Mobile Ubiquitous System Adapted to Locate Disabled and Old People Living in Rural Areas

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***Abstract*—People who depend on others to carry out daily activities face additional issues in rural areas. The design of assistive mobile technology adapted to the specific characteristics of this environment is a promising line of work. As an example, this paper presents a ubiquitous smartphone-based system to locate dependent people living in rural areas. A preliminary prototype has already been developed, which is aimed at both dependent users and their caregivers. Additionally, a 6-month pilot test has been conducted under real-life conditions, showing positive results.**

Keywords- ubiquitous systems; location; dependent people; rural areas; smartphones

I. INTRODUCTION

The number of people who depend on others to carry out daily activities is increasing in developed societies. In this sense, their quality of life can be affected by a range of factors including type of disability, time of onset, social support structures, life history and experiences, socio-economic factors, and each individual's level of psychological resilience [1].

The proportion of dependent people is higher in rural areas, which may be explained by the prevalence of older residents in remote environments [2]. In this context, the *Rural Assistance Centre* [3] argues that dependent people who live in rural areas face additional challenges. These include, among many others, poor and badly maintained roads, difficulties with medical appointments, extreme climatic conditions for parts of the year, difficulties in communication, lack of access to medical care or lack of educational opportunities.

In view of the significant number of rural dependent residents and the difficulties to which they are subjected, the use of appropriate assistive technologies is a major priority in this kind of region. In this sense, systems based on ubiquitous computing can help alleviate these problems.

Specifically, this work is focused on location systems. Lots of location applications to assist dependent people are available [4], although most of them were designed with the assumption that their operation is confined to urban areas where there are no communication barriers. However, when used in rural environments, they may experience from a mild to severe loss in performance, resulting in an abnormal operation of the system. If this situation persists, it could probably lead to device rejection by both the users and their caregivers. Specifically, there are three main factors that can compromise the operation of the ubiquitous locators in rural environments:

a) Few technical skills of the rural residents: Calvert et al. [5] identified a significant rural-urban digital divide in the day-to-day use of common technological devices, which was also confirmed by the study of Gandiya et al. [6]. They argued that there may be several potential barriers to the widespread implementation of communication technology to a general clinic population, particularly in remote and rural areas.

b) Internet access: Large differences exist in Internet access between rural and urban areas, which results in lower quality services at higher costs among the rural population. In 2007, broadband (DSL) coverage reached an average of 98% of the population in urban areas, while coverage of rural areas was limited to just 70% of the European Union rural population [7].

c) Mobile coverage: 3G mobile networks and, to a lesser extent, the brand new 4G networks, have a high level of penetration in urban areas, medium and small villages and the major transport routes of the European Union. However, coverage is limited in rural environments: blind areas (without mobile coverage) are common, many regions have only 2G coverage and 3G is exceptionally available.

To deal with all these additional issues, this paper presents a ubiquitous smartphone-based system to locate dependent people, even in remote areas. The system is adapted to be used by low skilled users and to operate in regions with frequent blind areas. Some strategies to infer the position of the user and to detect potentially dangerous situations are currently being developed.

The rest of this paper is organized as follows: Section 2 presents some related work, Section 3 shows the general structure of the system, Section 4 describes it in detail, Section 5 presents some preliminary results, and finally, Section 6 draws some initial conclusions.

II. RELATED WORK

Wearable location systems are a well-known technological support as demonstrated by the high number of existing devices [4]. As an example, we can cite either some research studies [8-10] or commercial products [11, 12]. However, among all these systems, we could not find any location assistive support specially adapted to operate in rural areas with communication restrictions.

If we change the search criteria to include not only location systems but also any other assistive technologies, we find that the work proposed by Havasi et al. [13] is one of the few studies that incorporate an adapted version of the prototype for rural areas. They present a PDA-centred medical sensor system that is suitable for the ambient assisting living homecare scenario. The PDA has been equipped with a network layer that can provide Internet access even in rural areas. Similarly, Sasaki et al. [14] propose a Life Support Network for elderly people living in a rural area. It consists of a type of Intranet, which incorporates a safety confirmation system, a remote healthcare system, an emergency information system and other useful daily network services in the closed life area. This work is just a proposal and only two of the sub-systems have been implemented.

Apart from these few works, we could not find many more assistive devices specially adapted to rural environments, which is a clear sign that this is an emerging line of work. Another proof of this is that there are some doctoral theses being conducted on this topic, such as the ones included within the TOPs project [15].

In this sense, the lack of rural-adapted assistive devices may be explained by the traditional reluctance of rural residents towards the use of technological tools. But as the digital generations of today reach old age, this trend is very likely to reverse. Thus, it is necessary to prepare for what is to come.

III. General Structure of the System

The proposed location system comprises three different parts:

a) A ubiquitous smartphone application to be used by the dependent people: It is in charge of recording the location information, adopting strategies to ensure the operation in remote areas. All this is accomplished transparently to the user.

b) A smartphone application and a Web application handled by the caregivers: Their main objectives are to manage, in a remote way, the users' smartphone applications and obtain feedback about their locations and the potentially dangerous situations that might occur.

c) A Web server with which the other two modules of the system communicate: It performs data processing, and manages the flow of information.

A general scheme of the system is shown in Figure 1.

IV. Description of the System

The following subsections describe each one of the three parts of the system.

A. Ubiquitous application for the dependent people

The smartphone application is in intermittent contact with the Web server, which allows it to obtain updated values of the following parameters:

- The time interval at which the location function should be active.
- The location frequency.

When, at a certain date and time, the location function is active, the device takes the corresponding coordinates and sends them periodically to the server.

This is a typical operation of the location systems, but the novelty lies in the way those data are sent to the server. The application considers the case where there is no coverage and the locations cannot be sent, thus they are stored in a 'stack'. When mobile networks are again available, the whole 'stack' is sent to the Web server, which has been programmed to deal with different input data formats. Together with the locations (latitude, longitude), the exact time at which they were recorded and a field indicating whether they were taken in a blind area or not are also sent to the server.

As the application is aimed at disabled and old people, it has been designed to run in the background, minimizing interaction of the users with smartphones. Thus, their participation is limited to carrying the devices with themselves and remembering to charge them.

Additionally, notifications to the caregivers reporting on low battery levels of the devices will be incorporated in future versions of the prototype.

B. The Caregivers' Management Tools

The caregivers' management module is composed of two complementary platforms: a Web server application, which has been almost completely implemented, and a smartphone application, which is still to be developed.

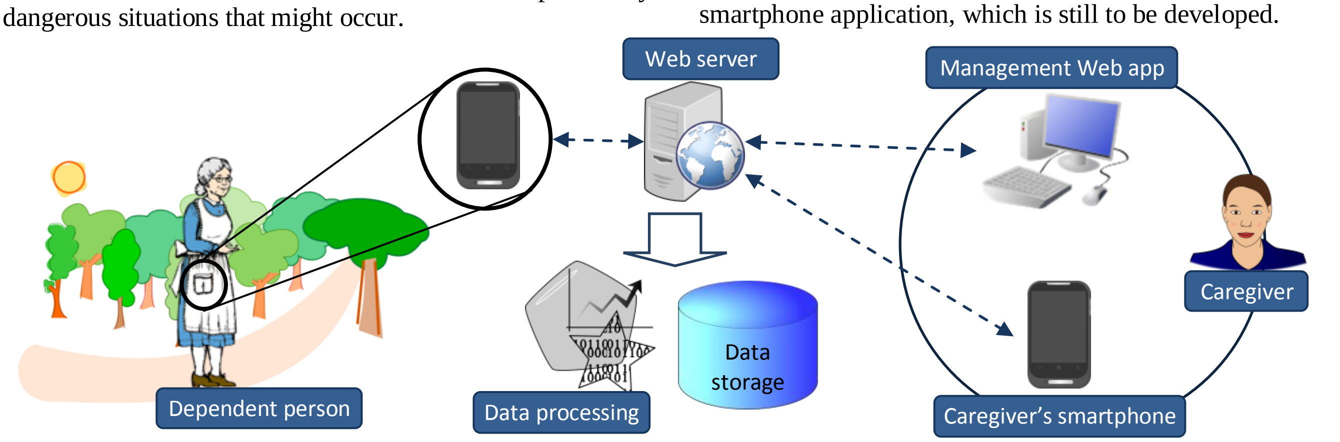

Figure 1. General structure of the system

On the one hand, the Web server application has three basic screens:

- A configuration screen to define the settings of the location function (date, time and frequency).
- A screen that displays the last location of the users on a map. It should also contain a notification area to report the caregivers on potentially dangerous situations (still to be done).
- A screen to visualize the routes performed by the users (see Figure 2).

On the other hand, the smartphone application should have a basic screen showing the current location of the dependent users. Additionally, the caregivers should receive notifications reporting on potentially dangerous situations.

C. *Web Server to Control the System*

The Web server is the central part of the system whose main purpose is to interact with the distributed applications. The Web server is composed of two different modules of increasing complexity: the storage and representation module and the processing module. The first module has already been developed, while the second part is still to be done.

On the one hand, the storage and representation module is in charge of receiving the location data from the ubiquitous applications of the dependent users and storing them in a database. It can also receive a request from the caregivers' management tools (either the Web application or the smartphone application) in order to display a specific route or location on a map. In this sense, it retrieves the information from the permanent storage and sends it back to the agent that made the request. Additionally, the transmission of the location settings, previously defined by the caregivers, to the smartphone applications of the dependent users is carried out by this module.

On the other hand, the processing module, which is still to be done, is more challenging and its main purpose is to add a further level of intelligence to the system in order to compensate for the limitations of the location function in remote areas. Its first phase will consist of training the system to obtain a pattern of the users' displacements. This stage may last for several weeks. The training dataset would be composed of the location data (latitude, longitude, time, a field indicating whether the point was taken in a blind area or not) provided by the smartphone applications. Machine learning strategies will be used for this purpose [16]. This approach is based on the assumption that dependent people usually follow similar paths during their walks. This does not mean that people have to do the same displacements at the same time every day, but it is true that their movements tend to follow a certain pattern to some extent.

Once the processing module was trained, it could provide two different outputs:

a) Estimate the position of the user: If a particular caregiver makes a request for information about the current location of a person and the smartphone application of the user cannot provide a proper response (it is in a blind area), the Web server may estimate the position of the user according to the model obtained after training. Of course, the provision of a response would be conditioned upon the previous locations fit with the expected pattern. It could happen that the Web server was not able to estimate the position (smartphone switched off, etc.), in which case it would return an alert message reporting this situation.

Figure 2. Screen of the Web application to visualize the routes on a map. The caregivers should select the target user and the date and time intervals.

b) Notify potentially dangerous situations: The Web server should send a notification to both the Web application and the smartphone application of the caregivers in case something unusual was detected (the application does not communicate with the server for a long time, the user deviates from his/her usual path, the user remains for a long time in an unusual location, etc). Figure 3 shows an example of a use case that should trigger an alert.

V. Preliminary Results

A preliminary evaluation of this first prototype has been conducted under real-life conditions. Specifically, three users were selected to wear the location application continuously during six months. Additionally, three caregivers were in charge of managing the whole system. At the end of this period, we collected the views of the two groups using the ISO/IEC 2500X (SQUARE) family of standards (under development). The SQUARE model is based on the previous ISO/IEC 9126 *Software engineering – Product Quality* standards [17], which provide a quality model for the evaluation of software products.

Specifically, as we aimed to conduct a real-world evaluation, we focused on part four ISO/IEC TR 9126-4 *Quality in use metrics*. The quality in use metrics measure whether a product meets the needs of specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in a specified context of use. This can be only achieved in a realistic system environment.

The results of the evaluation are shown in Figure 4. A value in the range 0 to 5 is provided for each quality-in-use characteristic. Both safety and satisfaction were highly valued by the two groups, while there is still room to improve the effectiveness and productivity of the system, which may be because it is still a preliminary prototype rather than a final version.

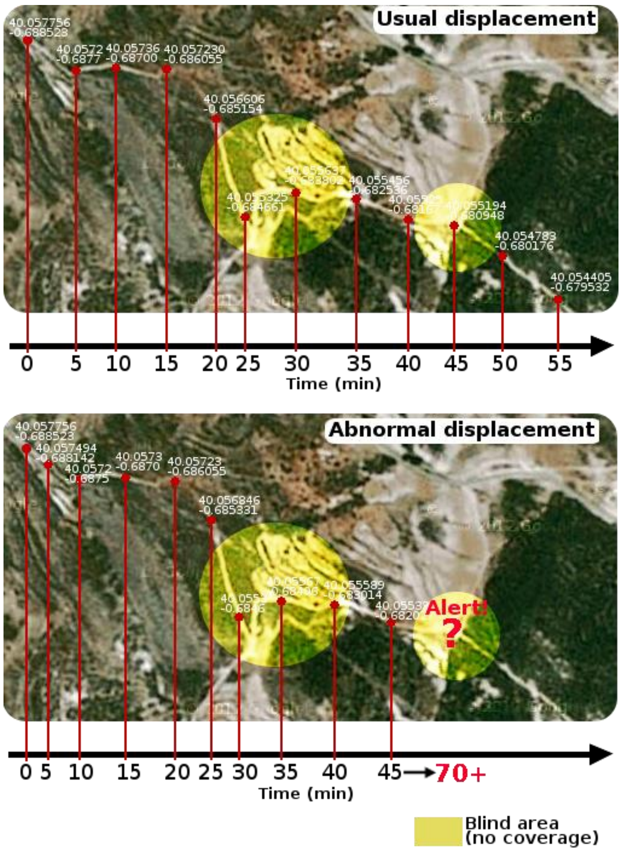

Figure 3. Use case that should trigger an alert. On top, a normal displacement pattern; On bottom, a potentially dangerous situation.

VI. Conclusion and Future Work

This paper deals with a novel topic: the design of mobile ubiquitous assistive technology for rural environments. As an example, we have presented a smartphone-based location system to assist dependent people living in rural areas. This work, which is still in progress, has been evaluated under real-life conditions. We expected that the older residents were reluctant to use the prototype, but instead it was perceived as a useful support to help them stay in their own villages for longer. But although the preliminary results are promising, the most challenging stages of the project are still to be carried out.

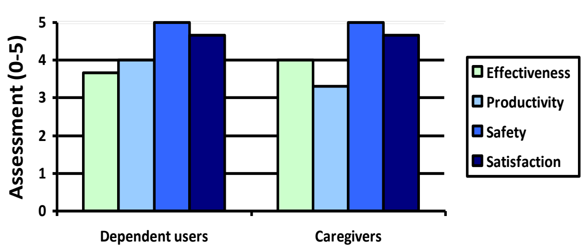

Figure 4. Preliminary evaluation of the system. The assessment of the quality in use for both the dependent users and their caregivers are shown.

In this sense, the demand for this kind of aids is likely to increase in the next decades since the digital generations of today will be the elders of tomorrow. Therefore, it is time to start preparing for the future, and the design of assistive ubiquitous technology adapted to rural environments is a promising line of work.

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