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Improving pedestrian navigation for older adults and persons with mild dementia through landmarks

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Abstract

Nowadays, ageing is considered a global epidemic due to the rapid growth of the older population throughout the world. It is predicted that, in 2050, for the first time in recorded history, the older population is set to surpass the young population.

Therefore, an increase of incidence of age-related physical and mental impairments can been noticed. Dementia, in particular, is a well known syndrome which older adults are prone to develop. This condition is connected to a progressive loss of cognitive ability, leading to many difficulties such as mobility issues and time and spatial disorientation. A wandering behaviour, consisting on an aimless and disoriented walk, may present itself as a most worrying symptom, sometimes leading to accidents, injuries or even death. Such issues lead to decreased navigation skills - the skills a person needs to find their way to a location - and increased dependency on the patient's caregiver.

This report focuses on these mobility problems and describes the state of the art in related fields. As such, focus will be given to navigation methods used to instruct or guide users throughout a route to their destination. Facing the aforementioned issues, a thesis proposal is presented, with the purpose of aiding older persons in navigation tasks.

A prototype of a pedestrian-oriented navigation application, to be used in mobile devices by older adults and persons with mild dementia, will be developed employing new and emergent navigation concepts. This solution will follow a landmark-based approach, introducing landmarks in the generated instructions whenever deemed relevant.

This solution will be validated through the conduction of usability test sessions. The purpose of these sessions will be to compare the developed prototype with an existing application that follows a turn-by-turn approach, the most common navigation method.

Resumo

O envelhecimento é hoje considerado uma epidemia global devido ao rápido aumento do número de pessoas idosas em todo o mundo. Prevê-se assim, que em 2050, pela primeira vez na história, a proporção de pessoas idosas suplante a população jovem.

Por consequência, o aumento da incidência de alterações psicomotoras relacionadas com o avançar da idade têm sido realçadas. A demência, em particular, é uma síndrome bem conhecida e que as pessoas idosas são propensas a desenvolver. Esta condição está relacionada com uma perda progressiva das capacidades cognitivas, levando a várias dificuldades tais como problemas de mobilidade e desorientação temporal e espacial. Um comportamento de *wandering* (vaguear, em português), que consiste numa caminhada desorientada e sem objectivo aparente, pode apresentar-se como um sintoma deveras preocupante, resultando em acidentes, ferimentos ou até em morte. Tais alterações levam a uma reduzida capacidade de navegação - capacidades que uma pessoa precisa para encontrar o caminho para um determinado local - e a um aumento da dependência do cuidador por parte do paciente.

Este relatório centra-se nestes problemas de mobilidade e descreve o estado da arte nos campos relacionados. Como tal, irá ser dado foco aos métodos de navegação usados para instruir ou guiar um utilizador ao longo de um percurso até ao seu destino. Face aos problemas supracitados, uma proposta de dissertação é apresentada, com o objectivo de auxiliar pessoas idosas em tarefas de navegação.

Um protótipo de uma aplicação de navegação orientada a pedestres, a ser usada em dispositivos móveis por pessoas idosas e em estados iniciais de demência, irá ser desenvolvido empregando novos e emergentes conceitos de navegação. A solução irá seguir uma abordagem baseada em pontos de referência, introduzindo esses pontos nas instruções geradas sempre que considerado pertinente.

Esta solução será submetida a um processo de validação através da condução de sessões de testes de usabilidade. O propósito destas sessões será comparar o protótipo desenvolvido com uma outra aplicação já existente que segue uma abordagem *turn-by-turn* (passo a passo), o método de navegação mais comum.

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Abbreviations

API	Application Programming Interface
FhP	Fraunhofer Portugal
GPS	Global Positioning System
HCI	Human-Computer Interaction
PND	Personal Navigation Device
TTS	Text-To-Speech

ABBREVIATIONS

Chapter 1

Introduction

This chapter describes the context in which this dissertation is inserted, providing relevant background. The problem this thesis aims to address is briefly described, as well as the motivation behind this study. Furthermore, the main goals to attain towards the envisioned solution will be described, followed by a description of the structure of the document.

1.1 Context

As the worldwide average life expectancy increases, so does the ageing of the worldwide population. Projections show that the number of older people (aged 65 or older) will outnumber the young population (aged 5 or younger) for the first time in history. [Wor11]. While in the middle of the 20th century there were 14 million people aged 80 years or older, this number is expected to grow to 400 million by 2050 [Wor12], which means an increase of the older population of approximately 2800% in such a short period of time.

The rapid formation of an older society leads to an increased incidence of age-related impairments, such as dementia. It is estimated that 35.6 million people worldwide have dementia, with a new case occurring every 7 seconds. This syndrome is characterized by a progressive loss of cognitive ability, including memory and, at later stages, it may exhibit a decline in the ability to execute motor activities. Furthermore, patients are likely to display a wandering behaviour, a symptom where the patient moves in a "seemingly aimless or disoriented fashion or in pursuit of an undefinable or unobtainable goal" [VPS+08].

Thus, navigation is an essential subject in order to maintain independence and mobility. For that reason, this is an area where technology can reveal great advantages. Undoubtedly, the scientific community has taken interest in exploring this subject and research has been made in order to continuously improve navigation methods.

The proposed project in this report, in the context of the author's master thesis, seeks to increase the efficiency of the current navigational solutions for older adults and, therefore, increase their mobility and sense of security.

1.2 Motivation and Goals

Dementia is a well established reality of the older population, that leads to many sensorial and spatial awareness difficulties. Part of the solution is to continuously provide better ways to increase their mobility and sense of safety when going outdoors. This process will improve their interaction with the environment, improving their life quality. On the other hand, this can also help put the patient's caregiver at ease and lessen the inflicted stress. In short, it is essential to fill in the gaps in older adult's capabilities, to facilitate caregiving and to add knowledge to the state of the art of the related technical field, namely, pedestrian navigation.

The proposed project comprehends the study of how current navigational solutions provide their services, targeting an older population or otherwise.

Following up on studies that show signs of a potentially more efficient navigational method, a prototype application will be studied, designed and developed. Issues such as how this paradigm should be adapted to pedestrian users and, moreover, to an older audience with cognitive impairments will be addressed, in order to acquire a simple and efficient solution.

The developed prototype will then be evaluated and compared against a current navigation application centred on this same audience. Usability tests with subjects of the target user group will be performed in the field. The results will then be judged, drawing conclusions as to the applicability of the employed methods and whether they may increase older people's mobility and independence.

1.3 Report Structure

Apart from this introduction, this report has 4 more chapters. Chapter 2 presents the state of the art of the fields related to the scope of the author's master thesis. Existing navigational methods, how they are applied and research on the subject are described, leaving the last section for conclusions. Chapter 3 presents the problem to be addressed. Chapter 4 details how the problem described in the previous chapter will be approached and how this solution will be evaluated. Lastly, Chapter 5 advances the work plan for the forthcoming months.

Chapter 2

State of the Art

This chapter is dedicated to the state of the art of the main technological aspects of this dissertation. Section 2.1 contains a description of modern and emergent navigation mechanisms, as well as practical applications. In the end, a global overview of the state of art, summarizing this section, is presented.

2.1 Navigation

As described by R. Baker [Bak81], navigation is the method of determining the direction of a familiar goal across unfamiliar terrain. This term comprises two others: route-based and location-based mechanisms. Route-based mechanisms are related to the direction of travel and the relative distances throughout the journey, whereas location-based mechanisms concern the orientation linked to distant, recognizable landmarks.

In this section, two large concepts that describe how to best navigate humans will be discussed: turn-by-turn navigation and landmark-based navigation. These are strongly coupled with the route-based and location-based mechanisms described by Baker, respectively. Furthermore, the state of the art of each of these concepts will be presented in two different contexts: driver-centered and pedestrian-centered navigation. In the last section of this chapter, existing APIs that support the development of such applications will be presented.

2.1.1 Turn-by-turn navigation

Turn-by-turn navigation systems guide pedestrians/drivers to their destiny providing them with information such as distance to the next decision point[1], the name of the street to turn

[1] "Intersection where a driving maneuver such as turning left or right is required" [DK12]

Figure 2.1: Garmin (on the left) and TomTom's (on the right) navigation interfaces.

onto and turn direction [WHW09]. This information is presented to the user in a turn-by-turn format, hence the name for this kind of navigation. In order to avoid distracting the user's attention from the road, the instructions are usually presented not only textually or visually through monitor displays, but also aurally.

Personal Navigation Devices

These systems began to emerge in the form of Personal Navigation Devices (PNDs) which, as the name suggests, are portable electronic devices that combine positioning capability and navigation functions, primarily intended for drivers. Currently, two brands stand out: Garmin[2] and TomTom[3] [Kim11].

Both solutions provide the driver with an overview map of their current location, as shown in Figure 2.1, as well as information such as distance to the next turn and arrows illustrating the next turn. They also include a Text-To-Speech (TTS) feature which instructs the driver of what they should do next in a turn-by-turn format. Other useful driver-centered information like traffic conditions and visual highway lane assistants are also supplied.

However, as researches predict the PND market to reach its peak in 2011 [Kim11] and the overtake of smartphones in navigation market in 2014 [Kim09], navigation systems taking the form of smartphone applications have been gaining popularity. As such, PND manufacturers have moved onto mobile platforms and began shifting their focus.

[2] http://www.garmin.com/
[3] http://www.tomtom.com/

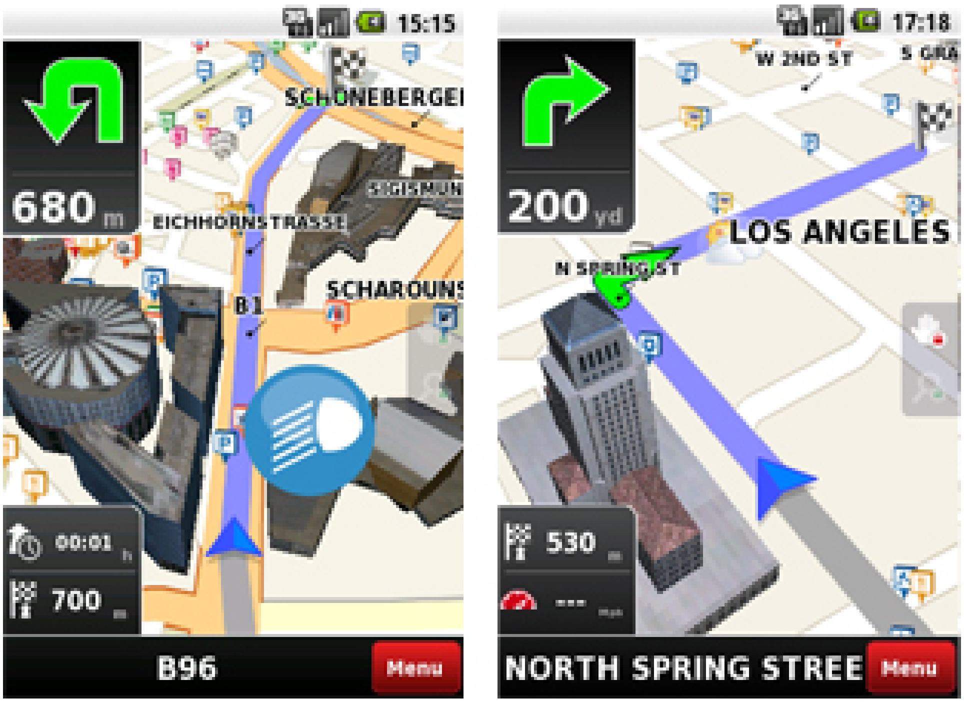

Figure 2.2: NDrive's navigation interface.

NDrive

NDrive[4], for instance, currently offers mobile solutions for most mobile operating systems, such as Android, iOS and Windows Mobile. Although NDrive's navigation style is very similar to Garmin and TomTom's, some 3D models of important landmarks (such as city halls, football stadiums and monuments) are displayed in the overview map, as illustrated in Figure 2.2. However, these landmarks are not in any way accounted for in the instructions given to the driver.

AlzNav

A noteworthy turn-by-turn solution focused on pedestrian navigation is AlzNav[5]. Developed by Fraunhofer Portugal[6], AlzNav is a monitoring smartphone application focused on older adults and persons with mild dementia, with a strong navigational component.

This solution tackles several problems related to the dementia syndrome in general and Alzheimer's disease in particular, such as spatial disorientation, decreased navigation skills and wandering behaviors. It allows the patient's caregiver to define the patient's safe zone as a graphical representation on top of a map view. When this happens, the caregiver

[4] http://www.ndrive.com/
[5] http://alznav.projects.fraunhofer.pt/
[6] http://www.fraunhofer.pt/

Figure 2.3: AlzNav's navigation module.

may be alerted through text messages, as well as the user himself by means of ringing and vibrating alarm. In these cases, the patient may either call his caregiver, friends or even a taxi for help.

The patient may also be guided back home through the application's navigational capability. This module makes use of the Google Maps Directions API, further described in Section 2.1.3, to obtain the directions needed. Throughout the navigation, the application extracts the following information from the API resources:

- the address of the patient's current location;
- the address and GPS coordinates of the next waypoint;
- the distance to the next waypoint.

This information is then presented to the user as seen in Figure 2.3. Having pedestrian users in mind, the way the information is presented was adapted to their needs. At the start of the journey, the user is immediately presented with a green arrow pointing towards the first waypoint (or decision point), as opposed to driver-oriented navigation systems where the user should start moving before the device obtains his current orientation and is able to point towards the right direction. This system is able to retrieve not only the patient's current location through the GPS receiver, but also his orientation resorting to the device's compass and gyroscope.

iWander

iWander [SDT10] is an Android application that aims to solve problems similar to those of AlzNav's, namely, the wandering behavior in dementia patients. By collecting data from the device's GPS receiver, user feedback and stage of dementia, the application determines whether the patient is displaying a wandering behavior. If so, iWander takes actions such as notifying caregivers, calling an emergency number or navigating the patient back to a safe location. In this last case, the application audibly prompts the user offering directions and uses Google Navigation API and Google Voice recognition to enable the navigation. This resource also allows to obtain the address of the patient's current location to be sent to a caregiver by reverse geocoding his GPS coordinates. However, unlike AlzNav, no special considerations regarding navigability for pedestrians were taken.

2.1.2 Landmark-based navigation

Landmarks, in the context of navigation, can be described as conceptually and perceptually distinct locations [HJ85]. These could range from bridges, traffic lights or parks to supermarkets, restaurants or city halls.

Although it has been shown that a well designed turn-by-turn navigation is the most suitable for drivers [Bur98], Andrew J. May et al. [MRBT03] demonstrated that the same cannot be said about pedestrian navigation and that landmarks play an essential role in this context. The authors led a requirement study with the purpose of gathering information requirements for pedestrian navigation or, in other words, "what information they [the pedestrians] need and how it is used".

In this experimental study, after being shown/walked through a series of routes, participants were asked to pinpoint the information they felt were crucial in order to achieve a successful navigation.

Based on the premise that a good environmental cue should be pertinent in the pedestrian's cognitive map[7] and/or visually prominent, two groups were formed: the cognitive map group and the walkthrough group. Both groups were given the task of recording instructions to enable a pedestrian unfamiliar with the area to navigate through a given route. The cognitive map group were given a schematic map (with just the information needed to understand the route) of a complex route and had 30 minutes to take notes and record the instructions. The same map was given to the walkthrough group who physically walked the route. Additionally, all participants filled in a questionnaire regarding pedestrian navigational habits among other details.

In order to identify the most useful information to be used in a pedestrian navigation context, this information was divided into the following five categories: distance,

[7] A cognitive map is an acquired spatial representation of the environment, upon which wayfinding decisions are made [MRBT03].

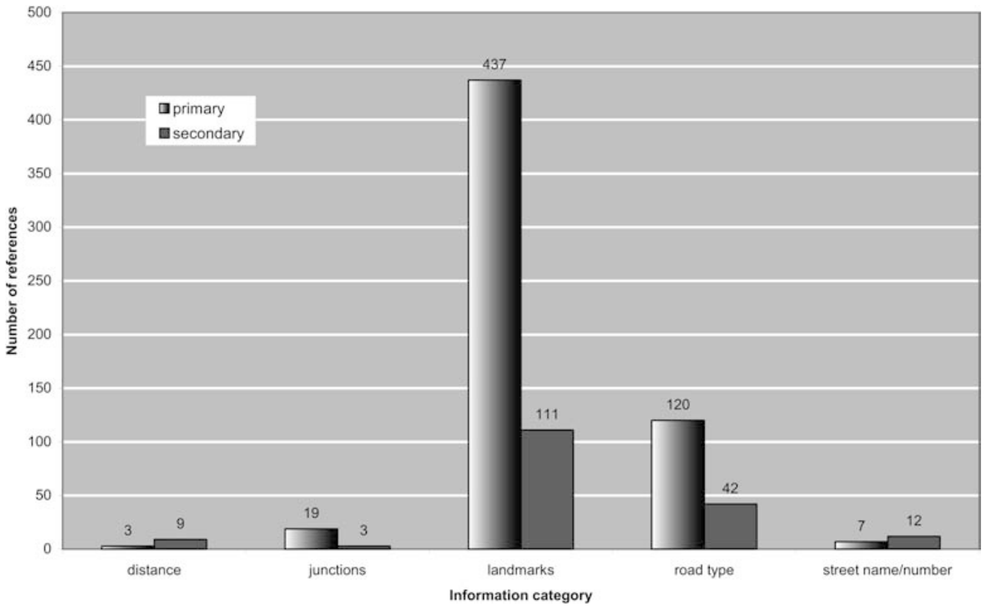

Figure 2.4: The use of general information categories such as primary (required) or secondary (redundant) information [MRBT03]

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junction, road type, street name/number and landmarks. In order to understand *how* this information was used, its context was categorized as follows:

- **preview information** — or preparatory information, was that used to inform the pedestrian that he is approaching a decision point;
- **identify information** — its purpose is to pinpoint an exact decision point;
- **confirm information** — is used to assure the pedestrian that he had successfully performed the instructed action.

Furthermore, information was also classified as either primary - extremely necessary in order to enable the pedestrian to reach his destination - or secondary - redundant information that is not strictly necessary, although it may help the pedestrian.

The study results, shown in Figure 2.4, demonstrate a high reliability on landmarks for guiding pedestrians to their destination, being the most used as both a primary source of information, with a 75% frequency rate, as well as secondary, with a 63% frequency rate.

Among these landmarks, it can be seen in Table 2.1 that shops, pubs and supermarkets are the most referenced landmarks, having been described as visually prominent and with recognisable logo. The fact that these are located on the pedestrian route also favours their usefulness, as opposed to Shopping precincts, for example.

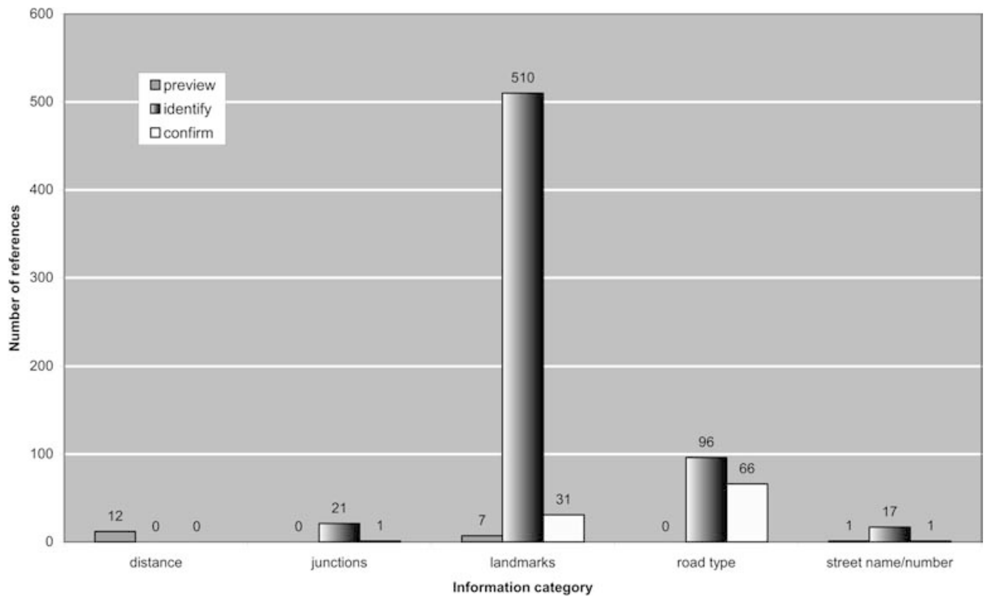

Figure 2.5: The use of information for preview, identify or confirm purposes [MRBT03]
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Moreover, Figure 2.5 shows that landmarks are most important for identifying purposes - e.g., "turn left at Sainsburys" -, although they still carry significant meaning for confirmation purposes - e.g., "turn left, the Lunn Poly is then on your right hand side".

The findings of May et al. are that the frequent use of this kind of information is due in part to the traditional usage of landmarks to help provide navigation directions, i.e., directions given by a bystander on the street often include references to landmarks such as "turn left past the supermarket".

Although distance information and street names are easy to obtain and are stable over time, the study results also reveal that these are infrequently used and do not support basic human navigation strategies. This fact is explained by the inherent difficulty humans have in judging distances.

In addition, results also show that information is not only needed when arriving at decision points, but approximately one third of the instructions were given *along* paths from one decision point to another. This brings to light the need to inform the pedestrian throughout the route in order to preserve his confidence, orientation and trust in the given instructions.

As pedestrian navigation became a prominent concern, a need for a more suitable navigation arose.

Tscheligi et al. [TS06] consider three prerequisites that must be met for a navigation solution to be suitable for pedestrians:

Table 2.1: References to the most frequent landmark categories [MRBT03].

Landmark category	**Number of references**
Shops (general)	60
Pubs	55
Supermarkets	52
Traffict lights	45
Parks	39
War memorials	34
Pelican crossings	34
Car parks	29
Shopping centre	23
Restaurants	20
Shopping precinct	20
Town hall	20

- integration of landmarks as a means of navigation;
- consideration of the context of use;
- yielding of content beyond navigational information.

According to the authors, the context in which pedestrians might need a navigational aid must be taken into consideration. While drivers are mostly focused on one task alone, pedestrians usually perform several tasks throughout journeys. Also, users might not always be able to hold the device with their hands as they might be carrying luggage or using other devices or tools. AlzNav's ability to point towards the next decision point at any given moment regardless of the user's orientation, as described in Section 2.1.1, can be seen as an approach to this requirement, since in a pedestrian context, the user doesn't always face the same directions even while walking in a straight line, whereas a driver would.

The second prerequisite mentions that navigational information might not be enough for many pedestrian users. Visitors of railway stations, for example, find train schedules to be very useful information during their journeys. Hikers agree that information on shortcuts, the length of a hike and accessibility of the route (e.g., seasonal information) are very important.

Lastly, corroborating the findings of May et al., the authors also states that landmarks are the "cornerstone" of pedestrian navigation. This remark is further supported by A. Millonig and K. Schechtner:

> "Landmarks play a vital role in human-navigation tasks. It is, therefore, necessary to develop methods to include landmark information in pedestrian-navigation services." [MS07]

Figure 2.6: Example screen from the navigation aid developed in [GGKB04].

However, including landmarks in pedestrian navigation presents difficulties and challenges. The former article also acknowledges that landmarks have to be defined and updated thoroughly. Additionally, R. Sefelin et al. [SBM+05] explains that users tend to refer to the same landmarks by different names, with a few exceptions where "only bigger chains seem to have a commonly agreed name" (e.g., Starbucks). In some cases, describing a sign above a shop, such as “Snack bar with the illuminated green sign”, may be more useful than the shop’s name. The authors concluded that a combination of shop-type and a description of its sign is the optimal solution.

Applicability in a dementia related context

Although the aforementioned studies had in mind a general audience without targeting any specific demographic group, certain audiences do, however, demand further study.

Such an example is the older population, who often find their mobility obstructed by the decrease in cognitive abilities and aptitude for performing motor activities.

Goodman et al. [GGKB04] contemplated this scenario and designed a navigational aid for handheld computers (merely as a proof of concept) which guides a user using photographs of landmarks present across a route, as shown in Figure 2.6. These landmarks were also presented using text and audio instructions.

The authors’ purpose was to study this approach on how well it fared in comparison to a standard paper-based map. 32 users (16 between the ages of 63 and 77 and 16 between 19 and 34) were asked to navigate through two different routes, using either the device or

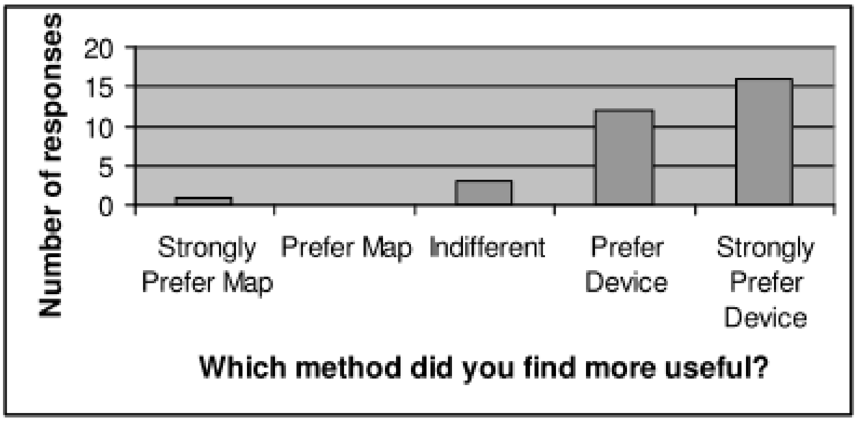

Figure 2.7: Perceived relative usefulness of the map and the navigation aid in [GGKB04].

the map. The experimenter, following the subject a few steps behind, took written notes on navigation behavior and measured the time taken to travel the route and the number of times that participants got lost.

Additionally, the subjects filled in a questionnaire on the device or map in order to ascertain how they felt about the employed methods, whose results can be seen in Figure 2.7. The majority felt the device to be more useful than the map. The most commonly given reason was the supply of images of landmarks which helped the participants confirm where they were and/or where they should go.

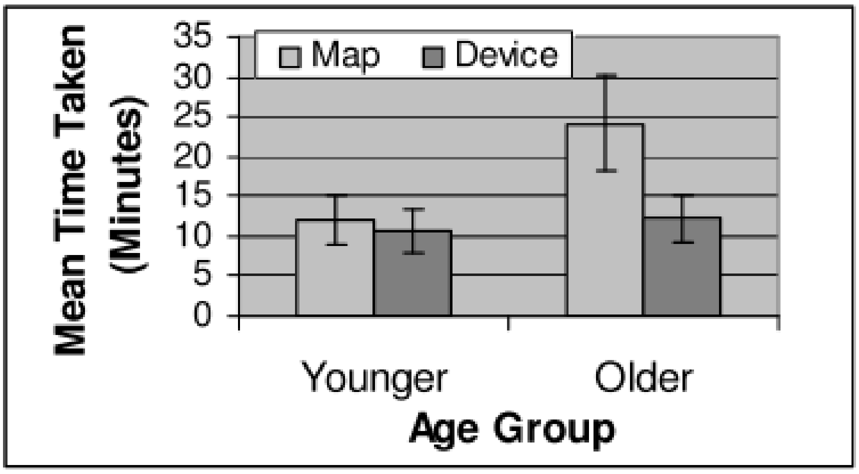

Figure 2.8: Mean time taken to navigate test routes (error bars show standard deviation) in [GGKB04].

In addition, both the younger participants and the older ones showed improvements in the time taken to reach the destination, as displayed in Figure 2.8, this being especially highlighted in the older participants.

Figure 2.9: Google Maps directions in India, 2008.

As the authors point out, this study outlines that landmarks can be used effectively to support navigation through a handheld device. Moreover, an older population could greatly benefit from this device who, unexpectedly, had little difficulty using it.

Pratical applications

Given the already established influence of landmarks, some entities haven taken their turn at approaching this subject. However, two distinct approaches will be given focus and described in detail. Google Maps India was chosen due to the underlying strong and solid foundation. Lumatic was chosen due to its audacity and innovation.

Google, for instance, added landmarks to their Google Maps India[8] [Khr09]. O. Khroustaleva explains that, although the problems behind this projects can be observed globally, they are especially highlighted in India. Information used commonly in turn-by-turn navigation, like street names, are infrequently known in India and pedestrians tend to resort to asking passers-by for directions. Due to this lack of information, turn-by-turn directions were very difficult to produce, as illustrated on Figure 2.9.

Following up on the already made research on the reliance on landmarks, Google conducted their own studies in order to ascertain how indian locals use these visual cues. With this purpose in mind, Google asked businesses how to get to their stores and recruited people to keep track of directions they gave and received, for example. This study showed that the benefits of using landmarks are explained by two reasons: they are *easier to see* than street signs and *easier to remember* than street names. Google identified three main applications for landmarks, the last two complying with the study of May et al.:

- pedestrians use them for **spatial orientation**, i.e., "Start walking away from the McDonald's" as opposed to "Head southeast for 0.2 miles";
- they are also used to **describe a decision-point** (e.g., "Turn right after the Starbucks");
- and to **confirm** the pedestrian that he is on the right course.

[8] http://maps.google.co.in/

Approaching a more efficient and human-like navigation through the use of landmarks, the results are illustrated in Figure 2.10.

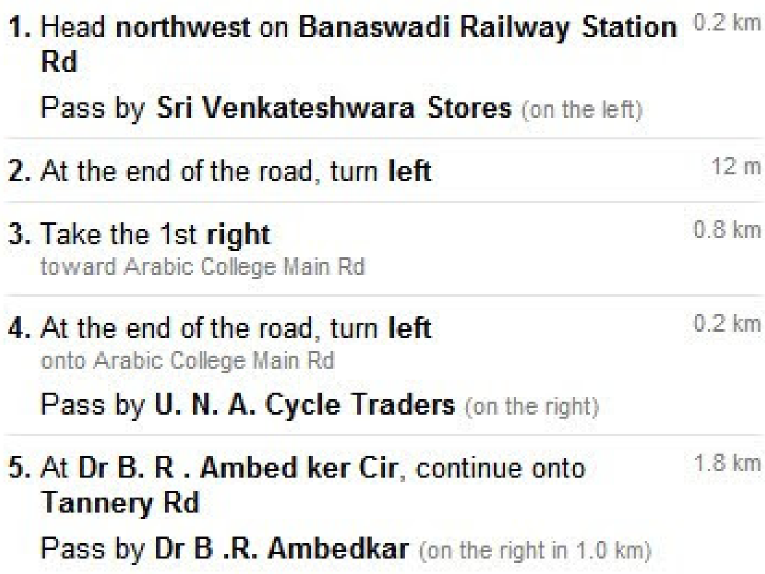

Figure 2.10: Google Maps landmark-based directions in India, 2009.

As already mentioned, Lumatic is another bold and innovative approach. Lumatic[9] is a smartphone application available for iOS and Android that navigates pedestrians, cyclists and transit riders (currently, only through the cities of San Francisco and New York City).

This application takes a very different approach from others in the usage of landmarks. The Lumatic team built photographic maps of the aforementioned cities in order to offer a photo-driven pedestrian navigation while encouraging landmark discovery. As displayed in Figure 2.11, Lumatic's routes are made of a sequence of photographs depicting several landmarks throughout the path in order to guide the user. An interesting feature is the ability to see a slideshow of a journey even before departing that allows the user to become familiar with the route.

2.1.3 APIs

As of the writing of this report, there are several APIs available for obtaining highly detailed routes between two points.

[9] http://lumatic.com/

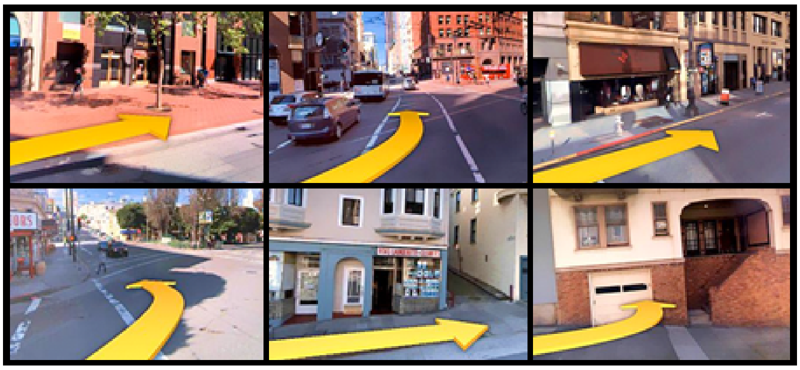

Figure 2.11: Lumatic's concept of a route.

Google Maps Directions API[10] stands out by providing developers with a wide range of features and options allowing for great flexibility for different contexts. The service features:

- selection of different transportation modes (such as driving, walking, bicycling or public transportation);
- adherence to tolls/highway avoidance restrictions;
- selection of additional waypoints that should be comprised in the route;
- selection of the unit system to use for displaying results;
- selection of the language to use for displaying results (from a total of 54 currently supported languages for the most current version of the service, v3);
- request of alternative routes;
- reliance on several means of transportation like subways, trams, buses, ferries or funiculars (for the public transportation mode).

The routes are represented as a sequence of waypoints - or decision points - through which the user must pass in the given order to reach his destination. In order to enable a finer representation of a route, Google recently included encoded polylines in their API responses. These are made of a sequence of points that represent with a higher definition a smoothed path of the corresponding set of directions.

Like the Google Maps web interface described in Section 2.1.2, the Google Maps Directions API also includes landmarks in the given directions, although this feature is currently only available in India.

[10] https://developers.google.com/maps/documentation/directions/

Google also offers a Google Places API[11], which enables the fetching of information related to places or landmarks (such as restaurants, shops or bars). Given the latitude and longitude of a place, the developer can search for nearby landmarks. Information retrieved includes address, associated events, contacts, location (latitude/longitude), user ratings, name and types. Users can contribute by adding new places through Google Map Maker[12].

MapQuest also offers a Directions Web Service[13]. Although its features are very similar to Google Map Directions', some distinctions can be made:

- it allows two different modes for drivers: fastest (quickest driving time) and shortest (shortest driving distance);
- may take timed conditions like Timed Turn Restrictions (e.g. "No right turns 7am-9am") or Seasonal Closures into consideration;
- estimates fuel usage for the driving modes based on the vehicle's fuel efficiency and the user's driving style (cautious, normal or aggressive).

Additionally, MapQuest provides two data sets: Licensed Data and Open Data. The former is a business-oriented solution that is built upon commercially updated and reliable data. It includes traffic data and accurate geocoding[14].The latter, as the name implies, is based on open data from open-source communities, being OpenStreetMaps[15] the primary source. This option offers a larger database of footpaths and bike paths as well as elevation data.

2.2 Conclusions

In this chapter, two major concepts of how humans should be navigated were explored.

Turn-by-turn navigation is a well established notion and played an important role throughout the history of navigational applications. It is by far the most popular mean of giving directions to a user, may it be a pedestrian or a driver, and relies on easily obtainable information. As such, it can be perceived as a simple way to integrate guidance in a navigation system.

[11] https://developers.google.com/places/documentation/
[12] www.google.com/mapmaker
[13] http://www.mapquestapi.com/directions/
[14] "Geocoding is an uncertain process that associates an address or a place name with geographic coordinates" [RK10]
[15] http://www.openstreetmap.org/

Nonetheless, we saw in Section 2.1.2 that turn-by-turn navigation is not the most efficient form of user guidance. A landmark-based approach has been proven to expose better results, specially in a pedestrian-centered context.

Various topics - such as what a landmark is, how and when they are useful and how do pedestrians benefit from their usage - were clarified.

Closing in on this report's focus, preliminary research regarding the applicability of a landmark-based approach to navigability targeting an older population was presented. This research shows that a handheld device with a simple design and making use of visually prominent landmarks to guide its users brings forward great results, when compared to a paper-based map.

Still, much work needs to be done regarding these topics.

Some of the studies only account for human-human interaction, i.e., how useful landmarks are when a persons instructs another on how to get to his destination. Although this can be seen as a good indicator that, for instance, a smartphone landmark-based navigation system would show similar results, this has not been yet fully explored.

The older population, in particular, has not been given sufficient attention. Although Goodman et al.'s findings suggest that a mobile landmark-based navigational aid may be useful, this approach still needs to be compared with other modern navigational means, other than paper-based maps.

Chapter 3

The Elderly: Landmarks or Turn-by-turn?

As made clear in Section 1.1, there is a need to aid and investigate increasingly better solutions to solve several common problems in an older population, especially in dementia patients. This report focuses on their mobility difficulties and adjacent problems, such as lack of confidence when going outdoors, dependency on their caregivers and the stress inflicted on both parties.

In the previous chapter, existing work has been reviewed. We have observed that, although most current navigation systems usually guide the user to his destination using turn-by-turn directions, this is not the most efficient approach to the problem; landmark-based approaches have revealed greater results in guiding pedestrians. Landmarks have been proven to play a key role in navigation regarding a general audience and studies indicate that they are also meaningful for an older population [GGKB04]. Furthermore, previous studies indicate that, even though Alzheimer's Disease (the most common form of dementia) patients have their spatial cognition ability compromised, patients are still able to retain and process information from objects relevant to navigability [KvDJ11].

It was pointed out that, although several important discoveries have been made, there are still plenty of questions surrounding us. The true impact of a landmark-based navigation system on an older population with cognitive impairments, when compared to modern turn-by-turn systems, remains illusive. This is a gap that, if bridged, may open way to further development of full-fledged navigation systems more suitable for the older population.

The present project aims to fulfil this need by developing a landmark-based pedestrian-centered navigational application focused on older adults and persons with mild dementia. This application shall be compared against existing ones that instead employ a turn-by-turn approach, through means of usability testing. May the validation yield positive results, this study may break ground for the development of more mature navigational technologies that further aim to improve older people mobility.

Chapter 4

Towards an Answer

This chapter contains the description of the solution proposed. An overview of the solution and its requirements is followed by the description of the prototype application to be developed and its key aspects. Finally, the adopted methodology to validate the developed prototype is described.

4.1 Overview

As a solution for the problem described in the previous chapter, a prototype will be developed. Concretely, this prototype will be a landmark-based pedestrian-centered navigation module focused on older adults and persons with mild dementia.

This prototype will have AlzNav (described in Section 2.1.1) as its starting point. As previously mentioned, AlzNav is an Android application aimed at older adults and persons in the initial stages of dementia. Its main goal is to increase the user's autonomy and sense of safety when going outdoors by monitoring his location - reporting back to his caregiver when needed or demanded -, aiding in requests for help and by giving the user the possibility to be navigated back home.

Presently, the navigation module relies on Google Maps Directions API to obtain a sequence of waypoints and adjacent details and provide the user with directions in a turn-by-turn format. Thus, this module will be decoupled from the application to make way for the development of this prototype. However, some components (from the interface, for example) may be reused.

4.2 Prototype Description

The prototype will collect well formatted data about a given route from existing routing services, such as:

- the sequence of decision points (as GPS coordinates) that must be traveled;
- the addresses of the stretches between each two decision points;
- the names and types of landmarks located along the route (along a stretch or near a decision point);
- distances between decision points;
- details about the maneuvers to be made at decision points (e.g., direction).

At this point, a further analysis of the existing APIs is still required.

Landmarks should then be evaluated in order to ascertain which may be useful. In Section 2.1.2, three forms of how this information is most useful were described. In order of significance: to *identify* or pinpoint a decision point ("Turn left at the supermarket"); to *confirm* that the user is on the right track ("The city hall should be to your right"); to *preview* or give advanced warning that the user is approaching a decision point ("Turn right in 50m when you see the restaurant"). As follows, landmarks located near or at decision points are considered to be very useful for identifying and previewing purposes. Landmarks located along a stretch may be useful for confirming purposes. Landmarks should also be evaluated according to their type - as an indicator of visual prominence and familiarity -, using Table 2.1 in Section 2.1.2 as a ranking reference.

If, for the generation of a specific instruction, meaningful landmarks are found, they will be used. Otherwise, information such as street intersections (e.g., "turn left at the second intersection") will be given priority. Metric distances should only be used as a last resort. This information will then be processed and, employing natural language generation, navigation instructions will be produced.

Upon generating instruction, a very important detail must be considered: *when* to deliver them. If these were to be delivered too early, they would be at risk of being uninterpretable. Too late, and they may become misleading. Thus, timing is of the utmost importance. Three factors should be taken into account when scheduling the instructions:

- the time taken to travel from the user's current position to the decision point or place where the instruction must be acknowledged (based on the user's recent walking speed average, for example);
- the time spent relaying the message audibly through a TTS system;

- the time spent interpreting the instruction - the user's cognitive impairments must be borne in mind.

After an appropriate scheduling of the instructions, they then need to be relayed to the user in a suitable fashion. The prototype will follow the same design guidelines as used in the former navigation module and throughout the application, as they have been studied and validated with the target audience and proven to be efficient [Mou11], to display the instructions visually. In addition, as already mentioned, these will also be delivered audibly through Android's built-in TTS engine. Although this engine only supports English, French, German, Italian and Spanish, custom TTS engines that support other languages (e.g. Portuguese) can be obtained from the Android Market.

4.3 Prototype Evaluation

Once the prototype attains a certain level of advancement, it will be submitted to functionality tests. These tests will be conducted with the help of volunteers (not necessarily of the target user group), who will use the prototype to navigate them through a certain route to be designated. The purpose of this tests will be to assess whether the instructions are being correctly generated and delivered.

Once the prototype reaches the desirable maturity, it will undergo a final validation process, during which proper usability test sessions will be conducted out on the field. Participants fitting the target user group profile will be selected. This profile includes:

- age of at least 65 years old, as per the commonly agreed definition of "older person" [Wor];
- possibly a dementia patient (if so, in its early stages);
- reasonable or intact motor abilities (not to be mistaken for cognitive ability to execute motor activities, which, when diminished, is one of the possible symptoms of dementia [ADF12]);

Then, they will be divided into two groups, here designated as the *turn-by-turn group* and the *landmark group*. No significant distinctions should be observed between the two groups in regard to:

- gender;
- age;
- experience with smartphones.

Accompanied by their caregivers (for safety reasons), the subjects will be led through a designated course and will rely on the prototype to find their way to the destination. All participants will be given an Android device with AlzNav installed. The *turn-by-turn group*'s devices will make use of the current navigation module, whilst the *landmark group* will use the developed landmark-based module.

Following recommendations studied in [GF91], the route to be travelled will be of a sufficiently complex nature in order to establish a meaningful navigation task demand on participants and to encourage the generalisation of the observed results. On the other hand, a too complex route, lengthwise, would tire the participants. Moreover, in order to form a safe environment, the course should have a low volume of traffic.

The goals of this validation process will be to ascertain how the performance of developed module compares to the performance of the former module, in regard to confidence of the user in the taken course and in the system and navigational errors propensity.

All participants will be asked to answer a questionnaire in order to investigate whether (1) they found the directions to be helpful/meaningful, (2)they thought the directions were clear or whether (3) they trusted the given directions. This questionnaire will comprise numeral statements employing a 5-point Likert scale[1].

Time taken to travel the route will be measured, as well as number of times that participants get lost. Although further study is required, other observational methods will be employed throughout the tests on the field. The user's confidence will be measured through (1) how often he hesitates at decision points and (2) how often he checks his smartphone for confirmation. Live feedback from the user, regarding his understandability of the given instructions, as he progresses in his journey may be required for a more detailed analysis.

Conclusions will be drawn as to the applicability and efficiency of a landmark-based approach in pedestrian navigation systems focused on older people and persons in the initial stages of dementia.

From this landmark-based approach point of view, it is expected a decrease in navigational errors frequency as well as an increase of the user's confidence that he is following the correct path and trust in the correct functioning of the navigational aid.

[1] http://www.icbl.hw.ac.uk/ltdi/cookbook/info_likert_scale/index.html

Chapter 5

Work Plan

As already mentioned in Chapter 4, the prototype will be developed using AlzNav as its starting point. Thereby, a study of the current implementation of the application in general, and of the navigational module in particular, must be performed. Particular attention will be given to the HCI guidelines originally applied to AlzNav, as these will be needed for the implementation of the prototype.

Posteriorly, in a preparation for the upcoming implementation, documentation such as a class model and interaction diagrams will be produced. A plan on how to decouple the navigation module will be elaborated, pinpointing as well what will be reused.

In an initial stage of the implementation phase, the navigation module will be decoupled from the application as planned. The implementation itself will be based on an iterative software development methodology. Agile practices such as test-driven development, refactoring, coding standards and simple design will play a major role in obtaining a high-quality prototype. As such, a continuous testing practice will accompany the development to ensure the faultlessness and exactness of the application. When a certain amount of advancement is attained, the functional tests described in Section 4.3 will be performed. Obviously, the obtained feedback will drive the forthcoming development.

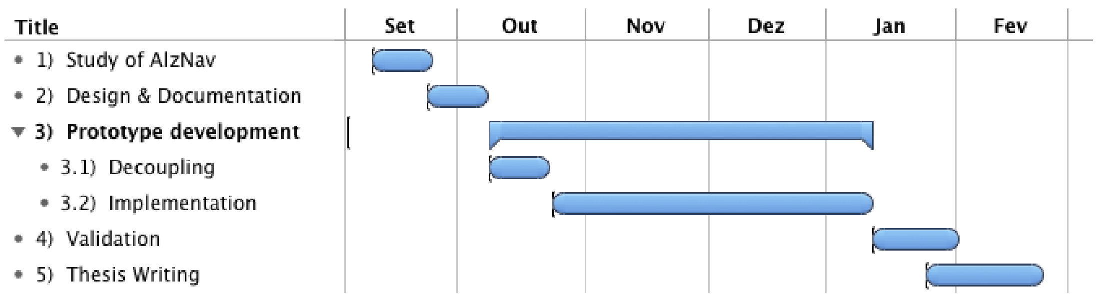

Figure 5.1: Project schedule - Gantt chart.

Closing the implementation phase, the prototype will be taken to the field and usability tests will be performed with participants of the target user group for validation purposes. Results will be gathered, organized and analyzed, leading to the drawing of conclusions.

Lastly, having developed and validated the prototype, the writing of the thesis will take place within the last month.

This project is set to start on September 10, 2012 and will finish in 22 February, 2013. The scheduling of the mentioned tasks can be seen in Figure 5.1.

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