An Orientation Service for Dependent People Based on an Open Service Architecture

A. Fernández-Montes[1], J. A. Álvarez[1], J. A. Ortega[1],
Natividad Martínez Madrid[2], and Ralf Seepold[2]

[1] Universidad de Sevilla, 41012 Sevilla, Spain
Escuela Técnica Superior de Ingeniería Informática,
alejandro.fdez@gmail.com, {juan,ortega}@lsi.us.es
[2] Universidad Carlos III de Madrid, 28911 Leganés, Madrid, Spain
Departamento de Ingeniería Telemática
{natividad.martinez, ralf.seepold}@uc3m.es

Abstract. This article describes a service architecture for ambient assisted living and in particular an orientation navigation service in open places for persons with memory problems such as those patients suffering from Alzheimer's in its early stages. The service has the following characteristics: one-day system autonomy; self-adjusting interfaces for simple interaction with patients, based on behavioural patterns to predict routes and destinations and to detect lost situations; easy browsing through simple spoken commands and use of photographs for reorientation, and independence of GISs (Geographic Information Systems) to reduce costs and increase accessibility. Initial testing results of the destination prediction algorithm are very positive. This system is integrated in a global e-health/e-care home service architecture platform (OSGi) that enables remote management of services and devices and seamless integration with other home service domains.

Keywords: Health care, dependent people, Alzheimer, service platform, OSGi, orientation service.

1 Introduction

The World Health Organization uses the term e-health to explain the relations between institutions, public health, e-learning, remote monitoring, telephone assistance, domiciliary care and any other system of remote medicine care. Each aspect of this very wide spectrum has undergone major technical improvement in recent years, however health care systems often lack adequate integration among the key actors, and also commonly fail to take certain social aspects into account which slow down the acceptance and usage of the system.

The social groups addressed by the work presented in this paper are made up of elderly or disabled people. Elderly people especially need to interact with health care services in a transparent and non-intrusive way, since their technical abilities are limited in many cases. Currently, some initiatives specifically address the training of elderly people to handle modern interfaces for assisted living [1], and elderly people are also the target of a EU project called SENIORITY [2], to improve the quality of assistance to elder people living in European residences or at home by means of integrating a quality model with new telemonitoring and telecommunications devices. Several design aspects need to be specially taken into consideration for elderly users, considering for instance physical [3] or visual [4] accuracy. Therefore, one of the objectives of the service architecture presented here is to offer a Human Computer Interface (HCI) which avoids technological barriers to elderly or disabled people.

Furthermore, there is another factor influencing the market penetration of health care services. Daily care for dependent people is often organized in two unconnected, parallel ways. On the one hand, dependent people always prefer to contact first of all their relatives and friends if they need anything. According to several studies, dependent people are reluctant to use many health care services because they do not personally know the operator or contact person in the service centre, and hence only use these services in emergency cases. Therefore, another objective of this work is to integrate these relatives and friends into the health care service provision, in an effort to increase the usability of the system.

A first scenario for the proposed service architecture addresses the mobility support for Alzheimer patients. For both these and for people suffering orientation problems or mild cognitive impairment (MCI), daily activities that require leaving the home and moving within the city or town present an important challenge, a high risk of getting lost and a certain possibility of accidents. In these situations, this group of people would benefit from personal navigation systems with simple human interfaces which would help them find the appropriate route, guiding them if necessary to their goal without configuring the system. The concrete target group in the study are the members of the Alzheimer Sevilla association (http://www.alzheimersevilla.com) that have provided the requirements and supported the tests.

The main objective of the service designed for this scenario is to develop a system that enables, in open areas, the detection of lost or disorientated persons suffering from Alzheimer's in its early or intermediate stages, or from similar psychical problems. Potentially dangerous situations can be prevented with the assistance of a system with a follow-up and intelligent navigation functionality which is able to distinguish the moment at which a patient loses orientation and can therefore help him reach his destination.

The next section presents the state of the art and introduces the proposal. The general service architecture of the system is then presented, and the orientation service is described in detail. Finally, some results and conclusions are presented.

2 State of the Art

The capacity of orientation and path-following of both humans and animals has been thoroughly studied [5] [6] [7]. Navigation or "wayfinding" systems have evolved from textual descriptions to 3-D interfaces with audio [8]. For persons with reduced or no sight, these types of systems have advanced considerably, with work such as [9], although these systems are commonly centred on navigation within interior areas.

Furthermore, the consequences of mental disabilities in learning and following paths have been studied [10], as well as the problems people have when trying to use public transport [11]. These orientation problems affect the independence and social life of these people. Considerable medical research suggests that one of the best ways to prolong their independence is to help them complete their daily routines. Several papers address the reorientation of people with mental disabilities in open [12] and in closed areas [13].

In this paper, a reorientation system for open areas is presented with the following characteristics: System autonomy of approximately 24 hours; self-adjusting interfaces for simple interaction with patients based on predictions of destinations to support decision-making; easy browsing through simple spoken commands and photographs, and independence of GISs (Geographic Information Systems), due to their high cost which would reduce accessibility. Instead, web planners such as Google Maps or Yahoo Maps are used, and are complemented with information about public services such as buses, trams or trains.

Moreover, this system is going to be integrated in a global e-health/e-care home service architecture. Several approaches address the integration of home-collected/monitored patient data and the use of mobile devices to view the information or receive alerts, like [14]. In the related work, several monitoring sensors form a body network on the patient or user and communicate with a base station to store the information, which can be visualized by the patient or by the medical personnel with a PDA. The approach has some commonalities with our work, in the sense that several monitoring data can be recorded and stored, but we use a service platform (OSGi) that allows remote management of services and devices (relevant if the users have no special technical knowledge) and seamless integration with other home service domains (like communication and audiovisual), with the purpose of allowing a direct participation of relatives and friends in the e-care services.

3 E-Care Service Architecture

The proposed service is part of a general e-health and e-care service platform, whose architecture is depicted in Fig 1. The general scheme is divided into three environments: the home of the dependent person, the home of one (or several) relatives or friends, and the medical/care centre. One of the main goals of this service architecture is to involve trusted people as well as professional people in the care activities.

In the home of a dependent person, several networks and devices can exist: medical, audiovisual and automation networks with different devices connected by wire or wireless to a residential gateway (RGW) with an embedded OSGi framework. (de facto standard for services in home, personal or automotive gateways). Heart-rate and blood-pressure monitors, and blood glucometers are examples of integrated devices in the medical network. The automation network includes sensors and actuators, for example light sensors and heating actuators. The audiovisual network typically includes a television, an IP camera or a webcam with microphone, necessary for the dependent person to communicate with relatives and carers. The residential gateway is able to physically interconnect all networks and devices, and to host the different services which can be managed remotely by the care service provider and/or by relatives or friends. The environment in the home of the relative only needs the audiovisual network for the communication, while the Medical/Assistance Centre requires servers to store the medical data. Medical staff and carers access information and communicate with the dependent person via PCs with audiovisual capabilities.

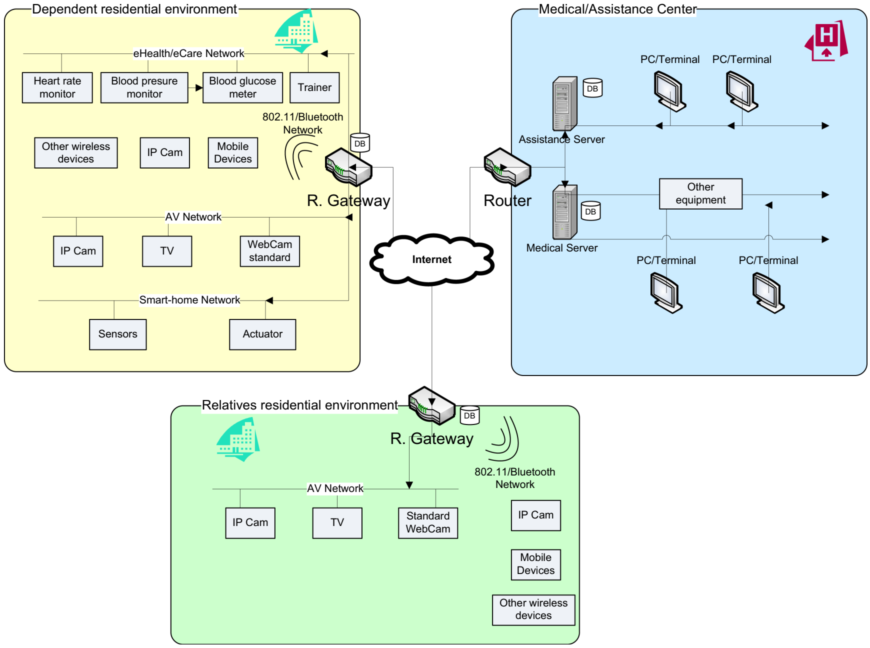

Fig. 1. General architecture of the e-care system

If the dependent person is outside the home, the same architecture applies, the gateways being a mobile phone or PDA. External communication takes place through GPRS/UMTS/Wi-Fi, and communication with the PAN (Personal Area Network) is carried out via Bluetooth or infrared (for instance, with a pacemaker). The services may use the audio and video facilities of the mobile device.

4 Orientation Service: *InMyOneWay*

The following scenario illustrates the orientation service that is presented in this paper. Pedro is 68 and suffers from Alzheimer in an early stage. Although he still has enough cognitive faculties to live alone, his family is afraid that he may get lost on the street and be unable to find his way home, so he is using the *InMyOneWay* system.

Unfortunately, one day Pedro loses his bearings and gets lost. Although he is on one of his usual routes, he is not able to recognize where he is. In his anxiety, he cannot remember that he is wearing an intelligent device, but after some instants of wandering, the device detects a strange behaviour pattern inside a known route. It automatically sends SMSs to relatives, indicating the exact position and a description of the behaviour. After one minute, no relative has called Pedro, therefore the device itself vibrates, and Pedro picks up the terminal. It shows four pictures: two of destinations where the system predicts that he is going to, and other two of his closest reference places, and tells him with text and voice to choose where he wants to go to. Once Pedro has chosen one of them, the orientation service specifically indicates how to reach it, using simple instructions and pictures of the places where he is walking. Shortly after reaching the reference place following the indications, his daughter phones asking whether he wants to be picked up, or if he knows where he is and does not need help. After the fright, Pedro prefers to be picked up, which is quite easy, as his daughter can check the street and house number closest to his position.

The functionality and data are distributed between the mobile device itself, the residential gateway, and the Internet (Fig. 2). The business logic and the information about the routes are in the mobile device. Connections to the network are sporadic to update information about the places along the usual routes of the user. These periodical updates are carried out using the residential gateway, which uses information coming from the Internet about public transport and services, traffic information, street repairs affecting the routes and new pictures of the area. Furthermore, the residential gateway processes the data to make it accessible to the terminal via Web services.

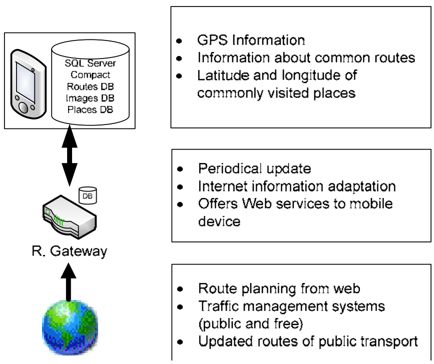

Fig. 2. Service function and data distribution

This architecture places most processing in the mobile device which needs to periodically recover the GPS position, calculate distances with the routes in the database, predict the destination and use pictures for navigation. Nevertheless, there are many devices allowing these computation and communication capabilities for a reasonable price, since the trend in the mobile phone market is heading towards a fusion between PDA and phone devices, handled with one or two hands, with high resolution screens and several communication interfaces.

We interviewed the people responsible for the Alzheimer Sevilla association (http://www.alzheimersevilla.com) to obtain the requirements for the devices. These devices should (1) be small and light enough not to annoy the carrier, (2) not attract attention to prevent theft, and (3) provide interaction that is simple and almost without buttons since people with Alzheimer find complex devices difficult to handle.

An HTC P3300 terminal was used, integrating the GPS, phone and PDA functionalities. This device fulfils the first two requirements. To improve the HCI, the picture-based interface previously described was used, as shown in Fig. 3. The photographs were not taken with the intention of being a part of a subsequence of images to give route directions, like in the studies of [15].

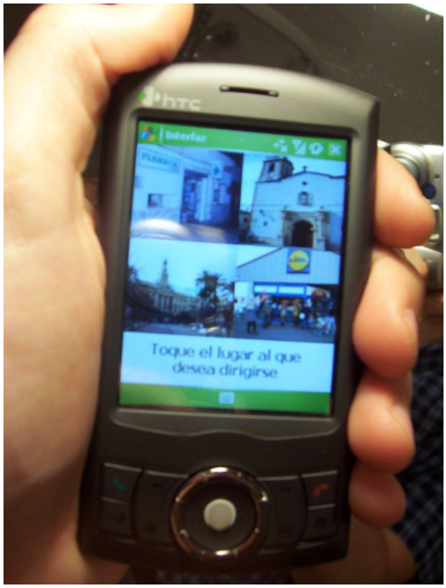

Fig. 3. HTC P3300 with Adaptive Interface

The complete functionality is based on several sub-processes:

1. Positioning. Through the integrated GPS chip, the receiver obtains the latitude, length and height once every second (configurable period).
2. Destination prediction. With the cumulated positioning data and the device databases, the most probable destinations of the user are calculated.
3. Lost detection. With the information of the detected destinations and current route, several patterns indicating disorientation situations are examined.
4. Navigation. Once a disorientation pattern has been detected, a communication with the user is established in order to offer pictures and instructions that allow him to regain his orientation and reach the desired destination.
5. Communication. When risk situations are detected, and taking into account that a fundamental requirement is to use simple interfaces and even to avoid interfaces for certain users, the communication capability of the device (GSM/GPRS) is used to make calls or send SMSs to relatives or carers without the need for the user to write anything.

5 Previous Experience Modelling

In order to retrieve information on the daily activity of the Alzheimer patients when they are outside it is necessary to build a model for previous experiences of their journeys. To this end, two techniques are used: (1) Retrieval of previous routes based on a GPS device, and (2) Route generation for frequently visited places using several points of reference.

The first technique makes it possible to record past routes which accurately represent the daily dynamic of the patient. However, since this method provides no information on where the dependant can get lost, this situation is counteracted by generating routes from information supplied by the user such as data about his residential location, the stores where the dependant goes shopping, his relatives' residential locations and the medical centre where he goes if he suffers any illness.

The data about streets and numbers where these places are located was linked to the corresponding geographical coordinates of latitude and longitude (geocoding process) using existing web tools such as Google Maps and Yahoo Maps APIS.

6 Destination Prediction

A journey (or path) can be defined as a set of points with information on sequentially ordered latitudes and longitudes. Additional information can be included, such as height or speed relative to the previous point.

When adaptive interfaces based on the activity performed are to be generated, understanding where the user is heading is of prime importance. If this goal is accomplished, the man-machine interaction is successful and image selection of possible destinations is more accurate. Software must compare points from the current journey to points of stored journeys to determine the possible destinations. To study the similarity of two paths, some distance functions have been defined in order to disregard irrelevant details such as shortcuts or short deviations due to roadworks.

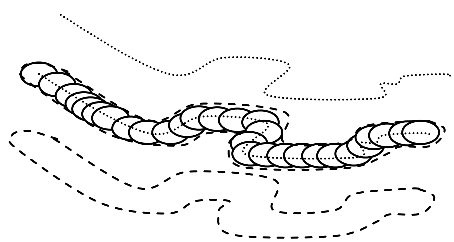

Fig. 4. Generation of the scope of a path

Scope of a path: Given a labelled path $X_{A\text{-}B} = \{ p_0, p_1, \ldots, p_n\}$ and a point q, this point belongs to the scope of the path if there exists some point of the path whose distance to q is less than a given value of δ:

$$q \in scope(X_{A\text{-}B}),\ if\ \exists j \mid dist(p_i,q) \leq \delta.$$

In this paper it is determined that δ =85 meters is an acceptable distance to consider. A point is in the scope of a path if it belongs to the generated region (see Fig. 4).

Similarity of paths: One path matches another if it has a certain percentage of points from their total that belong to the scope of the other. The similarity level is expressed in the following manner:

Given $X_{A\text{-}B} = \{ p_0, p_1, \ldots, p_n \} \wedge Y_{C\text{-}D} = \{ q_0, q_1, \ldots, q_m\}$, we define:

Similarity($X_{A\text{-}B}$ $Y_{C\text{-}D}$)=*100*(Number of qi* $\in$ *scope*($X_{A\text{-}B}$))/*m*)

Hence, given $X_{A\text{-}B}$ =$\{ p_0, p_1, \ldots, p_n \}$ ^ $Y=\{ q_0, q_1, \ldots, q_m \}$,

Y is identical to $X_{A\text{-}B}$ *if* $\forall i$, $q_i \in$ *scope*($X_{A\text{-}B}$) *then Y is labelled with the class A-B and therefore becomes a labelled path:* $Y_{A\text{-}B}$

Since the number of points of the two paths is not necessarily the same, the features are not commutative. Given X=$\{ p_0, p_1, \ldots, p_n \}$ ^ Y=$\{ q_0, q_1, \ldots, q_m \}$

similarity(X,Y)= similarity(Y,X) if and only if n=m.

Having checked the similarity index with all the representative (canonical) paths over all the points of the non-canonical path, the predicted destination in each point was obtained. The point when the real destination was predicted not being altered until the end of the path, was called **detection point**. Results were coherent with common sense: Until the itinerary did not enter in a non common area with other paths, it was impossible to distinguish where we go. Nonetheless, we also observed that although there were overstrike paths, frequently small changes taken on the paths allowed the system to distinguish the correct destination. The results (shown in Fig. 5) were very hopeful because the remaining distance to the destination measured in a straight line, on average was 69,65% of the total path and the remaining time to reach the destination was more than the 70% of the total (when the journey finally stops).

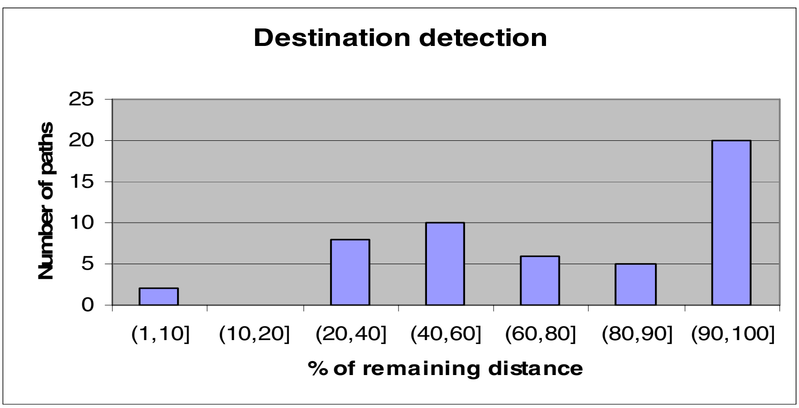

Fig. 5. On-line results of the destination detection algorithm

It was considered that a new detection point that remained stable for some meters, could be defined as a **decision point**. The spatial pertinent value seemed to be 120 meters. This value adds this amount of time and space to the decision point, being specially harmful for the paths in which the decision arrived very late (cases on the left of the graphic where the remaining distance to reach the destination is less than the 10% of the total distance path), as it causes that the arrival to the destination comes before we can predict it. In summary, the results were very positive: from the data collected about paths travelled during a month and five days, we got the actual destination in 98% of cases, after having made only 30,35% of the total path.

7 Lost Detection

In the same manner, the detection of disoriented dependants is essential to the system in order to be useful. The following situations were detected as a risk for the dependant.

- **Lost during known journeys or at known places**. When the dependant gets lost at a known place, similarity-of-path techniques are not applicable because the dependant has not left the route. Hence patterns which can show us that the dependant has got lost are required and these are defined as long delays at intermediate points which are not public transport elements (waiting for a bus is something normal).
- **Lost in new places**. When the system detects that the user is leaving a frequently used path can ask the dependant if he knows where he is going. If the answer is affirmative the system will be quiet the rest of the journey. Otherwise the dependant is offered some images of his frequently visited places.

8 Results and Conclusions

The *InMyOneWay* system is initially configured for the city of Seville and its public bus transportation service, but can be easily adapted to other cities. The system is currently in the testing phase. The pure functionality can be tested by the development team, but not the usability. The field evaluation is complicated, since the number of targeted users is reduced. Many families only realize that one of its members is suffering from Alzheimer's when he/she has already got lost and from this point do not trust them alone in the city. The ideal tester would be Alzheimer patients whose illness is detected in the early stages, or elderly people with (or without) memory problems who can make use of and evaluate the system, and obtain the extra benefits of using the scheduling capabilities of the system, such as referring to bus timetables, or exploring new routes for certain destinations.

Moreover, the cost of obtaining adequate pictures (for orientation and not for artistic purposes) to cover a complete city is very high. A Web portal is under preparation to allow the sending of pictures and video sequences of routes as a basis for a wider navigation system. Regarding the improvements in the detection of disorientation patterns, two options are being considered. One is the introduction of accelerometers and gyroscopes to detect fine scale movements and recognize strange movements which can be considered disorientation symptoms, such as turning around several times. The other option is the introduction of heart pulse sensors to help detect states of nervousness.

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