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An Alert System for People Monitoring Based on Multi-Agents using Maps

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Abstract: This paper describes an alert system for people monitoring based on multi-agent using maps. This system monitors the users' physical context using their mobile phone. The data acquisition is made using the available sensors on mobile phone. A set of agents on mobile phones are responsible for collecting, processing and sending data to the server. Another set of agents on server stores the data and checks the preconditions of the restrictions associated with the user, in order to trigger the appropriate alarms. These alarms are sent not only to the user that violates a restriction, but also to the one responsible for supervising the person monitored. The supervisor can control all the supervised people through a map interface with functionality such as sending a SMS or making a call directly from the map. The applicability of the system will be illustrated with an example for Alzheimer patient monitoring. These patients will carry on normal activity in the home environment or home for the elderly, monitored by their family or by nurses.

Keywords: Sensors, Physical Context, Monitoring, Multi-Agents System, JADE, Maps
Categories: H.5, I.2.8, I.2.11, J.1, M.0

1 Introduction

An alarm system is a passive safety feature that does not prevent an abnormal situation, but is able to warn of it, thus acting as a deterrent.

In order for an alarm system to work properly, you need a number of components such as: a) set of sensors connected to a central processor, b) mechanism to activate and deactivate the alarm, c) siren, d) central processing e) central receiving or monitoring.

Sensors are electronic devices that provide the system with the contextual information necessary for the system to make decisions and act accordingly. This component is critical because being well informed, accurately and on time, is usually a guarantee of success.

Being well informed is being aware of those facts relevant to the system. In this case, it is to have knowledge of those events that will trigger the activation of a particular alarm.

Given the above, an alarm system can be considered as a process of monitoring a parameter set, whose data comes from the sensors.

Once the alarm system has been activated, the sensors start to collect data from the environment. These data from the sensors will be stored and processed by a central processor, to verify the validity of such data and transmit them to the central monitor, whose function is to check whether to enable or disable the alarm. Furthermore, the central monitor can carry out a rigorous control of the whole process of monitoring.

When an alarm is triggered, it activates the corresponding audio and visual signal, indicating that the alarm is enabled.

Today, in addition to conventional alarm systems, such as smoke detection and fire or intrusion detectors, there are others that report on the weather, the price of a product, reception of a package, etc. That is, there is a multitude of services to which a user can subscribe and receive alarm signals when given the appropriate preconditions. This article focuses on the monitoring of people, taking into consideration issues such as health and safety.

Currently, there is a large variety of devices for monitoring. It is possible to find Caalyx [Al Shamsi, 11] a patient monitoring device that can measure vital signs, detect falls and alert emergencies to the nearest healthcare or Keruve [Keruve, 10] a watch pager that sends signals to a receiver with the position of the person wearing the watch and which is used primarily for people with Alzheimer. Another device is proposed by [Le, 10] for use in a cardiac monitoring system.

Most of the monitoring devices are often specifically designed for monitoring one or more parameters, but do not allow the incorporation of new sensors or to be used to monitor a different set of parameters, it being necessary to find other devices for monitoring. It is also desirable to enable the incorporation of new sensors into these devices in a simple and dynamic way.

Nowadays, mobile phones have more processing power, memory and a large number of sensors that provide a fairly comprehensive environmental status. They also provide information about the activity made by the person carrying the mobile phone. For these reasons they are the appropriate instrument to remain continuously connected and reachable, by allowing a process of monitoring. These features enable mobile phones to be both the instrument of monitoring and control. In addition, they provide the capability to show alarms and play signal sounds.

This paper describes the AGATHA System, an Alert System for People Monitoring Based on Multi-Agents using Maps. AGATHA uses mobile phones to monitor the compliance of a set of defined constraints. The mechanisms for collecting data and triggering alarms are based on the definition of agents. In this system, mobile devices are not only used as elements to monitor people, but are also used to control the monitoring process. Depending on the user role (supervised or supervisor), the system component installed in the mobile device performs different types of actions showing different kinds of information. The system sends alarm signals to users when the person being supervised undertakes inappropriate activities with respect to their constraints. One of the most important elements of this system is the interactive map that is used to show the geographical position of the people monitored and that enables you to interact with them via SMS or phone call.

The paper is structured as follows: section 2 presents work related to monitoring systems based on mobile phone, section 3 describes an overview of the monitoring process. Section 4 analyzes the architecture of AGATHA, and this architecture is used in section 5 to describe an application of the systems for Alzheimer patient monitoring. Finally, conclusion is presented in section 6.

2 Related Work

2.1 Monitoring Based on Mobile Phones

The use of mobile devices for monitoring is an important area of development. For instance, Seto et al. [Seto, 11], show how a mobile phone-based remote monitoring system improves the heart function, quality of life, and self-care, and Ketabdar et al. [Ketabdar, 10], propose a system and methodology for using mobile phones for monitoring physical activities of a user based on processing acceleration data provided by accelerometers integrated in new mobile phones.

Cornelius et al. [Cornelius, 08] present Anonysense, a framework that collects data from anonymous users using sensors, but sometimes it is necessary to know the name of the user that provides the data. Kukkonen et al. [Kukkonen, 09] propose BeTelGeuse, an extensible data collection platform for mobile devices that automatically infers higher-level context from sensor data, which is only available for J2ME, a language and platform for devices with low processing power, memory and graphics.

However, today devices have improved, offering more resources, and for this reason it is now possible to use other languages and platforms in order to develop better systems. Froehlich et al. [Froehlich, 07] describe MyExperience, a system for in situ tracing and capturing of user feedback on mobile phones, but which is only applicable to Windows Phone devices.

None of the aforementioned monitoring systems allows alarm management or process control monitoring via the mobile device. In addition, these systems do not use all the capabilities provided by mobile phones, but rather usually use only one or a small number of its sensors, or don’t take advantage of their ability to connect to other sensors and to transmit the data collected from them.

2.2 Multi-Agent System on Monitoring Processes with Context Information

Monitoring process especially for the elderly is an important area of research and several ideas are being developed. García-Vázquez et al. [García-Vázquez, 10] propose the use of autonomous agents to cope with the design issues for developing activity-aware systems. This system characterizes activities of daily living for the elderly, such as medicine dispensers, and provides reminders about when and how much medicine must be taken, but it is a closed architecture because it does not allow one to define new restrictions or incorporate new sensors to increase the context information, such as the GPS position.

Camarinha-Matos et al., describes in [Camarinha-Matos, 03] a platform based on mobile agents combined with federated information management mechanisms, a flexible infrastructure on top of which specialized care services can be built. This work is focused on care service more than monitoring and alerting irregular or inappropriate behaviour. In addition, this system cannot monitor different types of restrictions for different kind of users.

Koutkias et al. in [Koutkias, 03] propose a Multi-Agent System architecture to support heart failure management in a generic home care setting. The ultimate goal of this system is the characterization of the patients' health status and, accordingly, the warning to the corresponding medical personnel to take medical actions. For this reason it cannot be considered as a generic alert system for monitoring people.

Capozzi et al. [Capozzi, 13] propose an abstract unifying infrastructure for telemedicine services which is loosely based on the multi-agent paradigm. It provides the capability of transferring to the clinic any remotely acquired information, and possibly sending back updates to the patient. The system collects clinic data (i.e. blood pressure monitors, scales, glucometers, etc.).

Kwon et al, propose in [Know, 2012] a model-based reasoning to generate secondary situational information from activity data gathered at the home, for example, in situations of alert. The detection sensors monitor for activity, fire and gas leaks.

In the studies presented above, there is no consideration of the possibility to monitor different types of restrictions, which can consider the same or different numbers of sensors. For this reason AGATHA has been developed, a multi-sensor monitoring system that incorporates a complete and customizable alarm system.

3 Monitoring Process in AGATHA

AGATHA is an innovative monitoring system and alarm management using the mobile phone capabilities and sensors to collect information about the environment and about the user carrying the mobile phone. The mobile phone is used to detect small changes in the position and activity of the user, in time to activate the necessary alarms that will enable correcting an inappropriate user action. People monitored with this system carry the mobile phone on a belt.

As all monitoring systems, AGATHA should have the appropriate media to obtain specific and continuous information of the parameters involved in a monitoring process. The first step is the choice of the object or process to monitor, as well as the parameters to be measured. These parameters must be valid, reliable and appropriate to detect user changes and violation of restrictions in order to act accordingly.

Once the parameters have been selected, the next step is to plan the monitoring process, including: a) the frequency of measurements, b) mechanisms for the gathering of parameter values, c) methods for processing and interpreting these values, and d) alarm mechanisms responsible for notifying the incidences or violation of restrictions.

3.1 Supervision Parameters

AGATHA monitors the compliance of a set of restrictions associated to users. Each restriction has a set of parameters to be measured. Restrictions are: geographical, about communications (calls, messages, etc.) or movements.

The system considers two basic user roles: supervisor and supervised. The one supervised is the person to be monitored and the supervisor is the one who carries the monitoring control and who sets the monitoring parameters, as well as restrictions. In addition, supervisors are those to whom the system should report the activity monitored from the supervised user. The system also informs the supervised user of any incorrect action or movement in order for it to be known and corrected.

The frequency of the measurements is defined by the supervisor and it is specific to every monitoring process. The supervisor will assess the importance of update monitoring data, and will establish for each monitored parameter the proper frequency. During the monitoring process, the frequency may vary, and the system will inform the mobile devices.

3.1.1 Geographical Restrictions

Geographical restrictions are constraints related to physical spaces that establish where the users can move. In this type of restriction the values provided by the GPS and compass are primarily used, but others are also used, such as the accelerometer or gyroscope. The system considers three types of geographical restrictions:

– *Prohibited zones*: fixed areas in which the user cannot enter.
– *Required zones*: fixed areas in which the subject must necessarily remain.
– *Relative zones*: dynamic areas in which the user cannot enter. These areas are built considering that the GPS positions of some user are the centre of prohibited areas for other users.

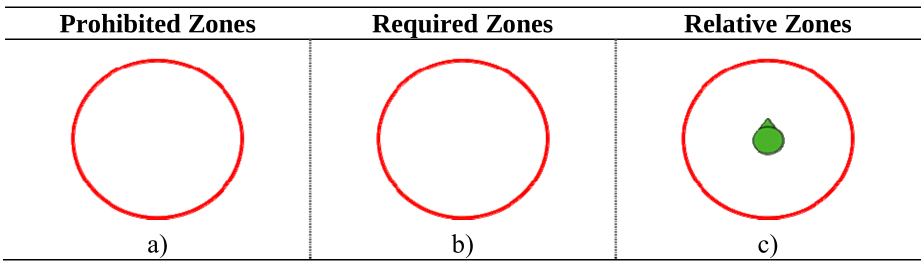

Figure 1: Graphical Representation of Geographical Restrictions

Figure 1 graphically represents the different geographical restrictions: a) coloured areas are controlled zones for the user independently of the other users, and b) non-coloured areas are controlled areas taking into account the location between two or more users (Fig. 1c). Green coloured areas indicate required areas (Fig. 1b) and red coloured areas (Fig. 1a) indicate prohibited areas. The red circle represents prohibition to enter or leave the area.

It is possible to represent circular, rectangular or polygonal zones for prohibited and required zones.

All restrictions are stored in a database. In order to facilitate operations and calculations of distances, as well as those geo-steering operations, both the areas and positions of the users are stored in a geographic database. In this case a PostgreSQL database with GIS supplement is used.

3.1.2 Communication Restrictions

The communication restrictions limit the use of the phone line, that is, the number of calls, SMS or MMS. Such restrictions can be of two types, depending on whether it limits the number of target line:

- *Phone restrictions*: limit the use that a user makes of his/her phone line, in terms of total calls, SMS and MMS.
- *Contact restrictions*: limit the number of calls, SMS and MMS the user can send to a specific user.

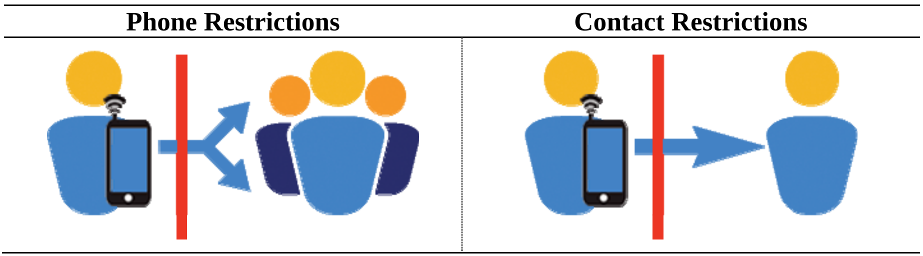

Figure 2: Graphical Representation of Communication Restrictions

Figure 2 graphically represents the different communication restrictions. Figure 2 (left) shows phone restrictions and if some user has associated this type of restriction, then he has a limit on the total number of call, SMS and MMS regardless of the destination user. Figure 2 (right) shows contact restrictions. In this case the user has a limit on the total number of calls, SMS and MMS, but considering only one user. In this last restriction, there is no limit to the number of calls, SMS and MMS with another user not specified on contact restrictions.

3.1.3 Movement Restrictions

Movement restrictions set a specific time that a user can remain at a specific point or area. Positions are determined through GPS. The accelerometer and gyroscope determine whether the user stands still in one position or makes another kind of movement different to walking. Finally, light and proximity sensors determine whether or not the device is being manipulated.

These restrictions measure different types of movements and not just displacement. The location is only used to determine the displacement.

The process for checking the activation of a movement restriction is the following:

- The first check is whether the user is in motion, checking his/her position since the last monitoring. If the user has remained in the same location for longer than the time established by the restriction, then accelerometer and gyroscope readings are checked.
- These two sensors indicate whether the user, despite remaining in the same position for a long time, has been doing other activities with the mobile phone, in which case it can be deduced that the user is active. However, if the sensors indicate that the user has been in the same geographical position

too long, and has not made any move with the mobile phone, it will be necessary to check the brightness and proximity sensors to determine whether the user is near his/her mobile phone.

– If none of the sensors provides a proper reading, we can deduce that the user has been motionless for too long and this situation should be checked first by activating an alarm and then making a phone call.

It is necessary to stress that the system uses triangulation when the GPS coverage is lost, for example, inside buildings. In addition, a person can only be associated to one movement restriction.

This kind of restriction is especially interesting for the care of old people.

3.2 Alarm Definition

Alarms inform users (supervisor and supervised) about the activation of any of the defined restrictions. Alarm signals are performed as a Toast and Push signal. Table 1 shows the different alarms defined on the system. Two types of alarms can be distinguished, related to user restrictions and related to the configuration of the system. These last enable the correct performance of the system.

Alarm	Sensors
User Restrictions	
Prohibited zones	GPS/Network, Compass
Required zones	GPS/Network, Compass
Relative zones	GPS/Network, Compass
Phone restrictions	Call, SMS and MMS Log
Contact restrictions	Call, SMS and MMS Log
Movement restrictions	GPS/Network, Accelerometer, Gyroscope, Light and Proximity sensor
Configuration	
Low battery	Battery level
Switch off mobile	Battery level, Network
No network coverage	Network
No sensor readings	Sensor reading

Table 1: Types of Alarm Defined on AGATHA

Each alarm has associated different severity levels. These levels are established considering defined limits for the different values of each sensor reading. In addition, for each level there is a set of degrees of persistence defined. Persistence levels are based on the time during which the person under supervision remains in violation of some of the restrictions that he/she has associated. For instance, in restrictions related to a prohibited area, the level of persistence increases with the time the user stays within that area.

For the different alarms defined in the system, there has been established a set of rules based on a set of preconditions. These preconditions are composed of a set of parameters corresponding to different values gathered from the sensors.

So, for example, to trigger the "*x*" level of an alarm for the user "*U*", the following preconditions must be met:

– "*U*" must have the constraint "*r*" associated with it.
– The restriction "*r*" must have an alarm "*a*" associated with it.
– The alarm "*a*" must have defined a set of alarm levels "*n*".
– Within the "*n*" alarm levels, there must be a level "*x*" with the appropriate values for sensor data to activate the alarm level.
– Readings "*l*" of the parameters of the sensors must be between the limits identified for the level "*x*" of the alarm "a".
– If this is the first time you reach this level, "*x*", the alarm level has a level of persistence associated "*p*", where p = 0. If it is not the first time, it is necessary to make a search in the database to determine the time elapsed since the activation of the alarm level, and with this value to determine the value of the persistence level.

Rules are implemented inside agents' behaviour in charge of alarms management.

The following table shows the behaviour definition of the agent that implements the rule associated with the activation of an alarm for a prohibited area.

```
Begin
    1.  Obtain supervised ID
    2.  Obtain supervisor ID
    3.  Obtain prohibited  zones of supervised
    4.  For each zone
        4.1.  Obtain distance between  last GPS position and zone
        4.2.  Consult alarm associated with this restriction zone
        4.3.  Search alarm level
        4.4.  If alarm  level is different to 0
            4.4.1.  If alarm level is greater than last level activated
                    -   Activate new alarm level
                    -   Send alarm  to supervisor and supervised
            4.4.2.  Else If alarm level is equal than last level activated
               -  Search new persistency level with last compass reading
               -  Send alarm  to supervisor and supervised
            4.4.3.  Else If alarm level is less than last level activated
                    -   Update alarm level
                    -   Set persistence level=0
            4.4.4.  End If
        4.5.  End If
    5.  End For
End
```

Table 2: Rule to Trigger Alarms for Prohibited Zones

The alarms are sent to the users when a new alarm level or persistence level is activated. The number of levels is established by the supervisor using a web interface.

4 AGATHA Architecture

Mechanisms for the gathering process and analysis data are based on the definition of agents. For this reason, the AGATHA architecture is based on a multi-agent architecture.

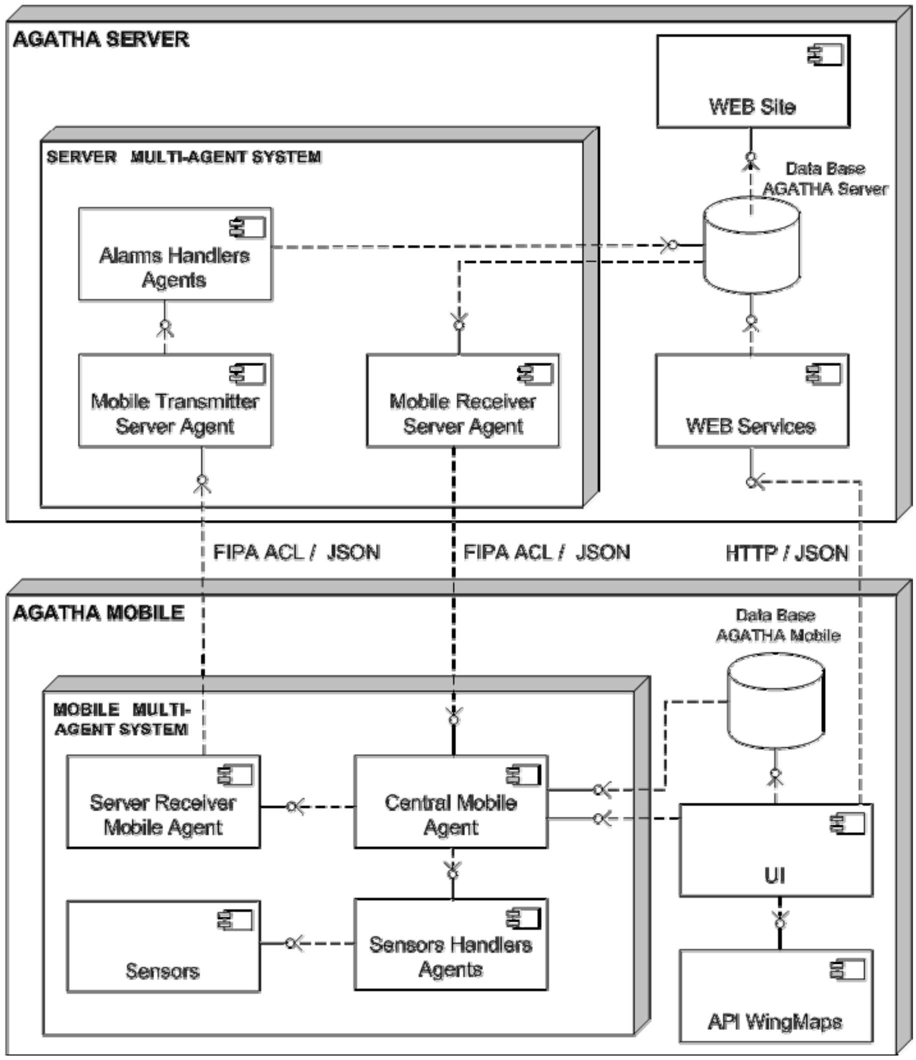

Figure 3: AGATHA Architecture

As shown in Figure 3, AGATHA is client-server architecture. Clients are the mobile devices, composed of a set of agents collecting data from sensors and sending them to the server. The server is composed of another set of agents, responsible for collecting, storing and processing information from mobile devices as well as the activation of different alarms.

The client side of the architecture is composed not only of a set of agents, but also of a database where some sensor readings are stored temporarily, and of an enhanced UI with a map library that enables incorporating context information to maps.

The mobile database is especially important for cases in which, due to the lack of connectivity, the mobile phone has not been able to send the sensor readings to the server. It thus prevents the loss of information, because, as soon as the connections are regained, all pending readings are sent.

The server side of the architecture, as well as the client, has other components besides the agents, such as a set of Web services available to clients and a powerful database that not only stores the user information and the definition of all restrictions and alarms, but also stores readings from sensors and activation history of alarms.

4.1 Multi-Agent Architecture

The methodology used to analyse and design the multi-agent system is GAIA [Wooldridge, 00]. GAIA is a methodology for agent-oriented analysis and design applicable to a wide range of multi-agent systems. It is based on concepts such as roles, protocols, activities, agents and acquaintances between others.

Figure 4 shows the acquaintance model of GAIA methodology for AGATHA system.

Acquaintance models simply define the communication links that exist between agent types. In this figure, the mobile phone has a set of agents ready to react to different events produced by the device sensors that capture information from the environment. This information is sent to a central agent, which is responsible for verifying that the information is valid and the user must be informed if any constraint has been violated. If the information received by the central agent is not correct, the data are forwarded. The agent in charge of receiving this information on the server will report data to agents responsible for triggering the alarms. The server agent (Mobile Receiver Server Agent) receives different information from monitored devices and sends two types of information:

- Information about the status of monitoring. This information is displayed on the mobile phone using maps and textual resources. The information displayed depends on the role played by the user of the mobile device.
- The different alarms that are sent to one type or another of the user. The alarms have a defined set of rules that either trigger alarms or not, depending on the values of the monitored parameters.

Software agents are developed on the JADE platform [JADE, 12] (Java Agents Development Environment). JADE is a platform developed by CSELT (Telecom Italia), complying with the FIPA specifications. JADE is implemented in Java and the agents can communicate each other using a pattern specified by FIPA, called protocols. Each of these protocols provides the basic exchange of messages between two agents for a given type of conversation. The content of the messages are JSON objects.

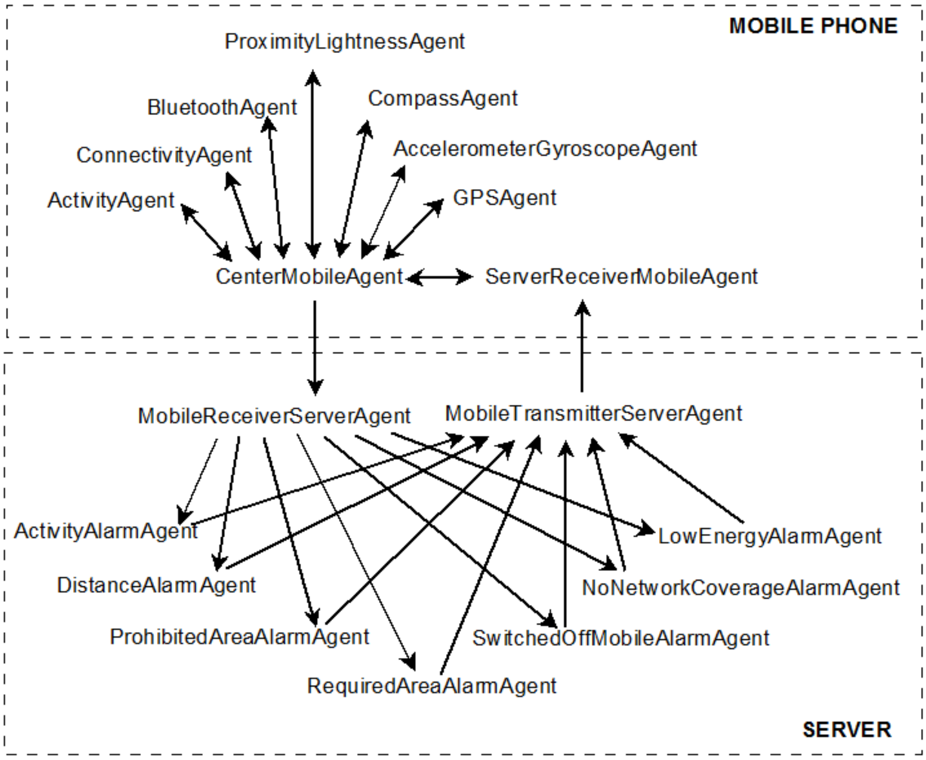

Figure 4:Multi-Agent Architecture

Importantly, while on the mobile side each device will have only one agent of each type, on the server side there will be multiple instances of each agent so they can respond adequately to the demands of mobile devices.

4.2 AGATHA Server

AGATHA Server is composed of two main components: a) a server in charge of alert service provider, and b) a web application in charge of user registration, management of user roles, constraints and alarm definition.

4.2.1 AGATHA Alarm Provider

This component implements the multi-agent system on the server side. This component is responsible for receiving the information from the mobile device and the information must be processed to obtain the actions to be executed. Depending on the source of information, user under surveillance or supervisor, activity of related users, and so on, the system evaluates a set of rules defined for the users involved, and it returns to the users the results, depending on the current context.

When the supervisor receives an alarm with high severity and/or persistence, he/she can send a text message or call the user who triggered the alarm. These actions may be made directly from the GUI application. The system will also notify the supervisor when some user under surveillance has the mobile phone switched off or without a signal, to try to locate it by other means.

Thus, when the alarm parameters receive values that trigger the alarm, the system starts the procedures that inform the users involved in the defined rules.

The functionality of the main agent on the server side corresponds to the continued receiving of information from the mobile side. The mobile device can send different types of messages: a) monitoring data, b) a request for information, c) activation of mobile agents. Monitoring data will correspond to each of the sensors and contain reading sensor values, the IMEI number and phone number. These last two values are used to verify the origin of the data.

4.2.2 AGATHA Web

AGATHA Web is a web site that provides the mechanisms needed to establish the parameters of the alert system. That is, it allows the management of information about users, relationship between the users, geographical areas, alert types, frequency of the gathering of information from mobile devices, etc.

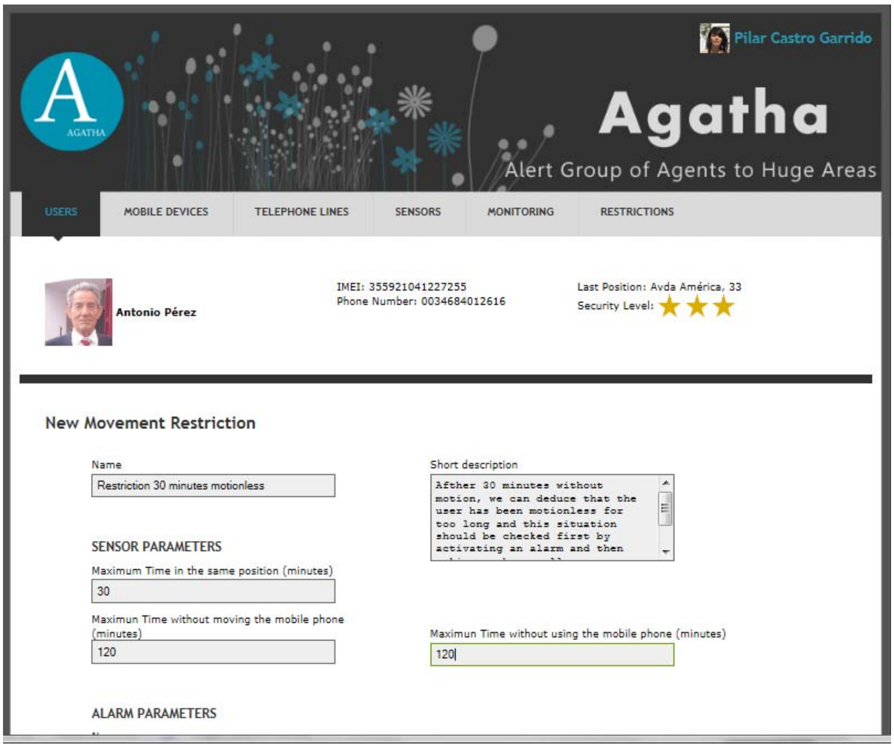

Figure 5: AGATHA Web Screenshot

Figure 5 shows a screenshot of the main page used to define new restrictions. Definition of users, user relationships, roles and alerts are managed by a powerful database that also stores real-time information about users' activity. This database is used for the rule component in order to analyze the user status and to trigger the necessary agents in charge of sending back information to users.

AGATHA Web also provides a set of web services available for clients. Web services will be returned as JSON objects.

4.3 AGATHA Client

This subsystem consists of a set of software agents and a graphical interface. The agents collect measures from the environment according to the phone sensors: GPS, accelerometer, gyroscope, compass, proximity sensor, lighting sensor, connectivity, and activity in the mobile: phone calls, SMS and MMS. Then this information is sent to the server.

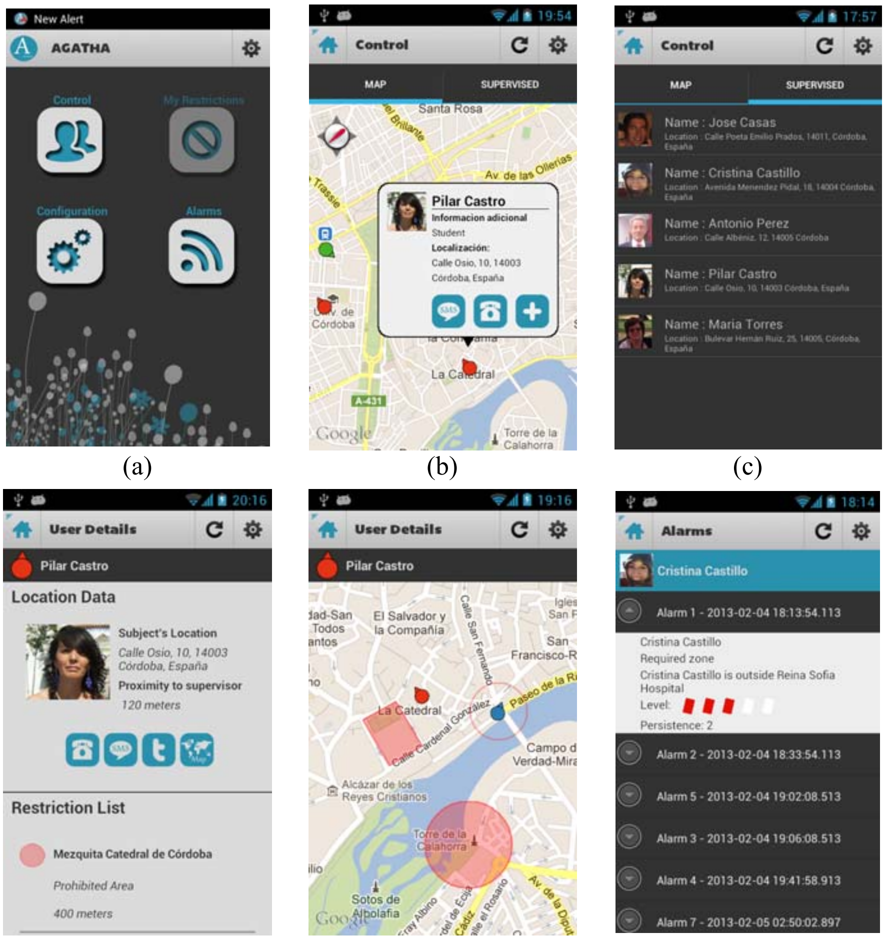

Figure 6: Some Screenshots of AGATHA Mobile

The mobile interface provides graphical information in the form of maps of user location, as well as zones and routes (see Fig. 6). In addition, it provides textual information such as security level, distance between users (only with supervisor role), list of alarms activated, and much more.

The mobile application is installed on the mobile device of supervisor and supervised. AGATHA is the same application for both, and depending on the role, some functionality is not available. Mobile and server applications interact via wireless communication.

Figure 6a provides the main menu of AGATHA. This application has been installed on the mobile phone of a supervisor because it enables the “Control” item. This supervisor does not have restrictions and so the item “My Restrictions” is not enabled. AGATHA allows a supervisor to be a supervised person too.

Figure 6b shows a map in which the supervisor can control his supervised users. All the maps in AGATHA have been developed using the WingMaps API. This API has been developed by our research group as an end of degree project. The main advantages that WingMaps offer are the possibility to represent contextual information on maps. For example, in Fig. 6b, the map zoom is automatically calculated depending on the user’s position. Moreover, the bubble associated with the user provides not only text information, but also actions via dynamic buttons. It is also possible to represent all the kinds of geographical restriction described in this paper (see Fig. 6e).

Figure 6c shows a list of all those being monitored. By clicking on any of them, you will see a new screen with the details of that user (see Fig. 6d). You can also display user details from the bubble button detail associated with a user on the map of supervised persons. The user details screen also provides a set of options, one of the most important being the possibility to show geographical restrictions for a user on the map (see Fig. 6e).

Finally, Fig. 6f shows a list of all alarms, sorted by date. This is a drop-down list with detail information as the alarm level and persistence for each alarm.

5 A Case Study: Care of People with Alzheimer

The increase in life expectancy in the population produces an interest in the development of solutions to monitor movement and activities of certain groups of people.

Elderly people live alone and need supervision and assistance. For them it would be desirable to develop a tool able to monitor at any time their position and movement for multiple goals: a) prevent from getting lost, and b) assist in case of falls.

One of the age-associated diseases is Alzheimer's, which increases the need to monitor the activity of the person who suffers from it.

Alzheimer’s is a progressive, irreversible neurological disorder that affects the brain causing the death of neurons [Aguera-Ortiz, 10]. It produces a deterioration of all cognitive functions. This disease has different stages, during which the patient usually loses memory, ability to follow directions, can get lost in the street and, in advanced stages may lose the ability to walk and move, reaching a vegetative state.

Bravo et al. [Bravo, 08] propose a solution which aims to improve and complement Alzheimer’s care in two ways: to manage the information easily, and as a complement for Alzheimer care, visualization activities at home. This solution does not monitor parameters.

For these patients, the AGATHA system is like a nurse, who monitors their behaviour, is able to activate the alarms defined for patients and to send valuable information to the supervisor as well as the patient him/herself. In this use case, we have defined initially the following main alarms:

– Alarms related to when a patient leaves a defined security zone (required zone).
– Alarms related to when a patient stands still for too long.
– Alarms related to when a patient is not capable of handling the device when he/she receives a phone call.

Signals of the triggered alarms will be sent to the supervisor and, depending on the alarm type, level and persistence, will also be sent to the patient (supervised).

The supervisor uses the mobile device for monitoring and he/she can display on the screen all Alzheimer patients under their care. The supervisor may at any time check the status of alarms and even, directly from the interface of AGATHA, may make a call to some patient simply by touching the user's avatar displayed on the map.

An Alzheimer's patient can live either in a residence with special care, or live at home in the care of their family. In both cases, these patients need constant monitoring. The process followed is detailed below:

Every morning the patient, when getting up, incorporates a mobile phone to his belt. During the night the phone is expected to stand still because it is time to rest, otherwise the phone reports activity made by the patient.

The patient will have associated an area in which to remain, the amplitude of the zone depends on the stage of the disease. This zone is represented by a coloured green circle. The area may represent the residence and its surroundings or the patient's home address and a radius around it. For example, it is possible to set an alarm for this area with 5 alarm levels and 3 levels of persistence for each alarm level. So for a 500-meter zone are defined alarm levels for 700, 900, 1100 and 1300 or more meters, with persistence to 10, 30 to 60 minutes or more for each level.

The patient will also have associated a restriction of movement, which will report on whether the patient stands still for too long a time. An alarm is set for this restriction with a single alarm level and 5 levels of persistence, associated with the time the patient remains immobile. These levels of persistence are 10, 30, 60, 90, and 120. It is necessary to note that to trigger a new level it is necessary to meet all the preconditions for this type of restriction, i.e. no linear or angular motion, and the device is not being manipulated (GPS, Accelerometer, Gyroscope, proximity and light sensor without data).

With the first restriction it is monitored that the patient does not walk to unknown places and the second restriction monitors that the patient has not suffered any accident and is not on the ground motionless.

Table 3 shows twenty alarms signals, allowing the supervisor to react in time to detect that the patient are not inside a secure area. The supervisor only needs 10 minutes to notice that the patient is not at home or at their residence. Without the appropriate media the supervisor necessarily has to control the patient in a visual way.

Position	Time	Alarm Level	Persistence
0-500 meters	none	0	0
500-700 meters			
	0-10 min.	1	0
	10-30 min.	1	1
	30-60 min.	1	2
	>60 min.	1	3
700-900 meters			
	0-10 min.	2	0
	10-30 min.	2	1
	30-60 min.	2	2
	>60 min.	2	3
900-1100 meters	3		
	0-10 min.	3	0
	10-30 min.	3	1
	30-60 min.	3	2
	>60 min.	3	3
1100-1300 meters			
	0-10 min.	4	0
	10-30 min.	4	1
	30-60 min.	4	2
	>60 min.	4	3
>1300 meters			
	0-10 min.	5	0
	10-30 min.	5	1
	30-60 min.	5	2
	>60 min.	5	3

Table 3: Enabling Alarms to the Area Required (500 meters)

Same Location	Without Accelerometer/Gyroscope	Without Light/proximity	Persistence
0-10 min.	0-10 min	0-10 min.	0
10-30 min.	10-30 min.	10-30 min.	1
30-60 min.	30-60 min.	30-60 min.	2
60-90 min.	60- 90 min.	60-90 min	3
90-120 min.	90-120 min.	90-120 min.	4
>120 min.	> 120 min.	120 min.	5

Table 4: Enabling Alarms to the Movement Restrictions

Table 4 shows the levels of persistence for movement restrictions. It is necessary to meet the three conditions in order to change level. As in the previous case, the first alarm is after 10 minutes, allowing for a good response time. Furthermore, as this time can be set during the creation of the alarm, it could be even less.

The restrictions and alarms can be personalized through AGATHA Web. Only the supervisor can change the parameters associated with the monitoring process. In this case, supervisors are the family or nurses depending on the patient's location.

From this example, it can be deduced that AGATHA is a good tool for elderly care, because it provides the least amount of time of response from the moment the patient performs an inappropriate action or has some accident.

In addition, even if the tools do not provide alarm signals because the patient acts in a correct way, the readings provide by the sensors can be used to study the Alzheimer stage of the patient. It is possible to analyze their routes, time walking, etc.

6 Conclusion

The aim of this work is to propose a novel system to monitor the movements and activities of different kinds of users. The system collects data from mobile device sensors via agents. They send the data to the server responsible for processing. When the server receives the data, it checks the activation ranges of alarms in order to return signals to the users involved whenever necessary.

An important characteristic of AGATHA it that this system allows defining new alarms, agents and functionalities, including new sensors by Bluetooth or other network technology in an easy way, allowing the scalability of the system.

The system may be used for any monitoring process where a user with supervisor role monitors another user with supervised role, for instance, children's surveillance. Thus, we show how AGATHA can be used for the surveillance of non-severe Alzheimer patients. The main advantages are not only that it is possible to collect a large number of parameters used on the alarm definition, but it is also possible to know the patient's stage of Alzheimer thanks to the history of sensor reading.

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References

[Aguera-Ortiz, 10] Aguera-Ortiz, L., Frank-Garcia, A., Gil, P., Moreno, A.: Clinical progression of moderate-to-severe Alzheimer's disease and caregiver burden: a 12-month multicenter prospective observational study. In: International Psychogeriatrics, 2010, 22(8), pp. 1265-1279.

[Al Shamsi, 11] Al Shamsi H., Ahmed, S., Redha, F.: Monitoring device for elders in UAE. In Proc. International Conference and Workshop on Current Trends in Information Technology, United Arab Emirates, October 2011, pp. 32 – 36.

[Bravo, 08] Bravo, J., Lopez-de-Ipina, D., Fuentes, C., Hervas, R., Pena, R., Vergara, M., Casero, G.: Enabling NFC Technology for Supporting Chronic Diseases: A Proposal for

Alzheimer Caregivers. In: Aarts, E; Crowley, JL., DeRuyter, B., Gerhauser, H., Pflaum, A., Schmidt, J., Wichert, R. (eds.), 2008, LNCS, vol. 5355, pp. 109-125. Springer, Verlag Berlin.

[Camarinha-Matos, 03] Camarinha-Matos, L.M., Castolo, O., Rosas, J.: A multi-agent based platform for virtual communities in elderly care. In Proc. IEEE Conference on Emerging Technologies and Factory Automation, Portugal, September 2003, vol. 2, pp. 421-428.

[Capozzi, 13] Capozzi, D., Lanzol, G.: A generic telemedicine infrastructure for monitoring anartificial pancreas trial. Comput. Methods Programs Biomed. (2013), http://dx.doi.org/10.1016/j.cmpb.2013.01.011

[Cornelius, 08] Cornelius, C., Kapadia, A., Kotz, D., Peebles, D., Shin, M., Triandopoulos, N.: Anonysense: privacy-aware people-centric sensing. In Proc. ACM Conf. on Mobile systems, applications and services, Breckenridge, Colorado, June 2008, pp. 211-224.

[Froehlich, 07] Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., Landay, J. A.: MyExperience: a system for in situ tracing and capturing of user feedback on mobile phones. In Proc. ACM Conf. on Mobile systems, applications and services, USA, June 2007, pp. 57-70.

[García-Vázquez, 10] García-Vázquez, J. P., Rodríguez, M. D., Tentori, M. E., Saldaña, D., Andrade, A. G., Espinoza, A.N.: An Agent-based Architecture for Developing Activity-Aware Systems for Assisting Elderly, Journal of Universal Computer Science, June 2010, vol. 16, no. 12, pp. 1500-1520.

[JADE, 12] JADE (Java Agent DEvelopment Framework), http://jade.tilab.com/index.html

[Keruve, 10] Keruve, http://www.keruve.es/

[Ketabdar, 10] Ketabdar, H., Lyra, M.: System and methodology for using mobile phones in live remote monitoring of physical activities, IEEE International Symposium on Technology and Society, Australia, June 2010, pp. 350-356.

[Koutkias, 03] Koutkias, V.G., Chouvarda, I., Maglaveras, N.: Multi-Agent System Architecture for Heart Failure Management in a Home Care Environment. In proc. Computers in Cardiology, Greek, September 2003, vol. 30, pp. 283-386.

[Kukkonen, 09] Kukkonen, J., Lagerspetz, E., Nurmi, P., Andersson, M.: BeTelGeuse: A Platform for Gathering and Processing Situational Data. In IEEE Perv. Comp., April 2009, vol. 8, 49-56.

[Kwon, 12] Kwon, O., Moon Shim, L., Lim, G.: Single activity sensor-based ensemble analysis for health monitoring of solitary elderly people. Expert Systems with Applications, 2012, vol. 39, pp. 5774–5783.

[Le, 10] Le, H., Kuttel, M., Chandran, G.: An electronic health care - cardiac monitoring system, IEEE International Communications Conference, South Africa, May 2010, pp. 1-5.

[Seto, 11] Seto, E., Leonard, K.J., Cafazzo, J.A. , Masino, C., Barnsley, J., Ross, H.J.: Mobile phone-based remote patient monitoring improves heart failure management and outcomes: a randomized controlled trial, Journal of the American College of Cardiology, New Orleans, LA, April 2011, pp. E1260-E1260.

[Wooldridge, 00] Wooldridge, M., Jennings, N.R., Kinny, D.: The Gaia Methodology for Agent-Oriented Analysis and Design. In Autonomous Agents and Multi-Agent Systems, Netherlands, 2000, vol. 3, pp. 285-312.