruction is not well understood or a doubt occurs, and also for reassurance of if the current path is the correct one.

Figure 6.9: Static instructions possibilities

When a patient gets near one of the path's decision points, the current instruction is automatically updated and the new instruction is read out loud. The static instruction image is also updated, according to a process that is later explained in Section 6.4.4. When between decision points, this instruction switches to a "walking" image to inform the patient that he just has to keep moving until a new instruction arrives. Finally, when reaching the final waypoint, the image changes to a house, informing that the final destination is close by. These images are presented on Figure 6.9 and a practical example can be seen on Figure 6.8. In case streetview is available at the destination location, the final screen should display a picture of the destination, like the example presented on Figure 6.10.

Figure 6.10: Destination screen using streetview

Before selecting this interface composed by a textual instruction supported by dynamic and static instructions, several other options were considered. Some of these are presented on Appendix A's Figure A.4.

6.3.4 Taxi

In this activity, the user can find out his location and quickly call a taxi service. Since the idea is to tell the user where he is, so that he can call a taxi to that location, the shown location needs to have a good accuracy. For this reason, when the user enters this screen and a precise enough location (with an accuracy of ten meters or less) is not available, a message is displayed informing the user that the application is trying to find out his precise location. If text-to-speech is enabled in the settings, this message will be read out loud to the user. If an accurate location becomes available, the interface is updated with information regarding that location and its accuracy as can be seen on Figure 6.11 and, once again, a message will be spoken to the user informing him that a new location has been obtained, followed by that location's information.

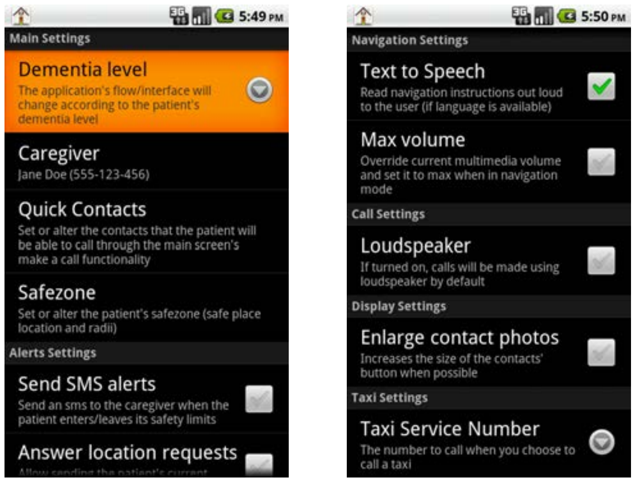
Figure 6.11: Call a taxi feature interface

Since the current location is the only information on screen, text-to-speech can be used to more effectively pass that information onto the user. Like in the navigation activity, the user can press the header to hear the corresponding information with the help of the text-to-speech engine.

6.3.5 Settings

This activity represents the settings of the application, and it is intended to be used by the caregiver. Ideally, all interfaces should be designed to be as older adult friendly as possible, but due to time constraints the caregiver's exclusive interfaces, like this one, are mostly implemented taking advantage of regular controls.

Some of the most important configurations that the caregiver can do are: changing the patient's dementia level, changing the current caregiver, and altering the quick contacts list or the safezone. In order to compensate for age-related hearing problems, the caregiver can choose to enable loudspeaker calls by default and also tell the application to automatically set the text-to-speech volume to its maximum during navigation. Regarding vision problems, there is an option to enlarge the buttons and pictures of the quick contacts list. Depending on the size of the screen and on its aspect ratio, this can cause a slight distortion on the pictures, but even still the patient may have an easier time spotting them. Figure 6.12, shows this activity's appearence.



(a) (b)

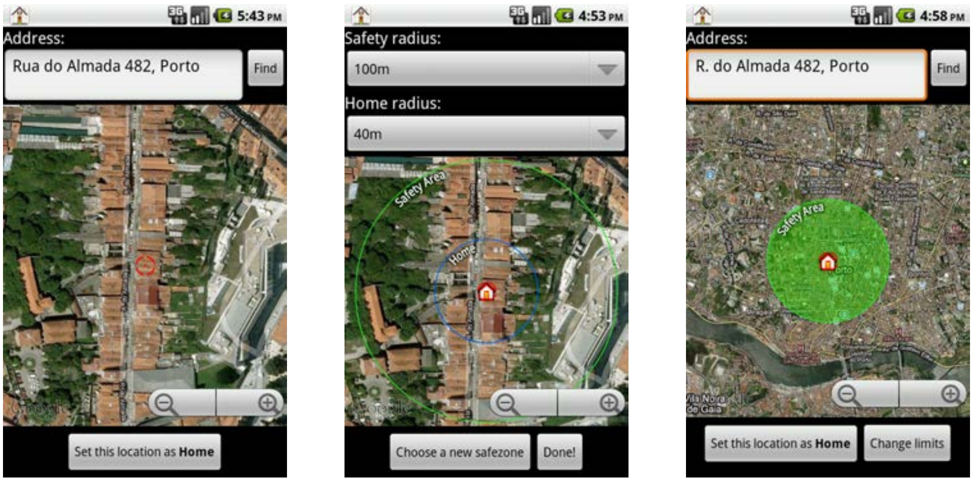
Figure 6.12: Settings interface

When a user selects to use text-to-speech, a background check is made to ensure that the required software is available on the device (both the engine as well as the current language). In case it is not, the user is sent to the market link of the required software, and asked to install it on the device if he wants to take advantage of this functionality.

6.3.6 Safezone

This activity allows the caregiver to set a safezone for the first time, or alter the properties of the currently existing one. If it is the first time the application is being run and there is no safezone set yet, the map will automatically center on the smartphone's current location and the address text view will be automatically filled with the corresponding address. By doing so, if the caregiver is using the application from within the address that he wishes to mark as the safe place, the map and address will already represent a near address that he is more likely to recognize. If that is not the case, than at least the caregiver already has an example of a well syntaxed address query, and can use that to search for the desired location. Figure 6.13a exemplifies a first screen the caregiver could see if he was setting a safezone for the first time, from within the proximities of "R. do

Almada 482". Figure 6.13b exemplifies what the caregiver would see after setting that address as his home address. In this screen he can choose both the safety and home radii and get a visual representation of each as the values are changed. Finally, Figure 6.13c exemplifies the screen that would be presented in case the caregiver selected to choose a new safezone after already having defined one. As you can see, he can always choose to edit the boundaries of the one currently set, or select a new home location.



(a) Search address (b) Alter radii (c) Safety area overview

Figure 6.13: Safezone definition process

As can be seen on Figure 6.13b, there are two distinct types of radii which can be set around the home location: the safety radius and the home radius. The safety radius is the most important of the two, since it delimits the locations on which the patient is considered to be safe. If such boundaries are crossed, the application alerts the patient and the caregiver is warned. The home radius on the other hand, is more related to the power efficiency of the application. Like previously mentioned, the application manages battery consumption according to each situation's level of emergency, so when a user is considered to be at home (in a safe place), the application favours battery over precise location updates, i.e. network based locations. These have the benefit of being available while indoors and of not requiring as much power as GPS, but their accuracy can vary greatly. It is recommended that WiFi is kept turned on, so that a more accurate and constant location can be obtained in this situation (usually these locations have an accuracy of about 45m, whereas without WiFi, they can reach values of 1 or 2km in less populated areas using cell towers trilateration only). What the home radius defines, is what is the distance around the house on which the application will assume the patient to be at home, or close enough to be safe, so that it can try to save the device's battery. This is necessary because the accuracy of these "home locations" varies from place to place, and the home radius value should be as close as possible to the actual difference between the network and the real location, in order to avoid situations in which the patient has already left the house and the application still thinks he is safe indoors.

On the options menu of this activity there are two extra options. The first is to center the current safezone, where the current zoom level is set so that the entire safety perimeter can be seen and centred. The second is the option to enable or disable the fill of the safety radii circles. Figure 6.13c exemplifies the alternate viewing mode which is better suited for overviews, where the safezone becomes easily distinguishable from the rest of the map, rather than detailed zoomed-in views.

Regarding the map itself and all information on it, they were implemented taking advantage of Google's Maps library. This library is not part of the core Android OS, hence the requirement for Google Apps to be present on the device.

6.4 Processes and Algorithms

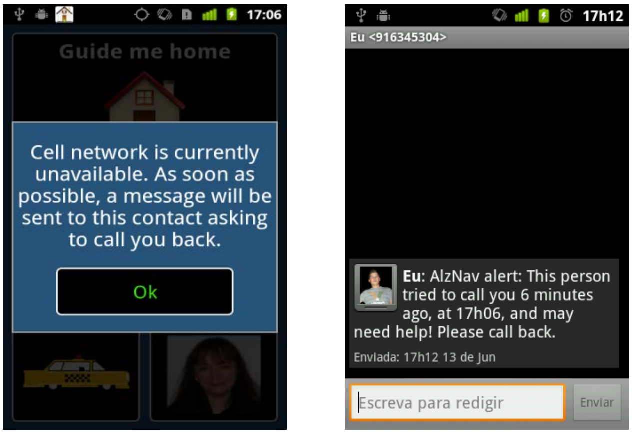
In this section, implementation details of specific processes and algorithms behind the main functionalities of the application are explained.

6.4.1 Calls

When the user clicks a contact button, a call confirmation dialog is displayed. The only exception to this rule, is the emergency caregiver call button on the main screen. When the user confirms that he wants do make the call, a verification is run to make sure that the mobile network is available at the time. If the network state reports no problem, a call can be initiated. To do so, an `Intent` is created with the destination number information. According to the Android reference, *"an Intent provides a facility for performing late runtime binding between the code in different applications. Its most significant use is in the launching of activities, where it can be thought of as the glue between activities. It is basically a passive data structure holding an abstract description of an action to be performed"* [Goo11b]. What this means, is that Android allows specific activities of an application, or the OS itself, that offer specific functionalities, to be initiated by other activities through the use of `Intent` messages. In this case, the call process will be handled by the operating system's default call activity, started from within the application. Unfortunately, when a call finishes, the operating system's default behavior is to take the user to the call log, not the previous screen, so a solution was needed to make sure the application would return to the foreground once the call had ended. To do so, before the call activity is started, a call state listener is registered within the operating system's Telephony Manager. This allows the application to receive an event when the call is terminated, and the previous activity can be brought back onto the screen.

```
//create an intent for a 'call' action
Intent callIntent = new Intent(Intent.ACTION_CALL);
//specify the number we want to call
callIntent.setData(Uri.parse("tel:" + call_number));
//register a call state listener so we can automatically return
//to the application when the call has ended
telephonyManager.listen(callEndedListener,
                        PhoneStateListener.LISTEN_CALL_STATE);
//start Android's call activity
startActivity(callIntent);
```

If the mobile network happens to be unavailable at the time, a dialog informing of the situation will be presented to the user and a text message will be enqueued to be sent to the destination contact as soon as the network returns, informing him that the user tried to call him. Figure 6.14 exemplifies this.



(a) The dialog presented (b) The received message

Figure 6.14: Call process when the network is unavailable

6.4.2 Location Management

Apart from phone calls, all the application's features revolve around locations. As such, whenever the application is active, whether in the foreground or in the background, it must be receiving and processing location updates. To make sure that this happens, a service was created. In Android, services represent an application's desire to perform a longer-running operation while not interacting with the user. However, even in this case, they can be killed by the OS in case it is running low on memory. To prevent this, the service requests foreground priority, meaning that even though it is running in the background the OS will treat it as if it was the current foreground application (it is still theoretically possible for the service to be killed under extreme memory pressure from the actual foreground application, but in practice this should not be a concern). This also leads to the creation of a permanent notification icon on the status bar informing that the application is running, which can be seen on Figure 6.15.

(a) Status bar icon (top left corner)

(b) Expanded status bar message

Figure 6.15: Status bar notifications that the application is running

6.4.2.1 Emergency State Algorithm

Whenever a new location is accepted, its distance to the safe place is measured. This distance is then compared with the set radii and a status is chosen. Possible choices are (from lowest to highest emergency):

Home: lowest emergency state, the patient is home (or within the set home radius);

Walking: the patient is out of the house, but still deep within its safety zone;

Near Border: the patient is still within its safety zone, but it is closing in on the limit;

Off Limits: highest emergency state, the patient has left its safety limits;

Navigation: special state that is invoked whenever the patient is being navigated by the application.

Each state has a set of variables associatated. For example, the Home state favours network locations over GPS ones and it only requests updates approximately every 10 minutes (or 20 minutes, if the battery level is under 35%) while the Off Limits and Navigation states favour precise GPS locations and constant location updates. These are the limit situations, in between states' values reflect their emergency. Several other factors also change, like how much time will the application try to obtain locations from the current state's ideal provider, for example. Imagine that a user is off limits, and the application can not get a GPS lock. In this situation it asks for network locations, since a location is better than no location at all, but it keeps trying to obtain a GPS lock for as long as the patient remains off limits. If the patient is in a Walking state however, and the application is not being able to receive GPS locations (which is the ideal provider for this situation), it will try to obtain a lock for about 5 minutes before it rests for the same period of time. Once the rest period is over, the process restarts. This is more power efficient than having the phone constantly trying to obtain a GPS signal lock.

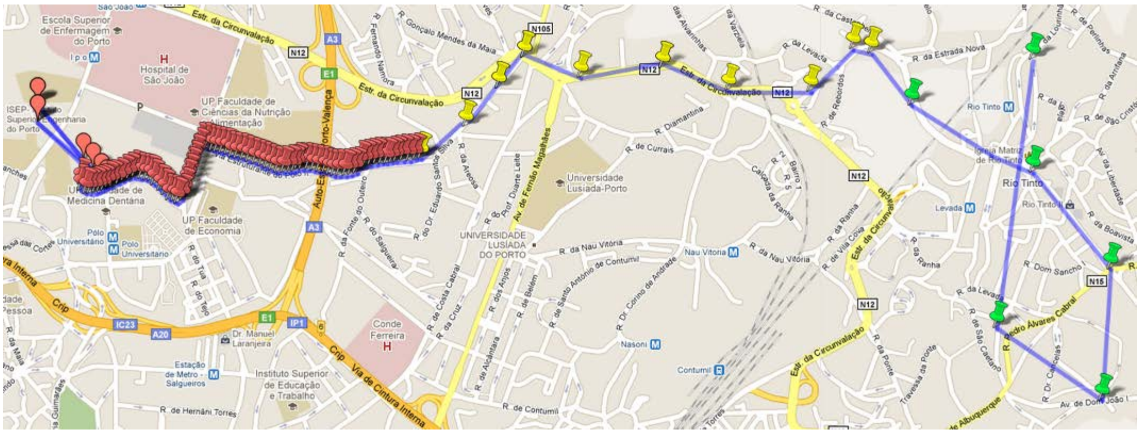


Figure 6.16: Influence of the emergency state on the location update frequency

Figure 6.16 showcases the influence of the emergency state on the location update frequency. On this image, the green pins indicate a "Walking" state, the yellow pins a "Near Border" state and the red pins mean that the user is "Off Limits". The red baloons on the left border still represent an "Off Limits" state, but those locations were obtained through the network provider (the user went indoors). As you can see, the green pins are more spaced in between than the yellow pins. Who, in turn, are more spaced out than the red pins. The impact of the power management implementation on locations can be better seen on Appendix B.

6.4.2.2 Managing New Locations

When constantly receiving location updates, in some cases from several providers at the same time, it is vital to choose wisely which locations are accepted and which are ignored. To do so, an algorithm was implemented to ascertain if a new location is better than the one currently available. Simply put, it considers a new location better if:

- There is no current location (a location is always better than no location at all);

- It is significantly newer, regardless of accuracy. The actual meaning of "significantly newer" changes according to state;

- It is more accurate and not significantly older. Again, "significantly older" changes according to state;

- It is newer and it is not less accurate;

- It is newer and it is not significantly less accurate. The acceptable accuracy loss also changes according to state.

Some extra verifications are included to keep rogue updates from being accepted. For example, if the GPS loses its lock for long enough for a network location to be requested, when this location is received, a verification is made to make sure that the distance difference from both locations is possible to be made by walking in the elapsed time period. If it is not, then the last known accurate location will be kept for as long as a better location is not received, or for a maximum period of time which is determined by the current state.

6.4.3 Alerts and Location Requests

One of the functionalities provided by the application, are location requests by the caregiver. This allows the caregiver to remotely, through an SMS, query the mobile phone for its current location and receive an automatic response with no need of interaction by the patient. For obvious privacy reasons, only the assigned caregiver can make these requests, and only if the corresponding option is enabled in the settings menu (which implies the patient's consent). To request a location, the caregiver must send an SMS that starts with a specific non-case sensitive string. In order for the application to respond to these requests, it must check every message that arrives. To do so, a Broadcast Receiver is registered to intercept events of incoming messages. These, as the name suggests, intercept system broadcasts regarding specific actions for which they are registered.

If a location request is received from the caregiver, a message is sent back with the current location (which is updated before it is sent), and the SMS broadcast is aborted, so that the location request message does not reach the system's messaging inbox. Other messages are ignored and pass through to the default messaging application.

Other than allowing the caregiver to request the patient's location at any time, the application also sends out alerts on its own when a patient leaves or returns to its safezone. An example of the messages sent to the caregiver on such events can be found on Figure 6.17.

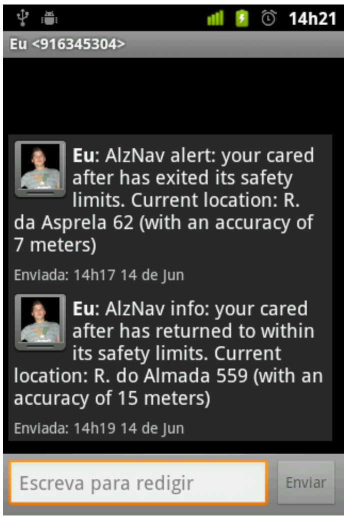


Figure 6.17: Example of the automatic alert messages

The patient is also warned when leaving its safezone. The smartphone tries to get its attention by means of a ringing and vibrating alarm. This alarm goes on for thirty seconds, or until the user presses a button on-screen. After this, it presents him with the application's main menu, where all the options that could be useful in this situation are easily available.

6.4.4 Navigation

The navigation process comprises several sub processes, which are presented in this section.

6.4.4.1 Obtaining the Current Location

The first of these processes consists of obtaining a location precise enough to calculate the best route to the destination. The value set as an acceptable accuracy for this first location, was of 10 meters. When the user requests to be navigated back home, he is first presented with a progress dialog informing him that the application is trying to obtain a precise location and asking him to remain still in an open, outdoor location. This message is read out loud to the user as soon as the dialog appears. Also at this time, the location manager switches to the *navigation state*. This state makes sure that only GPS locations are accepted and that they are requested as frequently as possible. Still, the time it takes to obtain a precise location varies in accordance with a variety of factors. However, since the application increases the frequency of location requests according to the emergency state – meaning that if a patient is close to reaching its border limit, the location request frequency will be greater than when he is well within the safety limits – it will take less time obtaining a precise location if the patient is close or off its limits. This is related to the way GPS locks are calculated. If precise locations were recently obtained, the GPS takes this information in consideration when determining the current location, generally reducing the time necessary to obtain a lock.

6.4.4.2 Obtaining and Parsing Directions

Once the current location is known, it is time to get the shortest walking path between that location and the safe place. To do so, a request to Google's Directions API is prepared and sent. If the request is successful, a JSON object is returned with the requested information (an example JSON response can be found on Appendix C). So that the UI thread is not blocked while waiting for the service's response, this operation is executed in a background thread. During this time, a dialog is shown informing that the application is currently searching for the best path for the patient do get home. After the response is received and its contents parsed, the dialog is dismissed, and the navigation *per se* is initiated.

When parsing the returned directions, a few changes to the received instructions are made. First of all, the first instruction that would be something like "Head northeast on (current street name)" is always replaced by an instruction saying "Start walking in the direction the white arrow is pointing to". Since the white arrow is always pointing to the current waypoint, this is a much easier process to inform the patient in which direction it needs to start walking. Furthermore, on the last instruction, right after the last turn indication there is a message indicating on which side of the road the destination will be, even if the destination is still dozens of meters away, e.g. "Turn right onto R. do Almada. The destination is on the left". This message was confusing, so it was split into two distinct instructions, and a final instruction was added to inform the patient that he is reaching his destination. After these alterations, on the last curve the instruction would read "Turn right onto R. do Almada", and only when the patient was actually reaching home the instruction would be updated to "The destination is on the left. Welcome home". The last sentence was added as a positive reinforcement.

6.4.4.3 Dynamic Arrow

During navigation, the white arrow is always pointing to the current waypoint. To implement this functionality, information regarding the device's orientation was required, so the internal magnetic sensor was used. By reading information from this sensor, it was possible to establish the device's orientation in relation to the Earth's magnetic north. From this value, the relation to the Earth's true north was obtained by adjusting the values in accordance to the World's Magnetic Model[2] produced by the United States National

[2] http://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml

Geospatial-Intelligence Agency. To do so, the values returned by the sensor are compensated with the magnetic declination from true north value of the current location. Next, the bearing (the direction one point is from another) between the current location and the current waypoint is calculated. Once this information is available, all that remains to be done is to point the arrow to the calculated angle.

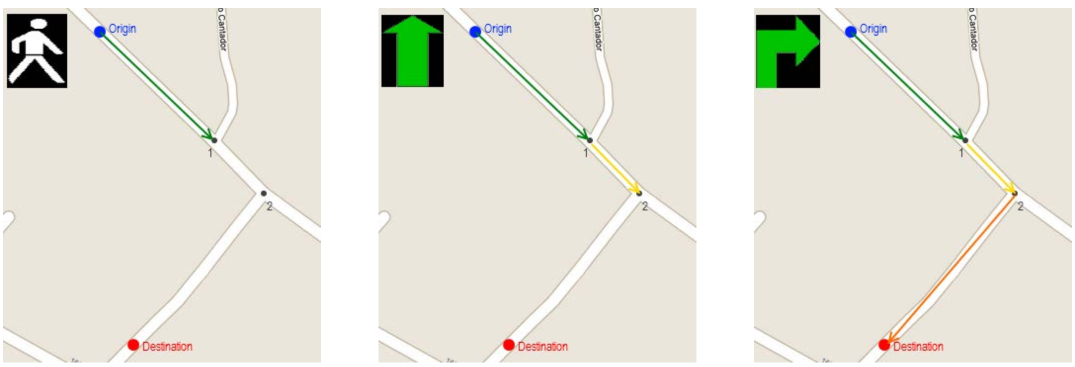
6.4.4.4 Static Instructions

Since the information that is returned from Google Directions has no visual instructions for each decision point, and the roads placements are unknown, a simple best effort algorithm is used to try to determine which instruction to show:

1. First, a straight line is drawn between the previous and the current decision point's location;
2. Then, a straight line is drawn between the current and the next decision point's location;
3. Finally, the bearing difference between the two lines will result in an aproximation of the trajectory shift which needs to be taken at the current waypoint.

The current algorithm only selects one of three instructions: a forward arrow, a turn right arrow or a turn left arrow (which can be seen, in this order, on Figure 6.9). Bearing differences larger that 15 degrees (for each side) are considered as turns, otherwise, the forward arrow is selected.

As a practical example, imagine the situation presented on Figure 6.18, where the blue dot stands for the start point of a route, the red point for the destination, and the grey dots for the two decision points where the patient will be presented with instructions. On the top left corner of each image, the displayed static instruction at each point is shown.



(a) Step 1 (b) Step 2 (c) Step 3

Figure 6.18: Static instructions calculation example

In this situation, when the patient reaches the first decision point, the green arrow (Figure 6.18a) represents the first line of the algorithm and the yellow arrow (added on Figure 6.18b) the second. As can be seen, these pretty much share the same bearing so the selected static instruction would be the forward arrow. When the patient reaches the second decision point, the first line would correspond to the yellow arrow, and the second line to the orange arrow (added on Figure 6.18c). These have almost a 90 degrees difference in trajectory, so a right arrow turn would be chosen.

6.4.4.5 Navigation Algorithm

The navigation algorithm itself is relatively simple. Since the streets themselves are not known, all the navigation has to be made on a best guess basis, taking only the locations provided by the GPS in consideration. When the patient comes to within a certain distance of the current waypoint (about 25m, but this changes according to the current location's accuracy), the on-screen instructions are updated with the information about that decision point. At this point the dynamic arrow begins pointing to the next waypoint. From this point forward, the distances to the current and next waypoints are monitored, and when the distance to the current waypoint increases by a certain margin and, at the same time, decreases by the same margin in relation to the next waypoint, the application assumes the instruction was carried out correctly. At this time, it updates the on-screen information to a "continuation state" (presented on Figure 6.8b) where a reassurance message is displayed and the static instruction is changed to the "walking" instruction. If the distance to the next waypoint is greater than 100m, the spoken reassurance message will include that distance at the end. This message will also be repeated out loud for every 50m, so that the patient receives an audio feedback that he is doing well every so often.

At any given time, the minimum distance the patient has been to its current waypoint is measured, and if he alienates from it for more than 15m, the application assumes that he has left its path and seamlessly reroutes. In case this has not happened, the current path will still be the best so nothing will change.

6.4.5 Safezone

When defining the safezone, the caregiver can choose to search for addresses. To get an address's corresponding location (in coordinates), Android's Geocoder class was used. This class's purpose is to handle geocoding and reverse geocoding. Geocoding is the process of transforming a street address or other description of a location into a (latitude, longitude) coordinate. Reverse geocoding, on the other hand, is the process of transforming a (latitude, longitude) coordinate into an address [Goo11a]. To perform the geocoding task, the method `getFromLocationName` is provided. This method takes an address and returns an array of locations that are known to describe that address. Results are obtained by means of a network lookup and the query will block while it waits for a response, so this method should not be called from within the primary UI thread. To avoid making the UI unresponsive, this request is processed in a background thread, with no interference to the user.

The application's geocoder is initialized with the device's Locale, and by doing so, becomes able to provide more accurate results even with incomplete information. In Android, a Locale represents a language/country combination. What this means is that if the user has Portugal set as his preferred locale, and he searches for a portuguese street address without mentioning city nor country, the geocoder will probably still be able to deliver the correct result since, if such information is not present, it assumes that the user must be searching for a location in its locale (in this case, in Portugal).

6.4.6 Phone State Management

Like location updates, the application needs phone state updates even when it is in the background. To achieve this, a secondary service was created, the `StateService`. Unlike the `LocationService` though, this service does not request foreground priority, instead, the service is just created as "sticky":

```
public int onStartCommand(Intent intent, int flags, int startId) {
    // We want this service to continue running until it is explicitly
    // stopped, so return sticky.
    return START_STICKY;
}
```

Services have two major modes of operation they can decide to run in, depending on the value they return from `onStartCommand`: the `START_STICKY` flag is used for services that are explicitly started and stopped as needed, while `START_NOT_STICKY` or `START_REDELIVER_INTENT` are used for services that should only remain running while processing any commands sent to them [Goo11e]. The difference between this and `LocationService`'s foreground state, is that if the system is low on memory, this service, unlike the `LocationService`, can be killed if necessary. The "sticky" property will, however, make sure that in case the system kills it, it will also create it again as soon as possible.

Chapter 7

Evaluation and Results Discussion

A questionnaire was made in order to identify what potential caregivers would find to be the most important features for this type of application to have. Regarding functionality, in order to verify how the developed prototype would handle a real case scenario, a trial was performed with the help of fellow developers. Apart from the functionality testing, a usability test session was also conducted with the help of ten participants (five older adults to take on the role of patients, and five randomly aged users to play the role of caregiver) to assess the ease of use of the application with target users and to obtain important user feedback.

All these procedures are explained in detail in the present chapter.

7.1 Questionnaire

In this section a summary of the most important conclusions that were taken from the questionnaire's results are presented. The full questionnaire and results can be seen on Appendix D.

The prepared questionnaire received a total of 475 responses. This questionnaire was aimed at potential caregivers, which was achieved with 99% of the responders having between 18 and 65 years of age. From all the responders, 134 (about 28%) claimed to have a close relation with someone who suffers from Alzheimer or other forms of dementia.

From this questionaire a couple of conclusions could be drawn:

- Most people feel that a dementia victim's safety radius should be smaller than that of a regular older odult. From this information, a wider range of values were chosen as possible default values for the safety radius;

- A large majority of the responders said that their preferred method for receiving alerts would be through SMS/MMS. Some would also like to receive the same information through e-mail;
- Exactly 50% of the responders said that their preferred information to be present on an alert would be a map with the cared-for's current location and recent path;
- 93% found the possibility to request locations as important (41%) or very important (52%);
- When considering the possibility to request the cared-for's recent path as well, this value decreased to 63%;
- 85% of the inquired found the existence of an online system that would allow the caregiver to monitor, in real-time, the cared-for's location, would be important (44%) or very important (41%);
- 75% considered that it would be important (46%) or very important (29%) to have the possibility to set various safezone radii according to the different days of the week/hours of the day;
- Finally, 94% considered that it would be important (51%) or very important (43%) to be able to specify several safe places.

7.2 Functionality Tests

This application was particularly hard to test during development since testing it under real use circumstances would require lots of outdoors traveling, which was impracticable. This meant that during development, specially during the initial stages, most of the testing had to be done through the simulation of these circumstances. So, once the location related functionalities reached a certain maturity level they were tested in "out-of-the-lab" conditions.

7.2.1 Location Management

Tests related to location management were made to make sure that the system was able to:

- Endure running continuously for long periods of time;
- Reliably reproduce, with as much accuracy as possible, the user's location throughout those periods of time;
- Effectively apply power management measures according to each situation;

7.2.1.1 Preparation

To be able to test these points, a location logger was implemented. This logger generates a KML file with the user's locations throughout the time the application was running, which is kept on the SD card. KML is a file format used to store geographic data which later can be viewed with tools such as Google Earth or Google Maps (an example of one of these logs was already presented on Figure 6.16). For every KML file, there was indication of the current safe zone, including the current safe place and both home and safety radius. On each of the locations that were stored, several information was also kept, including its capture time, accuracy, current status, home distance, location provider, etc.

7.2.1.2 Setup and Process

Ten volunteers were gathered to install the prototype onto their devices. They were explained the basic procedures of the application, and asked to configure their safezones in a pre-determined way. Once this process was complete, they were asked to keep the application running during their everyday routine for up to a maximum of five days, depending on availability. For privacy reasons, a pause/resume option was also included.

Once a day, an informal meeting with each of the volunteers was conducted to review its previous day log, while the memories were still fresh. The purpose of these meetings was to make sure that the recorded locations matched the actual paths taken by the testers. During these meetings, important feedback was also retrieved from the volunteers in regards to problems they had encountered. Aside from these meetings, the logs were also a valuable source of information regarding the application's behavior, so these would later be reviewed in the search for implementation issues.

7.2.1.3 Results

Aside from some problems with the actual application during the first day, the produced logs were being fairly accurate. However, some rogue network locations were being encountered among the results. The problem was traced back to the network provider, and an OS level issue was encountered: the network provider, on specific situations, would provide outdated locations as if they were new. This was problematic since those locations, in some cases, would have quite precise accuracies and, by being marked as new, they were being accepted by the location management algorithm. A solution for this problem could not be found for the time being, so its effects could only be toned down by the addition of an extra validation to the location algorithm. This extra validation was already described in the last paragraph of the implementation details regarding the management of new locations, on Section 6.4.2.2.

7.2.2 Navigation

Once the maturity level of the navigation module was ready for it, it was also tested out on the field. These functional tests helped identifying and sorting several issues. However, not all these issues could be solved and the following implementation limitations were encountered:

1. In the presence of strong magnetic fields, the device's magnetic sensor may become unreliable. Most alarmingly, it may become uncalibrated after which it will require manual recalibration, by waving the phone around in a figure 8 motion (Figure 7.1) a few times, until it provides accurate data again;

Figure 7.1: Compass calibration process

2. Google Maps geographical data is not completely reliable and accurate. What this means is that GPS locations with the maximum accuracy available (5 meters), were, sometimes, represented outside of the road. Since the dynamic arrow uses the geolocation returned by Google to know the location of the next waypoint and actual GPS location to know where it is standing at the moment, an error in the direction pointed out by the arrow is bound to happen in these situations. Throughout the conducted tests, errors by close to forty five degrees were rare, but occurred;
3. Static instructions are calculated on a best guess basis and, as such, fail to be a reliable representation of the actual decision that needs to be taken.

7.3 Usability Tests

To receive feedback and assess the developed prototype's ease of use, a usability test session was performed. In this section, the tests that were made are presented, along with their results.

7.3.1 Test Description

Each test was composed by two separate parts: one for the caregiver and one for the patient. The caregiver's part was composed of four main tasks:

Safezone definition: In this task, the tester was asked to find a given address and define it as the safe place. He was then asked to set specific home and safety radii.

Settings: In this task, the tester was asked to specify the patient's level of dementia and to set himself as its caregiver.

Quick Contacts: In this task, the tester was asked to add a contact to the patient's quick contacts list, and then to remove it.

Location Request: In this final task, the tester was asked to later on, during the navigational test with the patient, try to find out its location.

The patient's part was composed of three main tasks:

Call Process: In this task, the tester was asked to first call the caregiver, and then a specific contact from the quick contacts list.

Taxi Service: In this task, the tester was taken to an outdoor location nearby and was asked to try to call a taxi. Since they did not know where they were, they were also asked to try to obtain that information.

Navigation: In this task, the tester was asked to navigate from the same outdoor location back to its safe place.

Each of these tasks was divided into subtasks for easier evaluation.

7.3.2 Setup

The device chosen for the test was a Samsung Galaxy S, mainly due to its WVGA Super AMOLED display, which is capable of producing brighter and higher contrasted screens than most.

At the beginning of the test, the concept and purpose of the application were explained, as was the purpose of the test. It was stressed out that it was the prototype's performance what was being evaluated, not the tester's. Before actually starting, participants had the oportunity to touch and experiment a little with the device, and basic functionalities – like the use of the physical *back* button to return to the previous screen – were explained. For many, it was their first experience with a smartphone. At this point, the participants were paired in groups of two, consisting of one caregiver and one patient. Before the actual tests started, a picture was taken to all the participants and they were all added to the device's contact list. As a final note, all the tests were made with text-to-speech enabled.

7.3.3 Process

Testers were asked to vocalize their thoughts as much as possible, throughout each task. For each task, time required and number of errors were measured, and notes were taken. If the testers were having difficulties to complete a task, the initial provided information would be remembered to them. If still, they were unable to fulfill the task, this would be conducted by the moderator without the knowledge of the participant, who would be told that he had already done what was required on that task, before moving on to the next one. This was done to prevent the participant from believing that it was his fault, not being able to fulfill the task.

Tests were made individually – first with the caregiver, then with the patient – and tried to recreate a real case scenario in which the caregiver first configures the application, and then the patient uses it with those settings. The usability test's script can be found on Appendix E.1. At the end of each test, satisfaction questionnaires were handed to the testers. In these, their general level of satisfaction with each task was inquired, as well as their opinion and possible suggestions. The results from these satisfaction questionnaires can be seen on Appendix E.3.

7.3.4 Demographics

7.3.4.1 Caregivers

The five participants that took the role of caregivers had an average age of 40 years – the youngest was 24 years old and the oldest was 67. Four of them were female, one of them male. Two of them were regular smartphone users, two of them never owned one but were regular mobile phone users and were familiarized with their basic concepts, and one of them had never used a smartphone and was not a regular mobile phone user. Two of them used a computer on a daily basis, two of them were able to perform basic tasks with a computer, and one of them had no computer skills whatsoever.

7.3.4.2 Patients

The five participants that took the role of patients had an average age of 63 years – the youngest was 54 years old and the oldest was 70. Two of them were female, three of them male. None of the participants had ever owned a smartphone, but all of them had regular mobile phones. All the participants had very basic computer skills.

None of the participants had ever been diagnosed with any type of dementia, so only the interface developed for regular older adults was tested. Unfortunately, finding volunteer participants with diagnosed dementia for this test session was not possible. Finding testing volunteers in such conditions is, by itself, a hard accomplishment, but in this case it was particularly difficult since the tests would require an outdoor activity of an approximately 900 meters walk at a specific location, that should be the same for every participant.

7.3.5 Results

The complete test results and notes taken during each session can be found on Appendix E.2.

7.3.5.1 Caregivers

One of the chosen participants for the role of caregiver, showed difficulty in understanding the concept of having to conduct the tasks by using the device and according to the information displayed on-screen. This led to this participant not being able to fulfill any task or subtask. For example, when asked what option he would choose to perform a certain task from a screen with three choices, the participant would briefly look at the device and then instantly provide generic answers to the question asked. This may be related to the fact that this participant was not a regular mobile phone user. Not wanting to force this participant in any way, the tests were conducted as usual, and the results registered. In the following sections, this participant is referred to as participant E.

Task 1: Safezone Definition

On this entire task process (the sum of all the subtasks), an average of 0.5 errors per user was obtained, without taking into account participant E. Taking participant E into account, this value rises to 1.4 errors per user.

Subtask 1.1

The first subtask consisted of choosing the right option to set a safezone. Four out of the five participants were able to select the right choice, and only one of them made an error. The participant who did not manage to choose the correct option was participant E. The participant who made a mistake, entered the first option labeled "Application Settings", before coming back and realizing there was an "Edit Safezone" option. This user suggested that the button labels should be reviewed, to be more easily distinguishable.

The final average time to achieve this subtask was of 7.3 seconds.

Subtask 1.2

The second subtask consisted of being able to find the specified address. All the participants but participant E managed to achieve this subtask in an average time of 33.5 seconds. The fact that a nearby address was already automatically filled helped the participants, who only had to change the door number.

Subtask 1.3

The third subtask consisted of being able to define that location as the safe place. All the participants but participant E managed to achieve this subtask in an average time of 2.75 seconds. One of the participants suggested that a message should be added confirming that the safe place had been successfully set.

Subtasks 1.4 and 1.5

The fourth and fifth subtasks consisted of being able to define the requested radii. The required safety radius was not part of the default listed values – it was a value between two of them – and required the user to scroll the list to select the "Other" option and to insert it manually. Apart from participant E, one other did not manage to completely fulfill this subtask. This participant was however able to define the closest listed value to the one requested, and mentioned out loud that since it could not find the requested value it was going to set the one just above it since there was only a difference of 50 meters between them. As for the home radius, a default value was requested, and in this case, all the participants but participant E managed to easily set it.

The final average time to achieve both these subtasks was of 13.75 seconds.

Task 2: Settings

On this entire task process (the sum of all the subtasks), no errors occurred, without taking into account participant E. Taking participant E into account, this value rises to 0.4 errors per user.

Subtask 2.1

The first subtask consisted of choosing the right option to change the desired settings. All but participant E were able to do this in an average time of 3 seconds, with no errors recorded.

Subtask 2.2

The second subtask consisted of setting the requested dementia level. All participants but participant E managed to achieve this subtask in an average time of 4.5 seconds, with no errors recorded.

Subtask 2.3

The third subtask consisted of the participant setting himself as the caregiver. All participants but participant E managed to achieve this subtask in an average time of 8.75 seconds, with no errors recorded.

Task 3: Quick Contacts

On this entire task process an average of 0.25 errors per user occurred, without taking into account participant E. Taking participant E into account, this value rises to 0.6 errors per user.

Subtask 3.1

The first subtask consisted of choosing the right option to get to the quick contacts list. All but participant E were able to do this in an average time of 5.5 seconds, with one of the participants making a mistake. The user later suggested that the label for this action should be changed, since it was not clear.

Subtask 3.2

The second subtask consisted of adding a requested contact to the quick contacts list. All but participant E were able to do this in an average time of 9.25 seconds, with no errors being recorded.

Subtask 3.3

The third subtask consisted of deleting a requested contact from the quick contacts list. All but participant E were able to do this in an average time of 8 seconds, with no errors being recorded. Also, all the participants without smartphone experience clicked the contact – instead of long-cliking it – when trying to access contextual options, sustaining the design choices made in this regard.

Task 4: Location Request and Alerts

At the time of the requests, the test moderator was outdoors with the patient, testing the taxi and navigational features. This was chosen so that the usage scenario for this feature could be as realistic as possible. All the participants were able to obtain the patient's location but some of the obtained responses were outdated (by approximately 2 minutes).

Also, alerts of entering/exiting the safezone were turned on before going outdoors. All participants received the alerts but, again, some of the addresses sent in the alerts were outdated by a couple of minutes. Also, some caregivers received more than the expected two messages (one for leaving and another for re-entering the safety area).

Implemented Improvements

With the feedback received from these tests, the intermediate configuration screen which can be seen on Appendix A, Figure A.3 was completely removed, and all options were transported to the previously presented Settings interface, where the main settings were brought to the top of the list (Figure 6.12a shows this). Further, a message was added to inform the user of when he has defined a new safe place successfully, which also informs of the defined location's address. To fix the location requests and alerts issues, the application now forces an address update to be obtained before sending it out to the caregiver. Regarding the multiple alerts, a slightly larger threshold margin was set for these alerts, allowing the patient to walk along its safety borderline without its caregiver constantly receiving alerts.

7.3.5.2 Patients

Task 1: Quick Contacts

On this entire task process (the sum of all its subtasks), an average of 0.2 errors and 0.2 doubts per user have occurred.

Subtask 1.1

The first subtask consisted of being able to call the caregiver. All participants were able to do this in an average time of 8.8 seconds, with one of them making the mistake of entering the *Make a Call* functionality first, and only then realizing that the caregiver could be called directly from the main screen.

Subtask 1.2

The second subtask consisted of being able to select the right option to call one of the quick contacts. All participants were able to do this in an average time of 2.8 seconds, with no errors being recorded.

Subtask 1.3

The third subtask consisted of being able to find the requested contact from the list. All participants were able to do this in an average time of 4 seconds, with no errors being recorded.

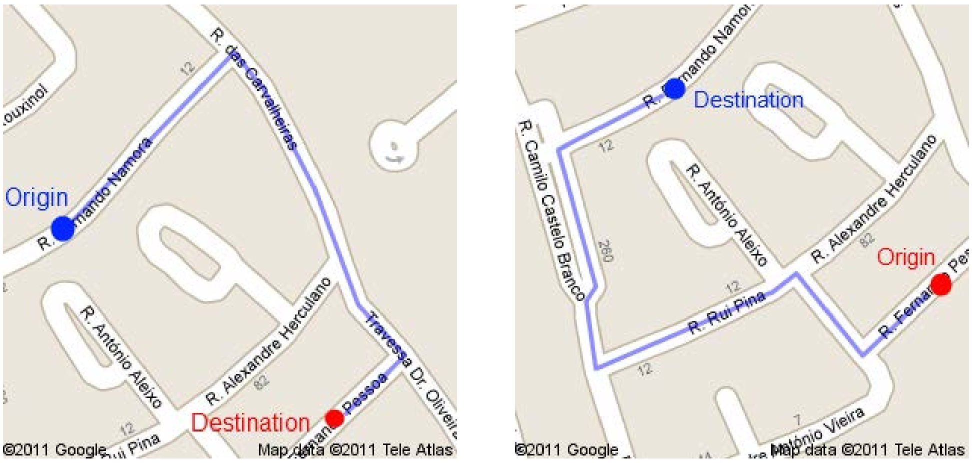
Subtask 1.4

The fourth and final subtask consisted of being able to call that same contact. All participants were able to do this in an average time of 2.8 seconds, with no errors being recorded.

Task 2: Taxi Service

On this entire task process, an average of 0.2 errors per user have occurred. No doubts were registered.

Before starting this task, the participant was asked to go with the moderator, to a previously chosen location. The path taken can be seen on Figure 7.2a.



(a) The path taken to reach the chosen location

(b) The path the participants took to navigate back to the safe place

Figure 7.2: Outdoor test route

Subtask 2.1

The first subtask consisted of selecting the right option to call the taxi service. All participants were able to do this in an average time of 2 seconds, with no errors being recorded.

Subtask 2.2

The second subtask consisted of being able to discover its current location. All participants were able to do this in an average time of 10.4 seconds. One of the participants, after finding out its current location, ignored the newer locations that provided better accuracy.

Subtask 2.3

The third subtask consisted of being able to start the call to the taxi service. All participants were able to do this in an average time of 1.8 seconds.

Task 3: Navigation

On this entire task process, an average of 0.4 errors per user and 1 doubt per route have occurred.

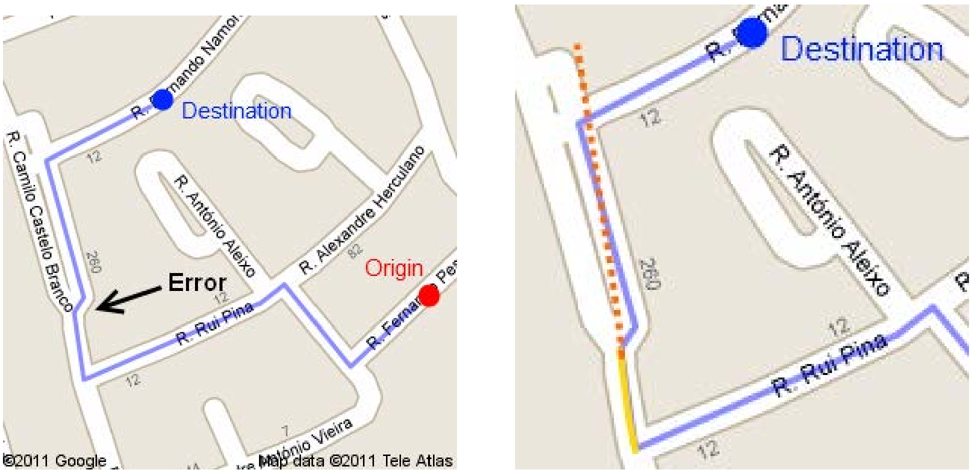
As Figure 7.2 shows, an alternative, slightly longer, route was chosen to reach the starting point of this test. This way, the participants did not have the chance to learn the route they were going to take in advance. This route had a distance of approximately 450m and 5 decision points.

Subtask 3.1

The first subtask consisted of selecting the right option to start the navigation process back to the safe place. All participants were able to do this in an average time of 4 seconds, with no errors being recorded.

Subtask 3.2

Finally, the second subtask consisted of the actual navigation back to the safe place. On this task, each misfollowed instruction counted as an error, while vocalized or whitnessed doubts were separately noted. All participants reached the safe place safely, in an average time of 9.8 minutes. An average of 0.4 errors per user and 1 doubt per route have occurred. All the errors that have occurred were due to the fact that the static and textual/spoken instruction gave contradictory instructions on the slight curve presented on Figure 7.3a.



(a) Decision point where the error occurred (b) Reason for the wrong static instruction

Figure 7.3: Contradictory instruction situation

The reason for this to happen is that, as you can see on Figure 7.3b, the decision point right after the one where the problem occurs, is almost in a straight line of the trajectory the user is headed at the time. According to the static instruction calculation algorithm, a forward arrow is the selected static instruction in this situation, contradicting the textual/spoken instruction that mentions a slight deviation to the right.

Implemented Improvements

With the feedback received from these tests, the *Call a Taxi* feature process was reviewed so that the first location the user receives is already accurate enough for the desired functionality. Until this point, a message is shown informing that the application is waiting for a precise location and the user can still make the call to the taxi service in case it already knows its current location.

7.4 Results Discussion

From these test results, we can infer that despite the room for improvement in certain areas, the developed prototype showed that even users that had never used a smartphone before were able to quickly perform most of the required tasks, using an interface that they had never seen before. Several of the usability test participants also stated that they found the interface for actions, such as calling a contact, much simpler and quicker than the ones they have on their regular mobile phones. On the other hand, caregiver's participant E was not able to perform any of the proposed tasks. This participant was the older of the caregivers, had no computer skills and was not a regular mobile phone user. These factors, in combination with the fact that the caregiver's interface is not "older adult friendly" in its totality, may have led to this result.

The fact that both the two errors found during the navigation process were caused by participants following an incorrect static instruction, when there were two other fonts of information indicating the right way, supports the idea that if these static, graphical instructions, were reliable and able to represent the actual path change (which Google already does – to a certain extent – within its own applications), they could completely replace the dynamic arrow when the user approaches a decision point. As an example, it can be seen on Figure 7.4, that in the decision point where the errors occurred, Google Maps presents a graphical instruction that would probably have prevented the errors from happening, if the developed prototype also had a way to access, or accurately calculate, such information.

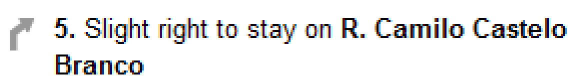


Figure 7.4: Google Maps' graphical instruction for the decision point on which the navigational errors occurred

Chapter 8

Conclusions and Future Work

8.1 Objectives Fulfillment

After a profound study of the target user, and of the several design guidelines and recommendations for it, existing products and solutions that tried to deal with the problem at hand were analysed. During this analysis, it was found that no other existing product provided the users with all the functionalities required to be able to fulfill every objective that this project aimed to. It was also discovered that recently, the number of smartphone applications regarding these issues, was increasing. However, these applications tended to focus on the caregiver only, while cared-for's were just monitored, not providing them, in any way, with the possibility to independently take action.

This dissertation's result is a functional proof of concept prototype that accomplishes the proposed objectives:

- It efficiently keeps track of the user's location, with special attention being given to power efficiency;
- Not only does it facilitate the process of calling for help (through the caregiver), but it also facilitates the process of calling in general, since the caregiver can set a list of contacts that the cared-for will then have easy access to;
- It is capable of determining when a user is leaving a predetermined safe perimeter, and on such event it alerts both the user as well as the caregiver. In case the user responds positively to the alert, he can take action himself and choose to call for help or be navigated back to a safe place by the application. Older adults with no diagnosed dementia, also have the possibility to easily call a taxi to take them back home;

- Apart from messages sent on alert situations, the caregiver has the possibility to request information regarding his cared-for's whereabouts which will be responded to autonomously. This feature should however, only be used with the consent of the cared-for, which is why it can be disabled through the application settings;
- Specific interfaces and work flows were designed for different levels of dementia – from the common older adult with no diagnosed dementia to a person with moderate dementia – in order to try to adapt the application to each specific user's needs.

The usability tests showed that the efforts put into making an interface focused on the application's target user group have paid off, with several of the participants mentioning that some of the same actions they had to perform during these tests, would have been much more difficult to achieve on their everyday mobile phone.

8.2 Contribution

As of today, a mobile phone application with an interface developed specifically for older adults and/or PwDs, and with the same core features as the ones of this project, could not be found.

A navigation mode that combines the best rated guidance modes for the target user group, tested in previous projects through non-functional prototypes, was implemented and tested with older adults. On top of that, issues present in these past projects – like the difficulty to get a user to start walking in the right direction in the first instruction – were also addressed and functional solutions presented. The new combined navigation mode also got good results despite its current limitations.

A power management algorithm based on the current level of emergency was also something that could not be found on any of the researched products, and that was successfully implemented on this prototype. This concept can be used on future projects that share the same principles.

Design decisions such as the option to completely remove disabled buttons can be used as reference for future projects, although this has not been extensively tested. Finally, the interface, which was designed in accordance with the several guidelines found on the subject, got good usability results and good feedback from target users, sustaining their effectiveness.

8.3 Future Work

First of all, there is room for improvement in some of the already implemented features. For example, the fact that the application has no access to the actual street layout data makes it impossible to implement algorithms that could make the navigational process much more robust. If the application had access to this information it would also be able to calculate, with precision, the graphical static instruction that should be presented at each decision point, possibly even by laying it out on top of the actual map data. In this last case, the information would always be as accurate as the map data behind it. The user's position error could also be dealt with if this information was available, since, like in commercial products, algorithms to correct the user's location onto the actual street could be used. As for the influence of magnetic fields on the returned orientation values, the best option would be to monitor the magnetic field for abnormal values, and to ignore orientations obtained under these circumstances.

On another note, the application's remote actions could also be extended. Allowing the caregiver to change the safezone remotely could be a valuable functionality, for example. Imagine the caregiver leaves early for work, and the weather takes a turn for the worse during the day. The caregiver might feel that under these circumstances, the set safezone should be much more concise. The interface for the caregiver to access its cared-for's information remotely could also be improved. Whether by simply enabling the application to also send out MMSs with the cared-for's location already pinpointed in a map or by a more complex solution consisting in the creation of a web service that would provide an interface for all the interaction with the device. The implemented KML logging functionality already started the process of enabling the application to transform the available information onto actual maps.

Regarding the location manager, the issue related to network locations was toned down, but is still present. A possible solution for it would be to request these locations from an alternative online location provider. Another improvement that could be done in the future would be to try to triangulate a more accurate location for the user using some of the last known locations, when these have big error margins. By triangulating the information from these locations and their accuracy margin, a more accurate location could be obtained.

As for the alert process, it could be extended in such a way that the patient would have the possibility to inform he is alright when he is alerted that he has left its safe zone. Only if no positive feedback would be obtained from the patient within a certain amount of time, should the caregiver be alerted. In case the patient informs that everything is well but remains off limits, this confirmation process should be repeated every so often.

The safezone definition process could also allow for several safe places to be set at once, and the application would automatically select to navigate to the closest one in emergency situations. The definition of several safezones that would change according to day of the week, or time of the day, could also be a valuable functionality, that would diminish the amount of times a caregiver would have to change these settings.

To facilitate the initial configuration of the application, a brief questionnaire – like the Mini Mental State Examination (MMSE) – could be used to determine the cared-for's level of dementia and automatically set the application settings accordingly. The MMSE is a brief questionnaire that is commonly used in medicine to screen for cognitive impairments. A wizard for the rest of the settings as well as help/tutorial screens for all the functionalities, would also greatly improve the application's ease of use.

Some extra features like fall detection could also be added. This way, not only would the caregiver receive alerts if its cared-for had left the perimeter he considered to be safe, but also if an unforeseen circumstance, such as a fall, would occur, even if within that safe perimeter.

Finally, it would be very important to be able to perform usability tests with PwDs as well, so that the application could be validated by these users. Despite the effectiveness revealed by the guidelines for older adults, actual user validation would be the only way to confirm that this effectiveness also applies to the guidelines that were followed regarding PwDs.

References

[AF03] E.M. Agree and V.A. Freedman. A comparison of assistive technology and personal care in alleviating disability and unmet need. *Gerontologist 43(3)*, pages 336–334, 2003.

[ANMF10] Nicola Armstrong, Chris Nugent, George Moore, and Dewar Finlay. Using smartphones to address the needs of persons with Alzheimer's disease. *Annals of Telecommunications - Annales Des Télécommunications*, 65(9-10):485–495, May 2010.

[Ass09] Alzheimer's Association. 2009 alzheimer's disease - facts and figures. Technical report, Alzheimer's Association, 2009.

[Ass10] Alzheimer's Association. 2010 alzheimer's disease - facts and figures. Technical report, Alzheimer's Association, 2010.

[Ass11a] Alzheimer's Association. About comfort zone, 2011. http://www.alz.org/comfortzone/about_comfort_zone.asp, accessed on the 7nd of February, 2011.

[Ass11b] Alzheimer's Association. What is alzheimer's, 2011. www.alz.org/alzheimers_disease_what_is_alzheimers.asp, accessed on the 5th of January, 2011.

[ATD11] ATDementia. Information on assistive technology for people with dementia., 2011. http://www.atdementia.org.uk/productSearch.asp, accessed on the 9th of January, 2011.

[Bjo04] Sidsel Bjoerneby. Enabling technologies for people with dementia: Report on user requirements. Technical report, 2004.

[BJZGA07] Ron Brookmeyer, Elizabeth Johnson, Kathryn Ziegler-Graham, and H. Michael Arrighi. Forecasting the global burden of alzheimer's disease. *Alzheimer's and Dementia 3.3*, pages 186–191, January 2007.

[BK04] David Burdick and Sunkyo Kwon. *Gerotechnology: Research and Practice in Technology and Aging*. Springer Publishing Company, First edition, 2004.

[BPPG09] Andrée-Anne Boisvert, Luc Paquette, Hélène Pigot, and Sylvain Giroux. Design challenges for mobile assistive technologies applied to people with cognitive impairments. *Ambient Assistive Health and Wellness Management in the Heart of the City: 7th International Conference on Smart Homes and Health Telematics*, pages 17–24, 2009.

[BTH99] S. Bjoerneby, P. Topo, and T. Holthe. Ted – technology, ethics and dementia. a guidebook on how to apply technology in dementia care. Technical report, Project report EU Biomed II, 1999.

[Cas04] Marilyn Cash. At home with at. Technical report, Dementia Voice, 2004.

[CFS+09] Neil Charness, Arthur D. Fisk, Joseph Sharit, Sara J. Czaja, and Wendy A. Rogers. *Designing For Older Adults - Principles And Creative Human Factors Approaches*. TAYLOR & FRANCIS INC, Second edition, 2009.

[CJM+97] Bettye Rose Connell, Mike Jones, Ron Mace, Jim Mueller, Abir Mullick, Elaine Ostroff, Jon Sanford, Ed Steinfeld, Molly Story, and Gregg Vanderheiden. The principles of universal design, 1997. http://www.ncsu.edu/www/ncsu/design/sod5/cud/about_ud/udprinciplestext.htm, accessed on the 10nd of February, 2011.

[Com10] The Nielsen Company. Android most popular operating system in u.s. among recent smartphone buyers, 2010. http://blog.nielsen.com/nielsenwire/online_mobile/android-most-popular-operating-system-in-u-s-among-recent-smartphone-buyers/, accessed on the 23nd of January, 2011.

[Com11a] The Nielsen Company. Apple leads smartphone race, while android attracts most recent customers, 2011. http://blog.nielsen.com/nielsenwire/online_mobile/apple-leads-smartphone-race-while-android-attracts-most-recent-customers/, accessed on the 22nd of January, 2011.

[Com11b] Marketing Charts ComScore. Us gains on eu5 in smartphone adoption, 2011. http://www.marketingcharts.com/direct/us-gains-on-eu5-in-smartphone-adoption-16304/, accessed on the 3rd of June, 2011.

[Coo09] Albert M. Cook. Using the web and ict to enable persons with disabilities. In *Biomedical Engineering Systems and Technologies*, volume 25 of *Communications in Computer and Information Science*, pages 3–18. Springer Berlin Heidelberg, 2009.

[Cor07] Matrix Corporation, 2007. www.matrixgulf.com/History.aspx, accessed on the 22nd of January, 2011.

[dB08] Johannes de Boer. Auditory navigation for persons with mild dementia. Technical report, Telematica Instituut & University of Twente, 2008.

[dR] dbS Research. Alzheimer's disease and related disorders overview. http://www.dbs-sar.com/SAR_Research/alzheimer_research.htm, accessed on the 6th of January, 2011.

[ea08] C.D Nugent et al. Mobile assistive technologies for people with mild dementia: the cogknow project, 2008.

[EDG+03] R. Eisma, A. Dickinson, J. Goodman, O. Mival, A. Syme, and L. Tiwari. Mutual inspiration in the development of new technology for older people. In *In Proceedings of Include 2003*, pages 7–252, 2003.

[Ena] Enable. Enable project. http://www.enableproject.org, accessed on the 9th of January, 2011.

[Fel03] V Feldmann. Mobile overtakes internet: implications for policy and regulations. Technical report, International Telecommunications Union, 2003.

[fHQ02] Agency for Healthcare and Research Quality. Preventing disability in the elderly with chronic disease. research in action, issue 3. Technical report, Agency for Healthcare and Research Quality (AHRQ), 2002.

[ftB] American Foundation for the Blind. The aging eye—normal changes and their symptoms. http://www.afb.org/Section.asp?SectionID=35&TopicID=212&SubTopicID=39, accessed on the 5th of January, 2011.

[ftHTI11] Canalys Expert Analysis for the High-Tech Industry. Canalys predicts android will grow more than twice the rate of major competitors in 2011, 2011. http://www.canalys.com/pr/2011/r2011011.html, accessed on the 23nd of January, 2011.

[FYSH07] S. Fickas, X. Yao, M. Sohlberg, and P. F. Hung. Route-finding assistances for community travelers with cognitive impairments: A comparison of four prompt modes. *Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI 2007)*, 2007.

[GNZ02] Peter Gregor, Alan F. Newell, and Mary Zajicek. Designing for dynamic diversity: interfaces for older people. In *Proceedings of the fifth international ACM conference on Assistive technologies*, Assets '02, pages 151–156, New York, NY, USA, 2002. ACM.

[Goo11a] Google. Android developers - geocoder, 2011. http://developer.android.com/reference/android/location/Geocoder.html, accessed on the 13th of June, 2011.

[Goo11b] Google. Android developers - intent, 2011. http://developer.android.com/reference/android/content/Intent.html, accessed on the 13th of June, 2011.

[Goo11c] Google. Android developers - platform versions, 2011. http://developer.android.com/resources/dashboard/platform-versions.html, accessed on the 8th of June, 2011.

[Goo11d] Google. Android developers - screen sizes and densities, 2011. http://developer.android.com/resources/dashboard/screens.html, accessed on the 8th of June, 2011.

[Goo11e] Google. Android developers - service, 2011. http://http://developer.android.com/reference/android/app/Service.html, accessed on the 14th of June, 2011.

[HGK+03] Sumi HELAL, Carlos GIRALDO, Youssef KADDOURA, Choonhwa LEE, Hicham EL ZABADANI, and William MANN. Smart phone based cognitive assistant. *Proceedings of the 2nd International Workshop on UbiquitousComputing for Pervasive Healthcare Applications*, October 2003.

[HM01] B.J. Holt and Roger W. Morrell. *Older Adults, Health Information, and the World Wide Web*. Psychology Press, First edition, 2001.

[IDW02] Carol Irizarry, Andrew Downing, and Deborah West. Promoting modern technology and internet access for under-represented older populations. *J. Technol. Human Services*, 19:13–30, September 2002.

[Int09] Alzheimer's Disease International. World alzheimer's report 2009, executive summary. Technical report, Alzheimer's Disease International (ADI), 2009.

[Jon04] Kerry Jones. Enabling technologies for people with dementia: Report of the assessment study in england. Technical report, 2004.

[Jud10] Simon Judge. Gartner q3 2010, 2010. http://www.mobilephonedevelopment.com/archives/1149, accessed on the 22nd of January, 2011.

[KH09] Kevin Kinsella and Wan He. An aging word: 2008. international population reports. Technical report, US Department of Commerce and US Department of Health and Human Services, June 2009.

[KM08] W. Kearns and D. Moore. Ultra wideband radio: A novel method for measuring wandering in persons with dementia. *Gerontechnology*, 2008.

[Kur08] S Kurniawan. Older people and mobile phones: a multimethod investigation, 2008.

[Lim] Cogknow Limited. Cogknow overview. http://www.cogknow.eu/, accessed on the 7nd of February, 2011.

[Lor06] D. Lorisa. An accessible technology to improve communication in dementia. *Visual Languages and Human–Centric Computing*, pages 226–227, 2006.

[LRR+10] Steve Lauriks, Annika Reinersmann, Henriëtte Geralde Roest, Franka Meiland, Richard Davies, Ferial Moelaert, Maurice D. Mulvenna, Chris D. Nugent, and Rose-Marie Dröes. Review of ict-based services for identified unmet needs in people with dementia. In Lakhmi Jain, Xindong Wu, Maurice D. Mulvenna, and Chris D. Nugent, editors, *Supporting People with Dementia Using Pervasive Health Technologies*, Advanced Information and Knowledge Processing, pages 37–61. Springer London, 2010.

[LWLS02] Françoise Lekeu, Vinciane Wojtasik, Martial Van Der Linden, and Eric Salmon. Training early alzheimer patients to use a mobile phone. 2002.

[Mar07] M. Marshall. Astrid - a guide to using technology within dementia care. *Journal of Technology and Disability*, 2007.

[Mis05] Frank Miskelly. Electronic tracking of patients with dementia and wandering using mobile phone technology. *Age and Ageing (34)*, page 497–518, 2005.

[MMR86] PK Mölsä, RJ Marttila, and UK Rinne. Survival and cause of death in alzheimer's disease and multi-infarct dementia. *Acta Neurol Scand 74 (2)*, pages 103–7, 1986.

[MMR95] PK Mölsä, RJ Marttila, and UK Rinne. Long-term survival and predictors of mortality in alzheimer's disease and multi-infarct dementia. *Acta Neurol Scand 91 (3)*, page 159–64, 1995.

[NHH+08] C. Nugent, X. Hong, J. Hallberg, D. Finlay, and K. Synnes. Assessing the impact of individual sensor reliability within smart living environments. *4th IEEE Conference on Automation: Science and Engineering*, 2008.

[oA] U.S. Administration on Aging. Assistive technology. http://www.eldercare.gov/ELDERCARE.NET/Public/Resources/Factsheets/Assistive_Technology.aspx, accessed on the 8th of January, 2011.

[oA08] National Institute of Aging. Home safety for people with alzheimer's disease. Technical report, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, 2008.

[oHW02] Australian Institute of Health and Welfare. Chronic diseases and associated risk factors in australia, 2001. Technical report, Australian Institute of Health and Welfare (AIHW), 2002.

[oMH95] Division of Mental Health. Who-qol, report no. 100. Technical report, World Health Organization (WHO), 1995.

[OPN05] Zaheer Osman, David Poulson, and Colette Nicolle. Introducing computers and the internet to older users: findings from the care online project. *Univers. Access Inf. Soc.*, 4:16–23, September 2005.

[Org05] World Health Organization. Chronic diseases, 2005. http://www.who.int/topics/chronic_diseases/en/, accessed on the 5th of January, 2011.

[OYM+04] H. Ogawa, Y. Yonezawa, H. Maki, H. Sato, and W.M. Caldwell. A mobile phone-based safety support system for wandering elderly persons. *Conference proceedings : ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference*, 5:3316–7, 2004.

[PMM+09] Carrie B. Peterson, Anelia Mitseva, Albena Mihovska, Neeli R Prasad, and Ramjee Prasad. The phenomenological experience of dementia and user interface development. *2009 2nd International Symposium on Applied Sciences in Biomedical and Communication Technologies*, pages 1–5, November 2009.

[PR09] David Prendergast and Simon Roberts. Community supports for ageing: Care pathways for older people in europe. Technical report, Intel Digital Health, 2009.

[Rub84] Jeffrey Rubin. *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests.* ohn Wiley and Sons, Inc., 1984.

[SDT10] Frank Sposaro, Justin Danielson, and Gary Tyson. iwander: An android application for dementia patients. *Conf Proc IEEE Eng Med Biol Soc*, 1:3875–8, 2010.

[SMBM99] J. Schneider, J. Murray, S. Banerjee, and A. Mann. Eurocare: a cross-national study of co-resident spouse carers for people with alzheimer's disease: Factors associated with carer burden. In *International Journal of Geriatric Psychiatry*, page 14:651–61, 1999.

[SS96] R. Seidler and G. Stelmach. *Motor control. Encyclopedia of Gerontology: Age, Aging, and the Aged.* Academic Press, First edition, 1996.

[Tea] Cogknow's Team. Cogknow | helping people with mild dementia to navigate their day. http://www.cogknow.eu/1/FP6_COGKNOW/index.html, accessed on the 7nd of February, 2011.

[TLH+10] Daniel Taub, Elmer Lupton, Roderick Hinman, Steven Leeb, John Zeisel, and Susan Blackler. The Escort System: A Safety Monitor for People Living with Alzheimer's. *IEEE Pervasive Computing*, 2010.

[TLL+10] Daniel Taub, Steven Leeb, Elmer Lupton, Roderick Hinman, John Zeisel, and Sue Blackler. The escort system: A safety monitor for people living with alzheimer's disease. 2010.

[US03] H. Umemuro and Y. Shirokane. Elderly japanese computer users; assessing changes in usage, attitude, and skill transfer over a one-year period. *Universal Access in the Information Society*, 2:305–314, 2003.

[UT99] G.R. Ungson and J.D. Trudel. The emerging knowledge-based economy. In *IEEE Spectrum*, volume 36, pages 60—-65. 1999.

[VPS+08] M. Vassallo, L. Poynter, J. C. Sharma, J. Kwan, and S. C. Fall risk-assessment tools compared with clinical judgment: an evaluation in a rehabilitation ward. *Age and Ageing*, 2008.

[XD07] Liu XZ and Yan D. Ageing and hearing loss. *The Journal of Pathology*, pages 188–197, January 2007.

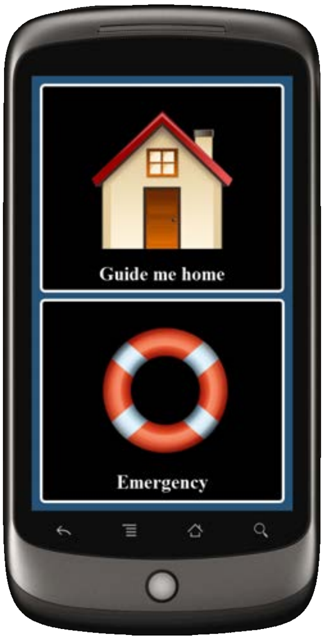
Appendix A

Initial Design Prototypes

A.1 Main Menu

(a) Older adult with no diagnosed dementia view

(b) Mild dementia user view



(c) Moderate dementia user view

Figure A.1: Initial main menu prototypes with an emergency number call button instead of the caregiver's quick call button

A.2 Contacts

Figure A.2: Initial arrowed scroll view prototype with disabled buttons

A.3 Configuration

Figure A.3: Initial configuration screen which was removed entirely after the feedback received from the usability tests

A.4 Navigation

(a) Typical navigational view

(b) Static arrow only

(c) Dynamic arrow complemented with a static arrow when needed

(d) Full route view

Figure A.4: Some of the alternative prototypes for the navigational interface

Initial Design Prototypes

Appendix B

Power Management

Green pins correspond to a "Walking" state (safe), yellow ones to a "Near Border" state, and red ones to an "Off Limits" state (dangerous).

Figure B.1: Log of a travel before the power management implementation

Figure B.2: Log of a similar travel after the power management implementation

These figures were obtained from functional tests and do not represent a walking journey (hence the great actual distances in between updates after the power management implementation). If the second figure was, in fact, from a walking journey, the update frequency relation between green, yellow and red pins would still be the same, but on a much more precise scale. Also, the safety area is not the same in both images so the states change in different locations.

The large gap between two of the green pins can be easily explained by the fact that the application was not able to obtain a GPS lock at the expected time. Since the user was still well within its safe zone, after not being able to obtain a location for a couple of minutes, the application "rested" and waited an equal amount of time before trying again, repeating this cycle until eventually succeeding. The same behavior can be witnessed between the yellow and red pins, but at this time, and as expected, the interval before regaining a signal is much smaller. This is due to the fact that under these circumstances – the user is near its safety limit – the application permanently tries to regain a signal lock.

Appendix C

Example JSON Response

An example of a JSON response sent by Google Directions.


```
{
  "status": "OK",
  "routes": [ {
    "summary": "I-40 W",
    "legs": [ {
      "steps": [ {
        "travel_mode": "WALKING",
        "start_location": {
          "lat": 41.8507300,
          "lng": -87.6512600
        },
        "end_location": {
          "lat": 41.8525800,
          "lng": -87.6514100
        },
        "polyline": {
          "points": "a~l~Fjk~uOwHJy@P",
          "levels": "B?B"
        },
        "duration": {
          "value": 19,
          "text": "1 min"
        },
        "html_instructions": "Head \u003cb\u003enorth\u003c/b\u003e on
        \u003cb\u003eS Morgan St\u003c/b\u003e toward \u003cb\u003eW Cermak
        Rd\u003c/b\u003e",
        "distance": {
          "value": 207,
          "text": "0.1 mi"
        }
      },
      ...
      ... additional steps of this leg
    ...
    ... additional legs of this route
      "duration": {
        "value": 74384,
        "text": "20 hours 40 mins"
      },
      "distance": {
        "value": 2137146,
```

```
        "text": "1,328 mi"
      },
      "start_location": {
        "lat": 35.4675602,
        "lng": -97.5164276
      },
      "end_location": {
        "lat": 34.0522342,
        "lng": -118.2436849
      },
      "start_address": "Oklahoma City, OK, USA",
      "end_address": "Los Angeles, CA, USA"
    } ],
    "copyrights": "Map data \textcopyright 2010 Google, Sanborn",
    "overview_polyline": {
      "points": "a~l~Fjk~uOnzh@vlbBtc~@tsE`vnApw{A`dw@~w\\|tNtqf@l{Yd_Fblh@
      rxo@b}@xxSfytAblk@xxaBeJxlcBb~t@zbh@jc|Bx}C`rv@rw|@rlhA~dVzeo@vrSnc}A
      xf]fjz@xfFbw~@dz{A~d{A|zOxbrBbdUvpo@`cFp~xBc`Hk@nurDznmFfwMbwz@bbl@lq
      ~@loPpxq@bw_@v|{CbtY~jGqeMb{iF|n\\~mbDzeVh_Wr|Efc\\x`Ij{kE}mAb~uF{cNd
      }xBjp]fulBiwJpgg@|kHntyArpb@bijCk_Kv~eGyqTj_|@`uV`k|DcsNdwxAott@r}q@_
      gc@nu`CnvHx`k@dse@j|p@zpiAp|gEicy@`omFvaErfo@igQxnlApqGze~AsyRzrjAb__
      @ftyB}pIlo_BflmA~yQftNboWzoAlzp@mz`@|}_@fda@jakEitAn{fB_a]lexClshBtmq
      AdmY_hLxiZd~XtaBndgC",
      "levels": "BBBAAAAABAABAAAAAABBAAABBAAAABBAAABABAAABABBAABAABAAAABABA
        BABBABAABB"
    },
    "warnings": [ ],
    "waypoint_order": [ 0, 1 ],
    "bounds": {
      "southwest": {
        "lat": 34.0523600,
        "lng": -118.2435600
      },
      "northeast": {
        "lat": 41.8781100,
        "lng": -87.6297900
      }
    }
  } ]
}
```

Appendix D

Questionnaire Results

At the start of the questionnaire, a small text introduced the application to the responder and informed him of where further information regarding relevant topics such as Alzheimer or Dementia could be obtained, if necessary.

D.1 Demographics

Gender

- Male: 273 (57%)
- Female: 202 (43%)

Age

- Under 18: 1 (0%)
- 18-25: 297 (63%)
- 26-40: 111 (23%)
- 41-65: 64 (13%)
- Over 65: 2 (0%)

Do you have a close relationship with someone victim of Alzheimer or any other form of dementia?

- Yes: 134 (28%)
- No: 341 (72%)

D.2 Questions

To monitor the state of the older adult/PwD, the caregiver has to initially specify a safety radius around a safe place (usually, the cared-for's residence). If that safety radius is crossed, the caregiver will be alerted.

In this section, please try to put yourself in the caregiver's shoes. If you are not in any similar circumstance, please try to imagine yourself in a situation in which a family member (e.g. parents or grand-parents) needed and could take advantage of an application like this.

Note: On the next two questions, please consider that the person in question, only travels on foot.

What would you consider to be the ideal safety radius for an older adult with no diagnosed dementia?

- The house: 78 (16%)
- 200m: 48 (10%)
- 500m: 46 (10%)
- 750m: 22 (5%)
- 1Km: 56 (12%)
- 2Km: 34 (7%)
- Dependant on a specific place: 184 (39%)
- Other: 7 (1%)

What would you consider to be the ideal safety radius for an Alzheimer/dementia victim?

- The house: 171 (36%)
- 200m: 52 (11%)
- 500m: 49 (10%)
- 750m: 16 (3%)
- 1Km: 45 (9%)
- 2Km: 17 (4%)
- Dependant on a specific place: 84 (18%)
- Other: 41 (9%)

In case the safety limit is crossed, how would you like to be alerted?

- SMS/MMS: 281 (59%)
- E-mail: 2 (0%)
- Both: 178 (37%)
- Other: 14 (3%)

What information would you like to receive in that alert?

- Just the alert is enough: 16 (3%)
- The cared-for's current location (in a textual manner): 109 (23%)

- A map with the cared-for's current location: 111 (23%)
- A map with the cared-for's current location, as well as its recent path: 236 50%)
- Other: 3 (1%)

How important would it be to be able to request, at any time, the cared-for's location?

- Indifferent: 5 (1%)
- Slightly important: 24 (5%)
- Important: 197 (41%)
- Very important: 249 (52%)

How important would it be to be able to request, at any time, the cared-for's recent path as well?

- Indifferent: 20 (4%)
- Slightly important: 146 (31%)
- Important: 201 (42%)
- Very important: 108 (23%)

How important would it be the existence of an online system that allowed the caregiver to monitor, in real-time, the cared-for's location?

- Indifferent: 10 (2%)
- Slightly important: 59 (12%)
- Important: 209 (44%)
- Very important: 197 (41%)

How important would it be able to schedule different safezones according to day of the week/hours of the day?

- Indifferent: 11 (2%)
- Slightly important: 109 (23%)
- Important: 217 (46%)
- Very important: 138 (29%)

How important would it be able to set multiple safe places, besides the regular safe place?

- Indifferent: 1 (0%)
- Slightly important: 27 (6%)
- Important: 242 (51%)
- Very important: 205 (43%)

Questionnaire Results

Appendix E

Usability Tests

E.1 Script

Notes:

1. Explain to all the participants the concept of the application – what it is, what is it for – and the motivation for the test. Stress out that it is the application that is being tested, not the participants!
2. Explain how the physical back button works, and let participants try out the touch screen;
3. Ask people to think out loud while trying to complete the tasks;
4. Fill out the profile form for each participant (name, age, and so on);
5. Before starting adding all contacts to the contacts list, with photos;

1 - Caregiver

1.1 - Safezone definition

Scenario: You just installed the application for your cared-for and you want to make some initial configurations, like choosing its safety area, defining the safe place, setting yourself as the person who will receive the alerts, etc.

Task: Set the address "Rua Fernando Namora, 152 Rio Tinto" as the home address. Specify a safety radius of 350 meters around it, and a home radius of 40 meters.

Subtasks

1. Select the correct option;
2. Find the requested address;
3. Set it as the home address;
4. Specify the correct safezone radius;
5. Specify the correct home radius;

1.2 - General Settings

Scenario: Now that you have specified the safezone, you want to change other settings, such as your cared-for's dementia level.

Task: In the application, set the dementia level of the cared-for as an older adult with no diagnosed dementia. Then, set yourself as its caregiver.

Subtasks

1. Select the correct option;
2. Alter the dementia level to the requested value;
3. Set the caregiver as requested.

1.3 - Quick Contacts

Scenario: Now that you have set the main configurations, you want to change the contacts your cared-for will be able to call.

Task: Try to add contact X (different for each) to your cared-for's quick contacts list. After that, try to remove it from the list.

Subtasks

1. Select the correct option;
2. Add the requested contact;
3. Remove the added contact.

1.4 - Location Requests

Scenario: Your cared-for is running late and you are wondering where he might be.

Task: (Five to ten minutes after we leave) Try to find that information out by requesting his location to the application.

2 - Patient

Notes:

1. Add 4 or 5 contacts to the quick contacts list;
2. Hand out a satisfaction questionnaire to the caregiver and thank him for his time;
3. Make sure the "patient" is still aware of who is his "caregiver";

2.1 - Calling

Scenario: You were walking to contact X's home for lunch but sudently, you felt too tired to go on. Try to call your caregiver so that he can come to help you get there. Then, call contact X to let him know what happened so that he does not get too worried.

Task: Call your caregiver. Then, call contact X.

Subtasks

1. Call the caregiver;
2. Select the correct option to make a call;
3. Find contact X;
4. Make the actual call.

2.2 - Taxi

Notes:

1. Before starting this test, go out with the patient, through an alternative route, to the determined location;
2. Inform this patient's caregiver that we are going out, so that he can, a few minutes later, execute the location request.

Scenario: You were in the middle of your way home but you felt too tired to go on. You are not sure what's your current street's name but you decide to call a taxi.

Task: By using the application, try to call a taxi and find out your current location's address.

Subtasks

1. Select the correct option;
2. Find out the current location;
3. Start the call to the taxi service.

2.3 - Navigation

Notes:

1. In this task, each misfollowed instruction represents an error;
2. Non vocalized doubts are also given special attention in this task.

Scenario: After finding out your current location, you decide that after all, you are close enough to go on foot, you are just not sure of the shortest way to get there.

Task: Using the application, try to be navigated back home safely.

Subtasks

1. Select the correct option;
2. Navigate back to the safe place.

In the end, hand out a satisfaction questionnaire to the patient and thank him for his time.

E.2 Results

In this section, the note taker's grids are presented. For each subtask column a field is filled with Y or N, depending on whether the participant was able to complete that subtask or not. Information regarding the time each participant took on each task is also presented, as well as an average time per task. Finally, the number of errors that each participant made is also shown.

After each task's results table, there is another table in which the notes taken during the tests, and the suggestions made by the participants, are presented.

E.2.1 Caregivers

Table E.1: Safezone Definition: Results

Participant	T1	Time (s)	T2	Time (s)	T3	Time (s)	T4	T5	Time (s)	Errors
A	Y	1	Y	28	Y	2	Y	Y	11	0
B	Y	22	Y	34	Y	6	Y	Y	5	1
C	Y	2	Y	44	Y	1	N	Y	21	1
D	Y	4	Y	28	Y	2	Y	Y	18	0
E	N	-	N	-	N	-	N	N	-	5
Average		7.3		33.5		2.75			13.8	1.4

Table E.2: Safezone Definition: Notes and Suggestions

Participant	Notes	Suggestions
A	Doubt because there was no save button;	Mentioned there should be a message informing a safe place has been set;
B	First choice was the application settings, only then came back and chose safezone;	Icons on the main configuration screen (the one with 3 choices)
C	Pressed the Find button before entering an address; 4.1 - chose the closest listed value;	
D	Was not sure if he could change the address that is already presented;	
E	Was not able to focus on the phone, nor the task;	

Table E.3: Settings: Results

Participant	T1	Time (s)	T2	Time (s)	T3	Time (s)	Errors
A	Y	2	Y	2	Y	6	0
B	Y	1	Y	5	Y	9	0
C	Y	3	Y	5	Y	7	0
D	Y	6	Y	6	Y	13	0
E	N	-	N	-	N	-	3
Average		3		4.5		8.75	0.6

Table E.4: Settings: Notes and Suggestions

Participant	Notes	Suggestions
A	No difficulties	
B	No difficulties	
C	No difficulties	
D	Doubt between first and second option on the config screen, when asked to set himself as the caregiver	
E	Was not able to focus on the phone, nor the task;	

Table E.5: Quick Contacts: Results

Participant	T1	Time (s)	T2	Time (s)	T3	Time (s)	Errors
A	Y	16	Y	10	Y	8	1
B	Y	1	Y	15	Y	7	0
C	Y	3	Y	4	Y	7	0
D	Y	2	Y	8	Y	10	0
E	N	-	N	-	N	-	3
Average		5.5		9.25		8	0.8

Table E.6: Quick Contacts: Notes and Suggestions

Participant	Notes	Suggestions
A	On the first try, it entered Application Settings (for altering the contacts)	Thought that "Edit Contacts" was only for the ones who already existed; Suggested a change of label
B	No difficulties	
C	No difficulties	
D	No difficulties	
E	Was not able to focus on the phone, nor the task;	

E.2.2 Patients

Table E.7: Calling: Results

Participant	T1	Time (s)	T2	Time (s)	T3	Time (s)	T4	Time (s)	Errors	Doubts
A	Y	6	Y	7	Y	2	Y	2	0	0
B	Y	6	Y	3	Y	1	Y	3	0	0
C	Y	17	Y	1	Y	7	Y	3	1	0
D	Y	10	Y	2	Y	1	Y	3	0	0
E	Y	5	Y	1	Y	9	Y	3	0	1
Average		8.8		2.8		4		2.8	0.2	0.2

Table E.8: Calling: Notes and Suggestions

Participant	Notes	Suggestions
A	No difficulties	
B	No difficulties	
C	T1. Chose "Make a call" first; T3 - Found the contact, using the arrows, with ease	
D	No difficulties	
E	T1. Doubt between "Make a call" and the caregiver "Call" button; T3. Found the contact, using the arrows, but took a little more time	

Table E.9: Taxi: Results

Participant	T1	Time (s)	T2	Time (s)	T3	Time (s)	Errors	Doubts
A	Y	2	Y	12	Y	2	0	0
B	Y	2	Y	11	Y	2	0	0
C	Y	2	Y	9	Y	2	0	0
D	Y	2	Y	7	Y	1	0	0
E	Y	2	Y	13	Y	2	1	0
Average		2		10.4		1.8	0.2	0

Table E.10: Taxi: Notes and Suggestions

Participant	Notes	Suggestions
A	No difficulties	
B	No difficulties	
C	No difficulties	
D	No difficulties	
E	Ignored new (more precise) locations - accepted the first as best	

Table E.11: Navigation: Results

Participant	T1	Time (s)	T2	Time (mins)	Errors	Doubts
A	Y	3	Y	9	0	1
B	Y	5	Y	12	1	2
C	Y	8	Y	9	0	0
D	Y	2	Y	8	1	1
E	Y	2	Y	11	0	1
Average		4		9.8	0.4	1

Table E.12: Navigation: Notes and Suggestions

Participant	Notes	Suggestions
A	Knew the area, and thought the street information was not correct (but it was)	Felt the screen was too sensitive
B	Had a doubt in the slight turn beacuse the static image told him to go forward. Ended up going forward (error); was not sure if he should turn right after the mistake; payed close attention to the distance information (meters to each turn)	
C	Followed the instructions with ease;	
D	Had a doubt in the slight turn beacuse the static image told him to go forward. Ended up going the right way after some consideration	When speaking, the application should call the user by its name
E	Had a doubt in the 4 way intersection: took a little time to look at the screen and eventualy went the right way	

E.3 Participants Satisfaction

In this section, charts obtained from the satisfaction questionnaires given to the participants at the end of the tests are shown. In these questionnaires a scale of 1 to 5 was used, where 1 stands for "Too complicated, would not use it" and 5 stands for "Completely satisfied, could not be any easier".

E.3.1 Caregivers

Caregiver participant E presented a total average satisfaction of 4 points. These values are however omitted from the following results since, for the reasons explained in subsection 7.3.5.1, they should not be considered representative.

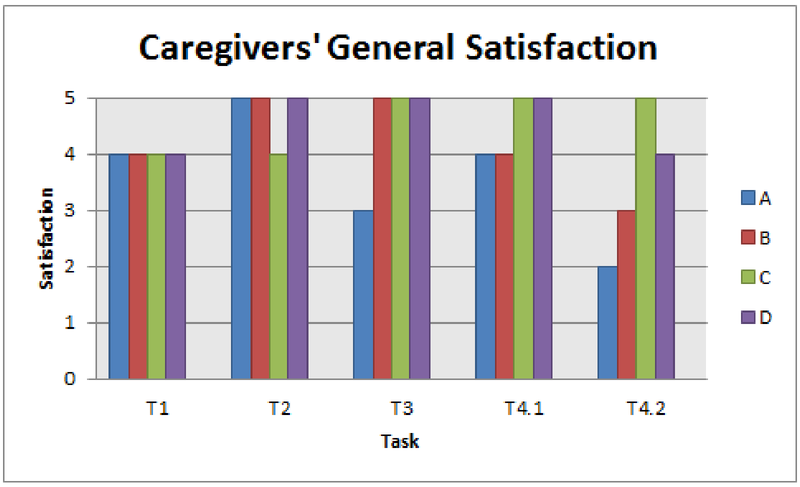


Figure E.1: Caregivers' general satisfaction per task

Average Caregiver Satisfaction per Task

T1: 4;

T2: 4.75;

T3: 4.5;

T4.1: 4.5;

T4.2: 3.5.

E.3.2 Patients

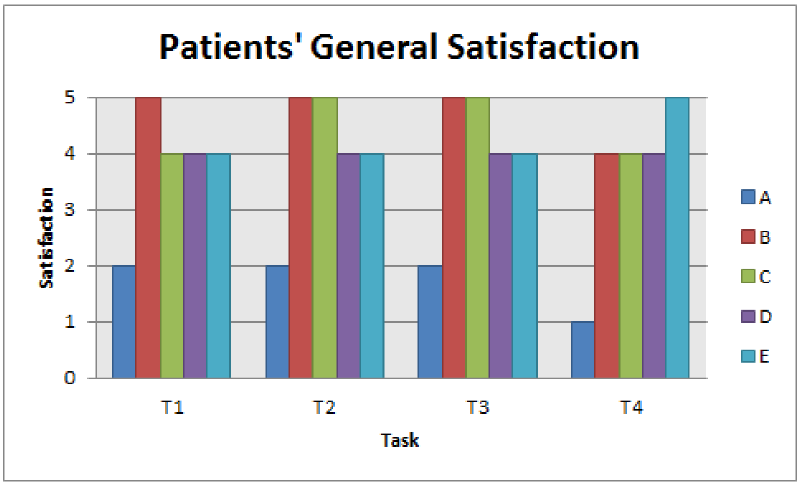


Figure E.2: Patients' general satisfaction per task

Average Patient Satisfaction per Task

T1: 3.8;

T2: 4;

T3: 4;

T4: 3.6.