Abstract

The demographic evolution of most western developed countries show a progressive increase on population aged 65 and older. One of the consequences of this gradual ageing is the rise of expensive age-related disabilities. Elder dementia patients often get lost due to temporary lack of a sense of direction. This may put them at risk and cause their families much worry. Our project aims to provide mobility monitoring support for fast location and help in case of loss caused by elder temporary mental disabilities.

Keywords: eHealth; ageing; mobility; pattern recognition

1. Introduction

The ageing patterns of modern developed societies has led to new needs in health care. Although enormous progress in the health sciences took place in the last decades, elder groups still suffer considerably from limited mobility and reduced mental abilities. Improving quality of life of these social groups represents a
social responsibility of increasing relevance. These problems have been subject of emerging concern on information and communication technology research communities. However, none of the known concerns and proposals are focused on helping the elder in outdoor contexts, to promote their independence and confidence on their daily mobility, in cases of temporary memory loss or related mental disorders. The system described in this article intends to fill this gap, by the means of elder mobility guidance and fast location in case of loss.

LOSTE (Location Oriented System Technology for the Elder) is a mobile computing (Smartphone) based project, for users mobility monitoring and mobility patterns analysis. When abnormal user mobility happen, a first level speech based warning is issued to the user, informing about the possibility of loss and asking for the need of electronic assisted guidance or human based help. In case help is need, the system can assist the user, by the means of sound indications on how to get to the safest place in the neighbourhood (e.g. police station), by the means of electronic alert initiation for relatives to provide assistance (sound pre-recorded messages used in software controlled phone calls, text messages, etc.), or ultimately by the means of local authorities electronic alerts initiation (SOS services).

LOSTE components consist on a mobile software application including a set of helper applications that collect, store, process and analyse user geo-referenced location data. Classification is supported by a logistic regression model [1-2] as the basis for the prediction of abnormal mobility patterns. Simulation and implementation was done with R statistical software package [3].

2. Introduction

European Union concerns on so called Ambient Assisted Living (AAL) lead to the creation of important European scale policies, devoted not only for improving the treatment of senior citizens but also for their social inclusion as an important asset, vital to the well-being of Europe’s economy and society.

Inclusion is the watchword associated with these policies, which originated several programmes and respective projects [4].

As an overview of the developments within European projects in this area, we present in Table1 some representative projects.

Table 1. Senior citizens and AAL centred European projects

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full title</th>
<th>Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLDES [5]</td>
<td>Older people’s e-service at home</td>
<td>Vital signs</td>
</tr>
<tr>
<td>CAALYX [6]</td>
<td>Complete Ambient Assisted Living Experiment</td>
<td>Vital signs, Fall sensor</td>
</tr>
<tr>
<td>ENABLE [7]</td>
<td>A wearable system supporting services to “enable” elderly people to live well, independently and at ease</td>
<td>Vital signs, Fall sensor</td>
</tr>
<tr>
<td>SHARE-IT [8]</td>
<td>Supported Human Autonomy for Recovery and Enhancement of cognitive and motor abilities using information technologies</td>
<td>Motion system</td>
</tr>
<tr>
<td>EASY LINE + [9]</td>
<td>Low Cost Advance White Goods For a Longer Independent Life of Elderly People</td>
<td>Home control</td>
</tr>
<tr>
<td>PERSONA [10]</td>
<td>Perceptive Spaces Promoting Independent Ageing</td>
<td>Support daily activities</td>
</tr>
<tr>
<td>ESBIRRO [11]</td>
<td>Enhanced Sensory Bipedal Rehabilitation Robot</td>
<td>Motion system</td>
</tr>
<tr>
<td>COGKNOW [12]</td>
<td>Helping people with mild dementia to navigate their day</td>
<td>House alerts</td>
</tr>
<tr>
<td>LOCOMOTION [13]</td>
<td>Location-based mobile phones applications for independent living of disabled and elderly citizens</td>
<td>Location system</td>
</tr>
<tr>
<td>ELDER CARE [14]</td>
<td>Elder Care Architecture</td>
<td>Vital signs, Fall sensor, Location system</td>
</tr>
</tbody>
</table>
LOSTE is a part of the Elder Care Architecture project [14] that is composed of three additional modules: local monitoring, control centre and virtual leisure room. The local monitoring will be installed at the elders home, getting vital signs and sending them to the control centre that will be responsible for setting the proper alerts and specialized help as a response to abnormal situations. Virtual leisure room module consists in a virtual room where users can meet virtually and interact, creating the basis for a thematic social network [14].

3. LOSTE

LOSTE aim is to provide a higher degree of confidence to elderly users for their outdoor daily mobility needs, guidance and help in case of loss.

In addition to the senior user actor, there is also the Responsible actor, which is the person responsible for elders assistance in case of loss. This actor is the first to be alerted electronically of abnormal mobility patterns of LOSTE elder users. He must provide LOSTE initial configuration of alerts, contacts, elder users personal data, etc. Table 2 illustrated some of the possible configuration parameters.

Table 2. Alerts configuration

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Irregular behaviour, Unsafe Zone, Night</td>
<td>Pre-recorded voice message</td>
</tr>
<tr>
<td>Medium</td>
<td>Irregular behaviour, Unsafe Zone/Night</td>
<td>Sms text message</td>
</tr>
<tr>
<td>Low</td>
<td>Irregular behaviour</td>
<td>Sms text message</td>
</tr>
</tbody>
</table>

LOSTE features are distributed along three main components to support the use cases shown in Fig. 1. The components are: the user mobile application, the responsible mobile application and the server. The user mobile application is installed on the user’s mobile device. Due to mobile devices limited resources, this component includes only a map with information regarding user geo-reference, visualization of a route to a safe destination and alerts generation in case of loss.

Fig. 1. LOSTE Main use case diagram
Two different ways of triggering the route to a safe destination feature are made available: by user explicit request; by abnormal mobility pattern automatic detection. In the last case the system notifies the mobile user that an assistance alert is going to be generated, allowing the user to cancel the alert (if it was a false alert generation). False alert events and respective conditions are recorded by the systems, for classification improvement purposes.

The Responsible (of elders care or assistance in case of need) mobile application is installed on his/her mobile device. The features of this application are:

- **Responsible** – configuration of the Responsible for elder users (add, edit, remove). Each Responsible has name, address(es), email(s), phone number(s) and safe destination GPS coordinates (corresponding to home and working addresses);
- **Elder** – configuration of monitoring features (e.g. sampling rates) and type of elder users mobility (e.g. wheelchair, vision impaired, etc.);
- **Agenda** - contains the elder users regular agenda (events, preferences, locations, etc.);
- **Zones** - configuration of zones and respective classifications (shopping, leisure, sportive, safe, unsafe, etc.);
- **Update** – configuration and synchronisation with the server, for collected data storage, backup, server data pre-processing, classification backend calculations, etc.

Mobile applications were developed for Android using Google Maps application programming interfaces.

4. **Classification technique**

The logistic model was chosen as the classification technique. It was preferred to other considered classification techniques (e.g. neural networks) due to its statistics foundations, opposite to the black box approach associate to other classification techniques (e.g. neural networks).

The logistic model is a Generalized Linear Model that presents a linear predictor (logit) defined as

$$\ln \left( \frac{\pi}{1-\pi} \right) = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p$$

where

$$\pi = P(Y = 1)$$

For LOSTE context, the Y variable only takes values 0 or 1, because we are interested in detecting whenever the elderly has a problem. Therefore, Y = 1 represents the situation when an alarm should be sent and Y = 0 the situation when such alert is unnecessary.

Each variable $X_i$, $i = 1, ..., p$, represent a location device. When some combination of $(X1, ..., Xp)$ suggests that the user is having problems (lost or hurt), the estimated value of $\pi$ should be greater than 0.5, and therefore the alert is triggered.

The $\beta_i$ parameters are connected to the importance of the respective $X_i$ variables, and represent the logit change produced by an unitary increase in $X_i$, assuming for simplicity purposes that $X_i$ has a linear effect and that no interactions between covariate $X_i$ variables are relevant. Under this conditions,

$$[ \beta_0 + \beta_1 x_1 + ... + \beta_i (x_i + 1) + .. + \beta_p x_p ] - [ \beta_0 + \beta_1 x_1 + ... + \beta_i x_i + .. + \beta_p x_p ] = \beta_i$$

(3)
as stated in [1-2].

Input variables in the system at this stage of the project are:

- **Mobility** – user ability to move (slow, fast, wheel chair, bus, car);
- **Day** – period of the day according to predefined slots/segments (dawn, sunrise, early morning, late morning, midday, afternoon, evening, night);
- **Zone** – areas and corresponding type (shopping, leisure, sportive, safe, unsafe, unknown);
- **Agenda** – deviation from the predefined/usual agenda/route (distance and delay with respect to agenda appointments coordinates and time);
- **Distance** – distance to the points of interest, usual locations and routes;
- **Location** – user current location and moves, for normal/abnormal patterns control (e.g. linear, circular patterns, etc).

5. Results

The training data for the logit model was generated based on a set of loss and normal mobility cases according to the variables mentioned in previous sections (time, user mobility type, distance to points of interest, etc.).

Hundreds of training cases representing several possible combination of variables and corresponding classification values allowed for the training of the logit model. The logit model was implemented with the statistical software package R, trained with the mentioned dataset, resulting in the following outcome:

\[
\ln \left( \frac{\pi}{1 - \pi} \right) = -1.36426 - 0.06808 \cdot \text{day}(2) + 0.12662 \cdot \text{day}(4) - 0.08115 \cdot \text{mobility}(1) - 0.08544 \cdot \text{mobility}(2) - 0.62566 \cdot \text{Zone}(1) - 0.30063 \cdot \text{Zone}(2) + 0.12896 \cdot \text{Point}(1) + 2.09727 \cdot \text{Agenda}(1) + 2.02200 \cdot \text{Agenda}(2) + 0.23463 \cdot \text{Distance}(1) + 0.34502 \cdot \text{Distance}(2)
\] (4)

Android LOSTE applications implements the logit model shown in equation 4. Logit input variables are provided by LOSTE application collected and configured data. The classification resulting from the continuous monitoring of elder users may trigger application alerts or continuous data collection actions for logit updated and permanent training.

For classification quality evaluation purposes, a testing set composed of dozens of cases, not included in the training process, were used. In this initial trial we came to a success rate of classification over 60%. Table 3 shows some testing representative cases.

Table 3. Testing examples

<table>
<thead>
<tr>
<th>Day</th>
<th>Mobility</th>
<th>Zone</th>
<th>Location</th>
<th>Agenda</th>
<th>Distance</th>
<th>( \ln \left( \frac{\pi}{1 - \pi} \right) )</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1.11921</td>
<td>Lost</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1.13172</td>
<td>Lost</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1.75033</td>
<td>Not Lost</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1.84073</td>
<td>Not Lost</td>
</tr>
</tbody>
</table>
6. Conclusions and future work

LOSTE project has been developed in the context of the Elder Care project for outdoor assistance in cases of loss, caused by elder mental disorders and temporary memory failures. LOSTE provides mobility data and user centric information for other Elder Care components and services (e.g. indoors mobility monitoring, vital signals monitoring, virtual room, etc.). Elder Care provides backend storage, backup, computing resources and overall user personal and behavioural data, coming from other Elder Care components and services.

LOSTE software prototype developed for Android includes integration with Google Maps for mobility monitoring and elder guided assistance. It also includes alert features to let the responsibles (individuals or public authorities) for assisting elder users in case of loss.

LOSTE adopted logit (logistic regression) model for classification of normal vs abnormal mobility patterns of elder users. Logit was chosen because its statistics foundations, opposite of other black box classification approaches. However, comparison of logit classification to neural networks and decision trees classification quality must be performed in future work.

The first evaluations of the classifier showed fairly high success classification rates (over 60%). In order to get higher success rates, the classifier needs to be trained with real data (instead of simulation generated data), fine tune of the classifier needs to be performed and new variables may also be introduced in the logit model (age, weather conditions, etc.) for classification improvements.

References