AlzRastreo: accompanying Alzheimer's patients and their caregivers

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Abstract. Spatial disorientation is one of the most characteristic symptoms associated with Alzheimer's disease. It manifests as an intense need for the person to go somewhere else, usually with no idea where. This, together with difficulties in recognizing familiar places, highlights the dangers that these patients may face. In this special degree work, the development of a multiplatform mobile application is implemented as a solution to this problem, and thus assists and improves the quality of life of people with Alzheimer's disease and their caregivers. In this sense, we developed the mobile application developed is based on geolocation and its main objective is to allow knowing the location of these patients through the location services of mobile devices, in addition to the definition of geographic areas considered safe, such as their home or work, to notify the relevant caregivers of their whereabouts in case the patients are away from a safe place, and thus provide assistance in case of a possible emergency. The mobile application proposed as a result of this work follows an adaptation of the agile methodology called Mobile-D. It is built under the Android platform, using Apache Cordova and Ionic for its development.

Keywords: mobile app, Alzheimer´s disease, Mobile-D, geolocation.

1 Introduction

Alzheimer's disease is one of the leading causes of death in older adults in the world and the most common form of dementia [1]. It is a neurodegenerative disease, characterized by beginning with a slow deterioration of memory functions, and progressively, other brain functions. As a consequence of this loss of cognitive functions, Alzheimer's disease culminates in death for those who suffer from it, usually between 3 and 9 years of diagnosis [2]. Some of the symptoms include memory loss, behavioral problems, hallucinations, delusions, and tendencies to wander, get lost, and not find your way home [3]. Although scientists continue to study the disease in search of its causes and cure, also investigations arise to provide better care and quality of life to these patients [1] - [4].

In this way, technology provides great relief not only for people who have this disease but also for their caregivers or protectors. Likewise, technological advances have led to an increase in devices and applications whose main purpose is to provide

these patients with a safer and more independent life, and their caregivers with tools that assist with the work of caring for them [1], [4], [5].

These assistive technologies promise to help with a variety of problems, including language, hearing, and vision problems, in addition to supporting these people in daily activities, offering monitoring capabilities, tracking, automated warnings and reminders, location and communication, and even social participation [6]. Those of location and communication, offer patients greater security when walking, find their way without getting lost, and it is possible for them to notify their caregivers of any emergency.

In this sense, the problem of spatial disorientation is one of the most discussed topics through technology. Although innovations regarding geospatial technologies have led to the creation of dedicated locator devices [4], [6], however, the use of this type of assistive technology can become quite expensive, especially if they are complex devices and sophisticated.

As an alternative, exist applications that use geolocation units integrated with mobile devices as a way to monitor and track the location of patients, offering solutions to patients and mainly to caregivers. However, many of these systems have certain limitations:

- They aren't autonomous and are linked to a web app that manages them
- They are proprietary software
- They haven't updated to new versions of the Mobile Operating Systems
- They don't use the map functionality for tracking patients
- Some are only available for use in developed countries.

In addition to this, in countries like Venezuela, there is a lack " (...) of a care policy for the elderly (...) When we individualize those over 80 years of age, we have a population where about 25% have some form of disability, dementia and the most frequent is Alzheimer's" [7]. This situation not only impacts the quality of life of people who suffer from the disease, but also the quality of the entire circle of their families and caregivers.

In this way, the following question arises: it is possible to have a mobile application that makes it easier for caregivers of patients with Alzheimer's to stay informed at all times of their location within safe areas, monitor several patients at the same time, generate timely alerts to through different channels to caregivers and that is not tied to limitations such as country of use and free license for download and use, as well as updated to emerging versions of the Android OS, thereby improving the quality of care they receive and your safety.

Thus, this work shows the development of a mobile application called AlzRastreo, as an alternative to the problem of spatial disorientation suffered by people with Alzheimer's disease and as an alternative to existing solutions. Specifically, in the following sections, the state of the art of mobile applications for the monitoring and tracking of patients with Alzheimer's is shown, the developed system is shown, emphasizing its architecture, the development environment, and methodology, the modules created, the tests carried out and finally the conclusions of the work.

2 State of the art

As mentioned above, there are mobile applications that use geolocation to monitor and track patients, offering solutions to patients and especially caregivers. These applications include Tweri, Alzheimer Patient - Caretaker, Comfort Zone, and Map4map.

Tweri is a mobile solution developed by the Spanish company Solusoft, which provides positional monitoring and allows Alzheimer's patients to leave the house autonomously [8]. This application allows for the establishment of safe limits, based on the maximum time that the user can be away from home, or the maximum distance radius that is allowed to be away from home [9]. Before leaving, the application must be activated, and when the maximum time or distance is exceeded, the registered caregiver is automatically alerted via email, with the most recent geographical position obtained by the device. Additionally, it has an emergency button that the patient can press at any time [9].

Tweri is not compatible with new versions of Android, is compatible with iOS, and works in conjunction with the Web application for user registration, so it is not a stand-alone application.

Alzheimer Patient and Alzheimer Caretaker are two Android applications that provide assistance services to caregivers and patients, developed as a project by the Department of Information and Communication Technology at the Prince of Songkla University in Thailand. They provide a tracking and monitoring system for users who have Alzheimer's Patients installed [10], and a notification system for those who have Alzheimer Caretaker installed [11].

Another mobile application is ComfortZone [12], [13], based on the OmniLink FocalPoint tracking software [14], which can, through GPS, find devices that can be used to locate people. If a patient leaves the pre-set area in the application, the software sends a text message or an email in a period of 2 and 30 minutes, with the location of the patient to his caregiver. The length of time depends on the follow-up plan chosen by the patient's caregiver.

ComfortZone additionally offers assistance to the patient's family through a monitoring service center 24 hours a day, 7 days a week, and the possibility of access to emergency physicians from the MedicAlert Foundation [15].

Another similar application is Map4map [16], offered free of charge, and like ComfortZone, it sends an alarm to the caregiver's mobile when the patient crosses the pre-established comfort zone.

Table 1 shows a simple comparison of some of the existing applications previously studied and analyzed, found for the monitoring and location of patients with Alzheimer's.

Of the analyzed applications, only two of them are free and free to use, two of them use maps, and all of them are for the Android mobile operating system, however, one of them, which works with maps and is free, does not work with the latest versions of Android.

From the above, the proposal arose to develop a system capable of working with the spatial location, through the device's GPS and maps, free of charge, which can send

Push notification messages to the caregiver's mobile device, text messages (SMS) and emails that include access to the patient's location map to caregivers, monitor the location of the patient in real-time and implement the functionality of the help button for the patient in possible situations of dislocation and loss.

Table 1. Comparison of some of the existing applications for monitoring and location of Alzheimer´s patients.

Application	Operating System	Functionalities	Free
Tweri	Android IOS	Location map, out-of-zone alarm, emails, stray button, emails	Yes
Alzheimer Patient - Caretaker	Android	Location map, out-of-zone alarm, emails	No
Comfort Zone	Android	Out-of-zone alarm, emails, and SMS	No
Map4map	Android	Out-of-zone alarm	Yes

3 System developed

We developed the AlzRastreo System using the Mobile-D agile methodology [17] - [19]. The solution consists of the AlzRastreo mobile application, and a web server that acts as an intermediary between the application and the database. Likewise, among the functionalities of the web server, there is also user authentication, monitoring of user databases, and sending notifications to caregivers.

Next, we describe the methodology used, and we show the architecture of the AlzRastreo System, the environment, and the modules developed.

3.1 Methodology

We used the Mobile-D agile methodology [17] - [19] which provides tools and practices that best suit the planning and design of applications, especially those projects with short development periods and with a small development team, since it especially focuses on overcoming the challenges associated with mobile developments. In Fig. 1 we show the phases of the Mobile-D methodology.

Fig.1. Methodology used. Adaptation of [18].

In the exploration phase [19], we did the initial planning and establishment of the project. In this phase, we define the requirements, scope, and development environment of AlzRastreo. In the Initialization phase, we prepare the development environment, analyze the requirements, refine the planning, and specify the AlzRastreo modules.

During the Production phase, we implemented the functionalities and requirements defined in the previous phases, including the implementation of the System. During production, we used an iterative and incremental development cycle [19], in addition to using test-driven development [18]. We used the plan-work-release process, and we repeated it iteratively until we completed all the functionalities. Our first activity was to plan the task of determining requirements, and the tasks to be carried out. Previously, we prepare the iteration tests (that is why the technique has the name Test-Driven Development, TDD [20], [21]).

We executed the tasks on working days. In the Stabilize phase, we integrated all the AlzRastreo modules and develop the final documentation of the application. Finally, in the testing phase, it was possible to evaluate that AlzRastreo implemented the required functionalities, this phase also allowed the debugging of errors in the application.

3.2 System architecture

AlzRastreo uses geospatial information, obtained through location services integrated into the operating systems of the mobile devices on which it runs. AlzRastreo uses this information to inform caregivers of the location of patients. Also, send push notifications when the patient leaves the defined safe zone so that the caregiver can assist in the event of a potential emergency.

The application defined Safe Zones, which are the geographical area with a specific radius that demarcates a real location where patients are safe. The caregivers must define these safe zones in the App, and these can be nearby areas to homes, jobs, etc.

Together with the mobile application, a Web server running in the background is necessary, whose objective is to establish a connection between the application and the central database, where the data generated by the users will be stored, as a form of monitoring. We show the architecture of the system in Fig.2.

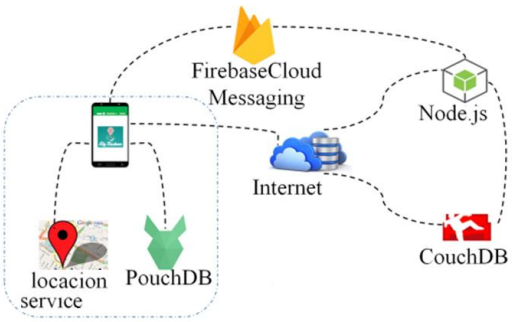

Fig.2. AlzRastreo architecture.

AlzRastreo works together with a Node.js Web server that acts as an intermediary between the mobile application and the CouchDB database. Likewise, among the functionalities of the Web server, there is also user authentication, monitoring of user databases, and sending notifications to users. The System establishes this connection to the server via the Internet and uses the phone's location services as well as a local PouchDB database. Also, the System used the Push notification mechanisms, with the server and connection to Google's Firebase Cloud Messaging.

3.3 Development environment

We developed the application using Ionic version 1.2, AngularJS version 1.4.6, and Apache Cordova version 6.5.0. We built the server on top of Node.js version 7.9.0, and the framework for Node.js was Express.js version 4.15.2. The database server used was CouchDB version 1.6.1 and for the local database of the devices, we worked with PouchDB version 5.4.5.

3.4 Developed modules

We structured AlzRastreo into 7 modules to satisfy the requirements defined in the exploration phase of the Mobile-D methodology [17]. The modules make up two planes: the Frontend, which are the user interface modules (Authentication, Patient, and Caregiver), and the Backend which covers all the internal functionalities of the application and communicates with the user interfaces. Fig.3 shows the model of the AlzRastreo System.

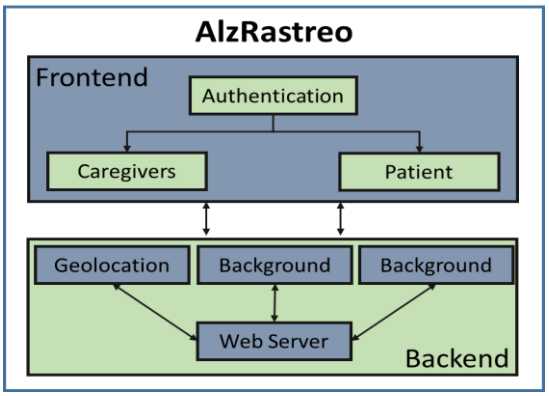

Fig.3. AlzRastreo modules.

1) Authentication: this module encompasses all aspects related to the authentication of the different user profiles in the system; from login and registration to password recovery in case it has been forgotten. Similarly, this module allows defining the types of users of the application, and how the system distinguishes them to provide the

different functionalities inherent to each type. The defined user profiles are patient and caregiver. Fig.4. shows the interfaces of this module.

2) Patient: where the system implements the functionalities and services necessary for patient-type users. It also involves the services that allow the synchronization between the local and remote databases, and the requests to the AlzRastreo server, as well as the implementation of the requirements specified in the exploration phase.

Among the main requirements implemented are the interfaces that indicate to the patient if he is geographically located within a safe zone, and screen alerts if the patient leaves a safe zone. This module also allows the patients to see their caregivers defined, as well as the safe areas defined.

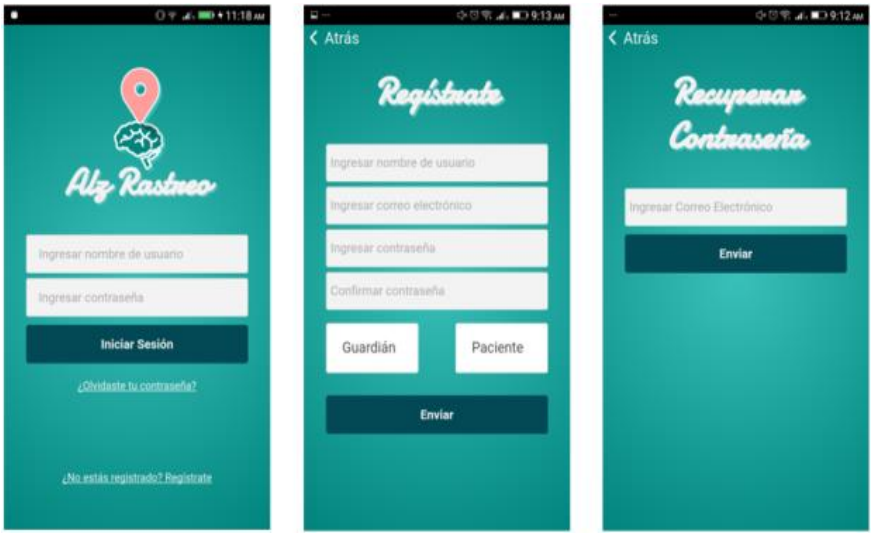

Fig.4. Authentication interface (start session, register, password recovery).

Fig.5 shows a subset of the interfaces associated with this module. First, the initial patient user interface after the authentication of the application, which will show the map with its safe coverage radius colored in purple, in case it is within this safe zone; then the initial interface of the patient type user is displayed once he has authenticated himself in the application, and he is outside some secure geographical zone.

Then the map and a notification in a red box will be displayed alerting the situation. Finally, Fig.5 shows the initial interface for the patient after he does authentication in the application, and even his caregiver has not configured safe zones for him.

3) Caregiver: in this module, we structured all the functionalities for the type of user called caregiver. Among the main functionalities determined in the exploration phase and implemented in this module are: displaying the list of patients associated with a caregiver and selecting a patient, being able to from another interface, and displaying the geographic location information of the same (a caregiver can have more than one patient in your care).

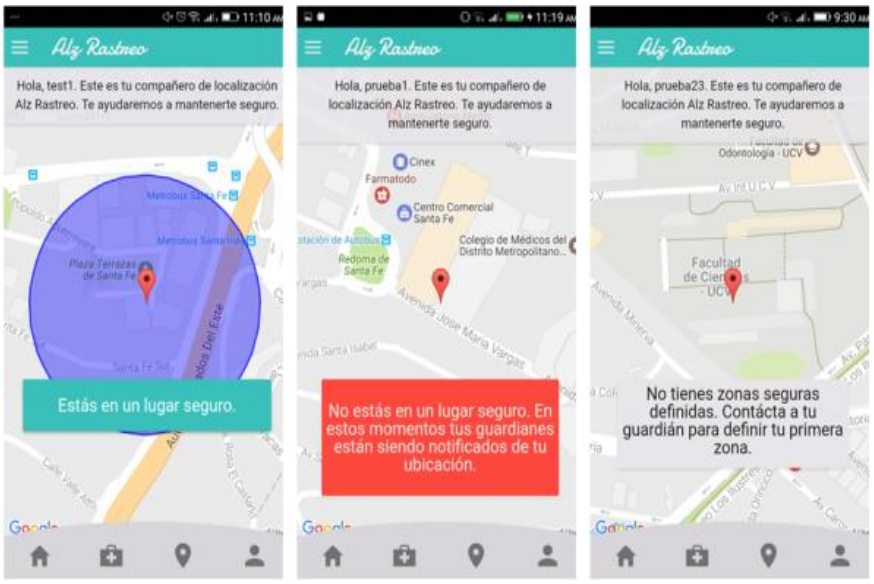

Fig.5. Start interface for the patient user (when he is in a safe zone; when he isn´t in a safe zone; when he hasn´t a safe zone defined).

Fig.6 shows the interface to select the patient and display its current location.

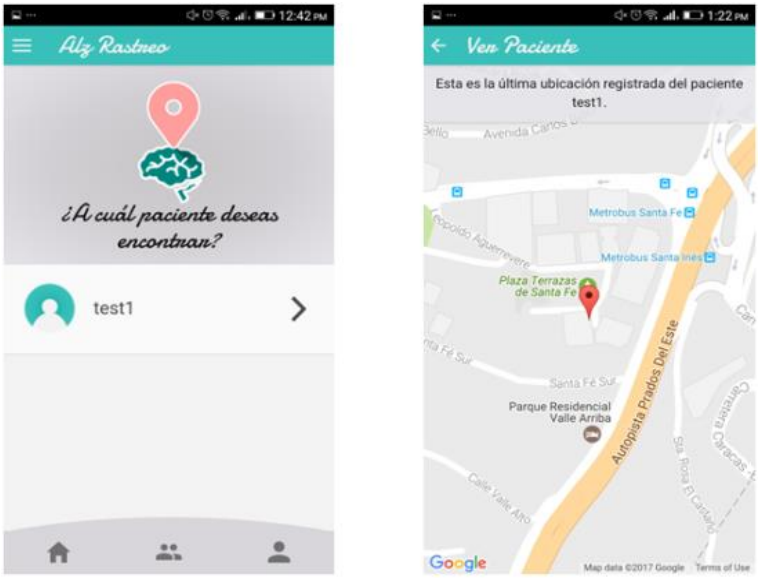

Fig.6. Start interface for caregivers where the system shows the patient list, and the patient location named test1.

Fig. 7 shows the invitations received for the caregiver to accept patients and manage the list of patients. Fig. 8 shows the administration interface for safe zones associated with a patient. Finally, in this module, it is also possible to have a caregiver with special "Primary Caregiver" privileges, who has access to a list of all the caregivers associated with a particular patient (see Fig.9) and can add or delete caregivers to that patient.

This primary caregiver can perform these actions by searching for caregivers in a special bar, which filters caregiver-type users and sends an invitation to the patient to accept it. In addition, she may assign her primary caregiver privilege to any other caregiver agreed to by the patient.

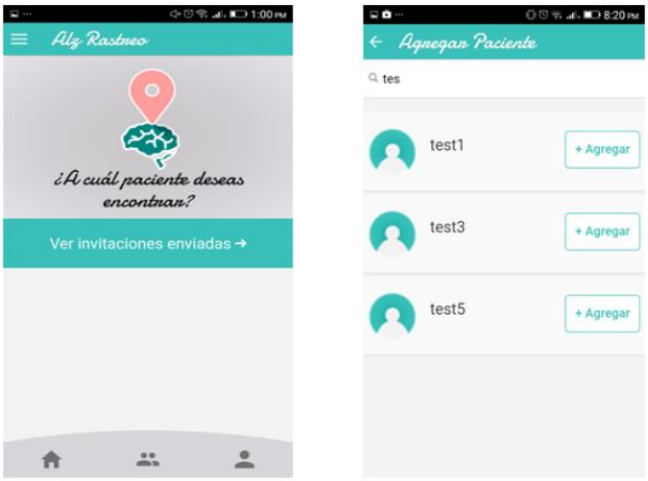

Fig.7. Caregiver's interface where he must see the pendent invitations for becoming caregiver, and the list of his patients.

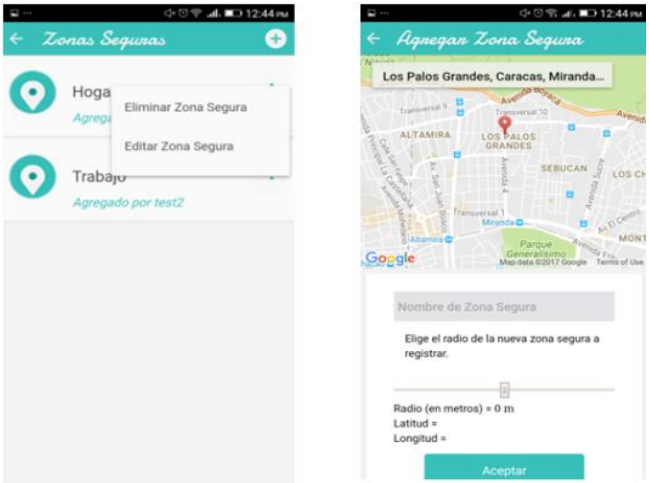

Fig.8. Caregiver interface where he must see the safe zones of his patient, and he must add new safe zones for his patients.

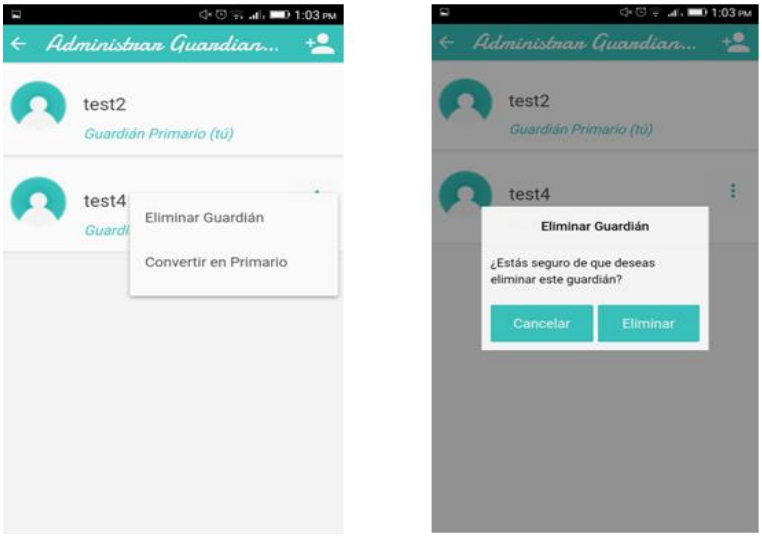

Fig.9. Interface for primary caregivers, where he must see the caregivers list related to a patient, and the erase of the secondary caregiver.

4) Geolocation: this module handles the location objects of the users obtained from the mobile device, as well as the connection with the Google Maps API for its correct display on the maps. Here, we implemented the necessary tools for the construction of safe zones through a given radius in meters (the caregiver can configure this parameter), as well as the necessary formulas to determine if given the longitude and latitude of a user's location, it is or is not within a safe zone (see Fig.10).

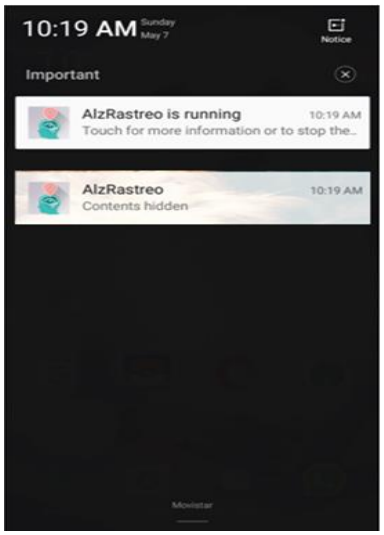

Fig.10. Geolocation interface which runs in the background in the smartphone.

5) Background: in this module, we implemented the services necessary for the application to continue running as a background process on the mobile device.

6) Push Notifications: this module involves the management of push notifications sent from the AlzRastreo server to caregivers and patients when the patient leaves a safe area, likewise, this module also involves the registration of devices for the operation of these notifications. Fig.11 shows the arrival of location notifications in the Caregiver App.

7) Web server: in this module, we implemented the web server that works as an intermediary between the requests of the mobile application and the CouchDB database server. At the same time, it also provides the necessary functionalities for the development of the events that allow the server to monitor the database updates; and in this way make the pertinent notifications. The server sends the notifications via email to the caregivers.

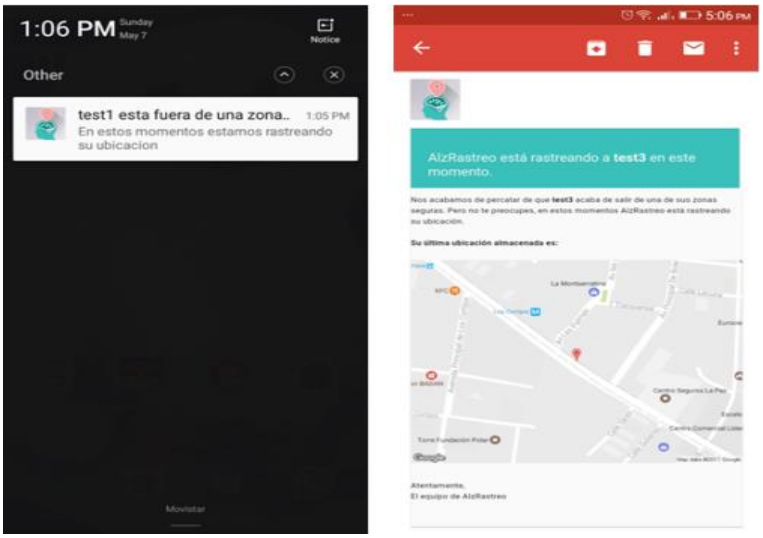

Fig.11. Push notification for the caregiver when the patient leaves the safe zone, and his location on the map.

4 Tests

The Mobile-D methodology indicates two types of tests, those functionalities and of acceptance and usability.

4.1 Functionality testing

Carried out throughout the development of the System and finally tested each one of the requirements and functionalities of the developed modules, such as user

registration, login, accept caregiver invitation, add caregiver and view caregivers (these last 3 for patient users), send invitation to the patient, search patient, add patient and view patients (for caregiver users), add, delete and edit safe zones, add caregivers to a patient and assign primary caregiver to another caregiver (for caregiver users).

4.2 Usability and acceptance test

Regarding these tests, we used a survey as an evaluation instrument, applied to 10 people from different professions. They had different knowledge in the area of computing, and especially the development of mobile applications. They were two Mechanical Engineers, two Computer Science graduates, web developers, a Chemical Engineer, and an Electronic Engineer, a mobile application developer. The other four people were two old housewives, and two students from the Central University of Venezuela.

We used the Likert scale to measure and know the degree of conformity of the users of the application. This scale evaluates each response value as follows: (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, and (5) strongly agree.

Below we show the questions of the survey

1. We present the functionalities of the application (login, register, add patient, etc.) intuitively.
2. The user interfaces are suitable for the subject on which it works.
3. You are satisfied with the functionalities provided by the application.
4. You are satisfied with the time used by the application to perform the functionalities.
5. Considers that the application uses a common language through phrases, terminology, and concepts.
6. Consider that the icons and terms used in the different interfaces and menus remain homogeneous throughout the application.
7. Considers that the design of the application is an aid and allows functions to be carried out more quickly or efficiently through the use of shortcuts.
8. Considers that the system presents help and documentation necessary for the correct use of the tools.

4.3 Results of the acceptance and usability test

After applying the survey, we obtained favorable results, which show usability and acceptance by users, as reflected in Fig.12.

The best-evaluated question turned out to be the first, where 100% of the respondents indicated that they strongly agreed. In question 2, nine people (90%) strongly agreed and one person agreed. 50%, that is, five people indicated that they strongly agreed with the third question, while four (40%) agreed and only one person neither agreed nor disagreed. The fourth question was answered by four people (40%) strongly in agreement, five people (50%) in agreement, and one neither in agreement nor in disagreement. In the fifth and sixth questions, eight people (80%) answered strongly in

agreement, and two (20%) in agreement. In the seventh question, 60% (six people) strongly agree, 30% agree, and maybe only one person neither agrees nor disagrees finally the eighth and last questions, were evaluated as disagreeing by one person, five people agreeing and four people strongly agreeing.

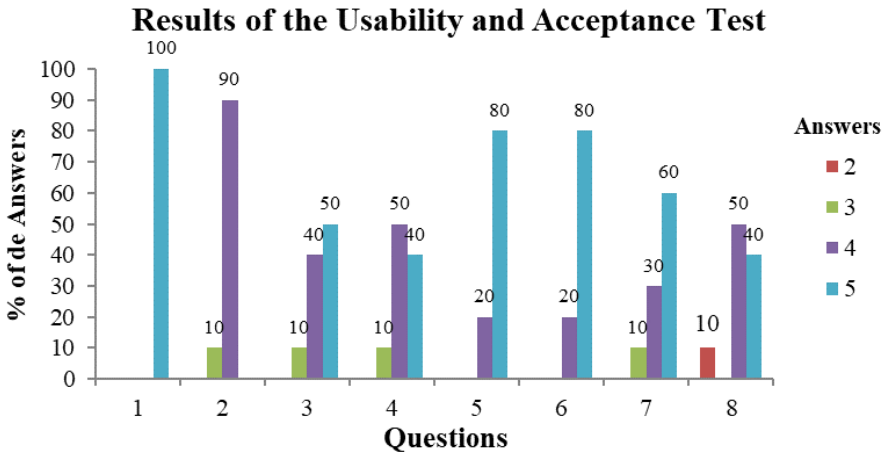

Fig.12. Results of the usability and acceptance test for AlzRastreo.

5 Conclusions

The AlzRastreo application works as an alternative solution for locating people, providing its users with more security, by avoiding the risks involved in spatial disorientation in patients with Alzheimer's. This application also notifies their caregivers when they are far from a safe zone, and provides tools to locate them and, in this way, find them.

The application also provides the possibility for caregivers to monitor more than one patient at a time. This functionality is extremely attractive with a view to the app being adopted by institutions or medical care service companies that can help in the care of patients suffering from the disease.

We applied the usability and acceptance test, and we could demonstrate that the AlzRastreo is usable, intuitive, and has a simple user interface, which is specifically focused on older people and their caregivers. This provides ease when using all the features it provides, especially the panic button.

It was also possible to implement all the development of notifications to caregiver users by email and push notifications, to alert them when their loved ones or patients are out of a safe place. Likewise, we developed a web server, which works as an intermediary between the database and the mobile application, to execute the aforementioned notifications when appropriate.

Even so, the application can implement other features and improvements in future works. These new functionalities will be the creation of a web portal that shows patients

on a map, and also functionalities to determine the speed of the patients in their movement, as well as the direction in which they are heading.

In the future, usability and acceptance tests will also be carried out on medical-health personnel or institutions specializing in this type of disease to obtain more specialized opinions and suggestions for improvements associated with the health and well-being of the patient.

AlzRastreo is a solution not only for the location and monitoring of patients with Alzheimer's but also an interesting solution for the peace of mind of caregivers who most of the time are forgotten when taking into account their needs and requirements that allow them to better carry way their care and surveillance.

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