MyVigi : An Android Application to Detect Fall and Wandering

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Abstract—**According to the World Health Organization, nearly 35.6 million people live with dementia through out the world. These people, who often live at home, are exposed to the risk of wandering and falling. The use of a discreet monitoring device such as a smart-phone could assist them, increase their mobility and decrease the stress level of the caregivers. The objective is to implement a mobile wearable tool aimed at detecting the wanderings and falls of people with dementia or mild cognitive impairment living at home. The tool must be easy-to-use, cost effective and ethically acceptable by patients at risk and their caregivers. The selected supportive hardware is an Android based smart phone selected for its high performance and durability, worldwide availability, and low cost. The software design method is based on a participative design approach involving disabled persons, family caregivers, and health professionals. The client application uses a three-axial accelerometer embedded in the smart phone to detect falls. The smart phone is also able to detect wandering using a global positioning system. In case of alert, caregivers are automatically contacted by phone call, SMS and mail. A web site also provides them with a map of the localization in real-time. This work-in-progress paper presents the method and the technological implementation of the MyVigi application.**

Keywords-Alzheimer's disease; fall; wandering; telemedecine; cellular phone.

I. INTRODUCTION

Alzheimer's disease is the most common form of dementia. It is characterized by memory loss, slow disintegration of the personality and physical control, with manifestation of aggressiveness, wandering, incontinence, disinhibition, binge-eating, hallucination, delusion an depression[1][2]. This disease leads to an almost complete loss of independence.

Nearly 35.6 million people live with dementia through out the world[3]. According the results of the PAQUID cohort study, 61.5 % of this population is living at home in France[4]. Considering the increase of the life expectancy, the number of affected people will double in 2020 and triple in 2050.

According the France Alzheimer's Association, wandering concerns 11% of independent people and 28% of people who need occasional help[5]. They lose their way on well-known routes[6]. Falling is also particularly dangerous for them, especially because of the risk of femoral neck fracture[7]. In both risk situations, a rapid rescue is essential for a better prognostic. After disappearing, half die or get serious injuries if they are not rescued within 24 hours[8]. These facts show that the risks are important and arrive early in the disease, which is why they are a source of considerable anxiety for the caregiver.

The natural caregiver is harshly affected by this disease. In France, they spend 6 hours per day watching over their relative and the cost is 570€ per month[9]. They are threatened by exhaustion, half of them suffer from depression and spouses in particular have an excess death rate of 63 %[10].

Gerontechnology is more and more useful and appreciated for caregivers and the professionals[11]. Current tele-alarm systems provide assistance for the caregiver, in particular for wandering. The devices use a global position system (GPS) to locate the user and detect the way out of a specific area. However, these devices are costly and not much accepted because of their stigmatizing appearance[12]. Recently, work has been done to transfer this function to mobile phones. The applications Tweri[13], Ifall[14] and Iwander[15] are remarkable examples.

This technology breaches the privacy of the users. Its usage under medical control is recommended to avoid misuse[16]. The ethical dilemma is the following[17]:

- It is unacceptable to track somebody without his knowing about it.
- It is unacceptable to let somebody wander without aid.
- It is unacceptable to confine somebody to their home during months or years when he could go out with technical aid.

Although this technology is available, it is rarely used[16] [18]. The reasons are :

- Lack of knowledge of the technology by the potential user and prescribing doctor
- Ignorance of the true needs of the users
- Inadequacy between the financial cost for the users and their budget

Thanks to a user-centered approach, our goal is to provide truly beneficial results for the user with a tool that is easy-to-use, cost effective and ethically acceptable. Section II describes the 3 main phases of the project: Requirements Analysis, Implementation and Experiment. Section III describes the technology used and the methods chosen to detect falls and wandering. Section IV describes related benefits of our technological choices. During the time of writing, the prototype is still developing, and therefore, the paper is being submitted as a work-in-progress.

II. Method

We use a design framework[19] named TEMSED, which stand for 'Technology, Ergonomics, Medicine, Society, Economics, Deontology'. This framework is described as a base of health informatics[20] and models a holistic approach featuring a set of 6 consistent areas of human values to investigate:

- 'Technology' focuses on the purely technical values such as functioning and robustness.
- 'Ergonomics' puts in relation the user and the technical devices.
- 'Medicine' concerns the impact in terms of medical practice.
- 'Society' concerns the impact in terms of social practice.
- 'Economics' refers to the dissemination capacities of the device and relies essentially on its economical viability.
- 'Deontology' conforms to the respect of rights and duties of the stakeholders.

TEMSED is a general framework that provides the values we take into account during the design and the assessment. Concretely, human values described are investigated using interviews and literature analysis.

A. Requirements Analysis

The requirements analysis consists in two complementary activities: the scientific literature analysis and the interviews of stakeholders[21][22][23]. The people interviewed are persons with dementia and mild cognitive impairment, family caregivers, and health professionals. Interviews are semi directive and a comprehensive approach is used[24]. It divided into two parts: first, potential functionalities are described in order to be criticized by the interviewees. Then, prototypes of the user interface are presented and the interviewed people are asked to test it. The results of this phase are scenarios of use prioritized according their importance.

B. Implementation

The implementation consists in developing client applications for an embed device, as well as server applications to centralize data and make it permanently accessible to the family caregivers and rescue team. The development is iterative and scenario-based[21]. Fig. 1 describes architecture and details are given in the chapter III.

One of the major issues for the dissemination of the gerontechnology is their prohibitive rates for the users[18]. In order to reduce the production costs and to facilitate technology transfer, we choose an open source approach. The source produced is under CeCCIL-C license[25]. This license similar to the LesserGPL allows to include the source as component in proprietary software. Then, the share of production cost of these components is possible between industrial companies.

C. Experiment

The experiment consists in testing the system for 3 weeks. The tester population is composed of people affected by Alzheimer's disease and their natural or professional caregivers. After the experiment, people would be interviewed. The objective is to get feedback about the material to make a sociological analysis of its use. The interviews are semi directive and conducted thanks to the interview's guide used in ESTIMA[26].

III. Technological Implementation

A. Hardware

The prototyped application is designed for the Samsung Galaxy SII. The device has a dual-core Cortex-A9 processor running at 1.2 GHz and 1 Go of RAM. Its dimensions are 125.3 mm × 66.1 mm × 8.5 mm and it weighs 116 grams.

The device is equipped with the SiRF Star IV chipset for navigation with Global Positioning System (GPS). The device also is equipped with nine-axis MPU-9150 as motion tracking sensor. It associates compass, three-axis gyroscope and three-axis accelerometer. The range of the accelerometer is set on 4G, this resolution 0.1 m/s² and this rate of response 100Hz.

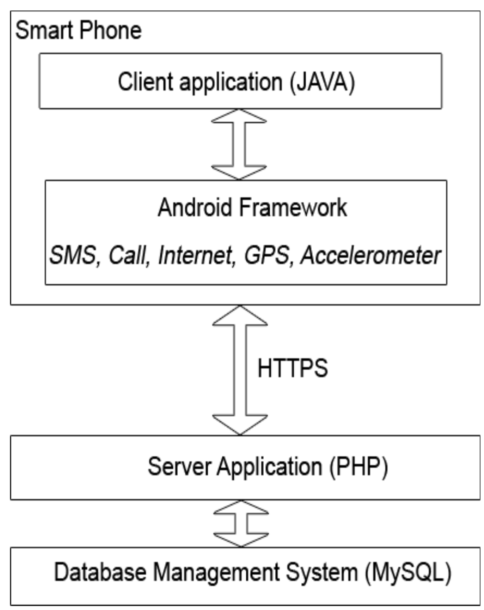

Figure 1. Architecture

B. Software

This device is built for Android, a Linux-based operating system designed for mobile devices such as smart phones and tablet computers. It also packages middleware and key applications[27]. Applications are written in Java and run on the Dalvik virtual machine. The Android service development kit provides libraries to interface with hardware

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as communication capabilities and sensors. This operating system is also the most widespread[28] and is supported by a large community of developers.

Data concerning localisations and configuration of the client is synchronised with a server application. The server is written in PHP, run on Apache server and uses a MySQL database to store persistent data. The GSM or WIFI connection is used following their availability.

C. Fall detection

In case of a fall, a simple button to press is not enough, 30% of people don't use it and stay lying on the floor[29]. Further, a rapid response increases the functional prognosis[30][31]. Therefore, an automatic system of detection is essential, and in particular for people suffering from dementia. The fall differs from the Activities of Daily Living (ADL) by the acceleration applied on the body and by the change of the position. These differences can be detected by an accelerometer in condition that the sensor is hanged close to the trunk[32].

The implemented algorithm uses android API to get the orientation and the acceleration exerted on the device. The data is given according to three orthogonal axes (X,Y,Z). The absolute acceleration (A_T) is obtained from the computation of the root sum of the square of the accelerometer's three axes (A_x, A_y, A_z).

$$A_T=\sqrt{\left(A_x^2+A_y^2+A_z^2\right)}$$

The algorithm uses thresholds and timers to detect three successive states: free fall, impact and lying position (Fig. 2):

- Free fall (T0 < t < T1): the fall starts with a free fall phase where the acceleration is under 1 G[33]. The laps of time is between 300ms and 500ms.
- Impact (T1 < t < T2): the body stroke the floor with an acceleration superior at 3 G[34].
- Lying position (T2 < t): the body stays lying with an orientation close to 90° when compared with the beginning of the free fall (T0).

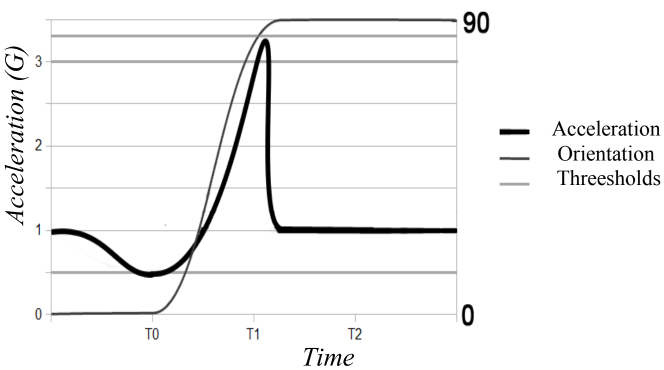

Figure 2. Fall modelling

In order to assess the sensibility of the algorithm we constitute a set of 10 scenarios summing up most of the fall[35].

The parameters taken under consideration are:

- The different sides: forward, backward and lateral.
- The end position: lying, sitting and on the knee.
- The possible quarter turning of the trunk.

The slow fall is not currently taken under consideration but will be included in the future using pressure sensors. The challenge of automatic detection is also to differentiate falls from ADL. The false positive detection is an important inconvenience that leads the user frequently to give up the system[26]. In order to decrease false positive, we set up scenarios that could provoke them. We take into account the nature of the sensors (gyroscope and accelerometer) to build these scenarios:

- Sitting down on a chair and get up.
- Lying on a bed and get up.
- Squat down and get up.
- Picking something on the floor and get up.
- Fall on the floor, lying and get up.

D. Wander detection

Wandering is a vital risk that is stressful for the caregiver. In a study of caregivers' wishes regarding technology[36], 53.3% of respondents reply “very much” to “would this technology be helpful to you ?”. According to a sociological survey[26], this technology is above all a tool to assist their vigilance. It's also essential that the system is easy to use and the detection algorithm is easy to understand by the caregiver.

The implemented algorithm to detect wandering. is based on the elapsed time when the user is outside its usual living areas. The algorithm handles :

- The living areas such home or shops.
- The time slot when these areas are possibly visited.
- The route duration from an area to an other.

This information is supplied by the caregiver from client or server applications. A timer is started when the user leaves a living zone. Wandering is detected when the timer goes past the longest duration to go to another area. If the areas take into account are the ones with a time slot matching the time of the day.

The life zones are bounded by a circle and located by latitude and longitude. The algorithm uses the Android API to track the device and check its inclusion in one of the living areas. The location with GPS consume highly the battery. Nevertheless, the challenge is to provide a system able to work as less over all day. Android offers the interesting possibility to localise the device using the identifiers of surrounding networks such cellular radio systems and wifi's. Android provides also a margin of error with Circular Error Probality (CEP) of 5%[37]. However, the accuracy is low and internet connection is required to associate network identifiers with locations.

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The implemented algorithm uses preferentially networks. The GPS chipset is used only if the accuracy is too low. The required accuracy to establish inclusion in the area depends on (figure 3):

– X: distance between the location and the centre of the closest living area.
– φ: radius of the current living zone.
– ME: margin of error (CEP < 5%).

The tracking is stopped when the accuracy is sufficient to establish the device in the area (1) or out the area (2).

$X < \varphi - ME$ (1) $X > \varphi + ME$ (2)

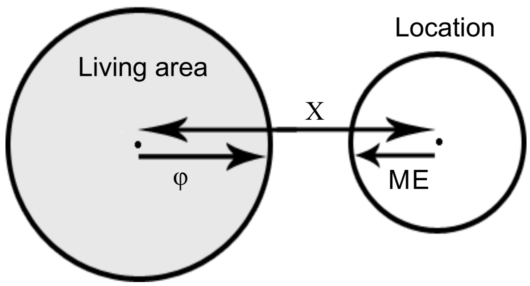

Figure 3. Detection of leaving or entering areas

E. *Alert*

The alert is activated automatically when a risky situation is detected (wandering or a fall). The user can also call for help using physical or tactile buttons. Another way to call for help manually, is to shake the phone. Once the alert is activated, the device tries to contact a list of caregivers in several ways until the alert is canceled. SMS and mails are sent every 5 minutes with the address of the last known position. At the same time, the smart-phone calls one caregiver after the other until someone responds. A map with the localization in real-time is also available on a website. The entire alert process is configurable online.

F. *Privacy protection*

The transport and the availability of personal information online such location involve risks for the privacy violation. We have followed European directives and tried to limit the risks as far as possible[38]:

- The access of personal information is password protected and can be deleted.
- The locations are encrypted with the advanced encryption standard algorithm[39] with the user password as the key.
- The locations are uploaded on the server only in case of alert. Then they are deleted.

IV. DISCUSSION

The smart phone's different communication capabilities offer several interesting possibilities. First, the internet connection allows the client application to upload data such as localization and alerts onto a single centralized database. In this way, it is possible to know more about user behaviour, and also to check whether the system is running the way it is supposed to.

The use of open format-based data and standard protocol favorises interoperability and permits the client application to add other telemedecine application. The internet connection allows it to use web services to enrich the detection of risky situations with the local weather for example. The bluetooth and wifi allow it to integrate into the system additional sensors such as a cardio frequency meter.

The choice of the smart phone as device has the advantage to not be stigmatising. However, phones are often forgotten[26]. Watch-phones are an inadequate option, because the fall detector has to hang close the waist to be effective[32]. An alternative is to use an accessory to hang the device on a belt, decreasing the chance of it being forgotten. In this way, it is always accessible, less bulky and less likely to get lost or stolen.

V. CONCLUSION AND FUTURE WORK

We ensure to match the user's need thanks to a participative design approach involving disabled persons, family caregivers, and health professionals. We also choose to support the TEMSED framework to make certain all the domain concerned by the use of the MyVigi application are investigated. The final result would be a mobile wearable tool aimed at detecting the wanderings and falls of people with dementia or mild cognitive impairment living at home. This tool would be easy-to-use, cost effective and ethically acceptable by patients at risk and their caregivers.

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