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RFID Application to Control Unauthorized Egress of People with Spatial Disorientation

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Abstract— **This article presents a "Wanderer Monitoring System" application based on radiofrequency identification systems, whose objective is to monitor the movement of individuals with spatial disorientation problems. The system architecture and description is shown, as well as the results of the tasks carried out. The system has been installed in 18 elderly peoples' homes belonging to the Andalusian Government (Southern Spain), and it is currently in used following more than one year of validation.**

Keywords— **Radiofrequency Identification, spatial disorientation, elderly care.**

I. Introduction

THE percentage of elderly people is increasing in Spain as in the rest in the world. Due to the ageing of the population, there increasing number of people suffering from certain types of illness, which through various forms lead to dependence on other people. The objective of this study is to introduce the 'Wanderer Monitoring System', promoted by the Regional Ministry for Equality and Social Welfare of the Andalusian government [12] and implemented by the Andalusian Foundation of Social Services [1], the development and implementation of which is an attempt to improve the quality of life and safety of those people who, for different reasons have spatial disorientation, (mainly caused by pathologies such as Alzheimer's or senile dementia), with the subsequent risks for themselves. The system is intended to avoid their uncontrolled movement from those areas where they carry out their daily life (for example, their homes or elderly peoples' homes) [3]–[6], thus preventing people with disorientation problems getting lost or accessing dangerous areas with the risks that this may involve. Therefore the system also serves as a **safety guarantee for the family, and an efficient instrument** for the support to the personnel responsible for their care.

The 'Wanderer Monitoring System' has been designed taking into account the needs of a very specific environment such as elderly people's homes in Andalusia (Southern Spain), benefiting from the input, opinion and experience of the professionals in the homes (doctors, social workers, etc…), allowing a far more bespoke implementation. The service is provided free of charge by the Andalusian government, which has meant certain specification demands and requirements have helped shape the system as will be discussed later on.

The 'Wanderer Monitoring' is an integrated system whose sensors have the capacity to detect the movements of those people provided with identification devices based on RFID (Radio Frequency Identification) technology [7]–[10], identify these people and notify supervisors of the movements of these people in those areas considered as a risk to their persons. With this objective, when the people included in this study move out of the monitored areas, an alarm in the Reception Centre sounds, prompting the appropriate action amongst which we can highlight the sending of short messages (SMS, Short Messages Service) to mobile (cellular) telephones set up for this purpose. In addition to its detection function, the system is also able to store and manage all the device information, the people and the incidents generated, as well as notifying third parties of the instances of undesired movements, with the objective of monitoring the safety of these people.

The following section covers the system architecture and the technology and devices used, along with the made-to-measure software tools for the monitoring of all the devices. Section III details the tasks carried out and the results obtained from the installation of the system in 18 elderly people's and Section IV includes the main conclusions of the work carried out.

II. System Description

During the design stages, one of the important influencing factors was that the system to be developed had, as its main objective, its implementation in a large number of homes, without cost to the resident. Thus the system's total cost had to be kept to a minimum in order to ensure the availability of the project. Some technologies have been studied such as GPS (Global Position System) or active devices for RFID, but they have been rejected for three main reasons, because these kind of devices are too big to be worn by elder people, they need power supply and finally, because of the cost which is too high. The cost of an active device is about 30 times higher than the cost of a passive device. For this reason, along with other requirements such as safety and reliability, the architecture shown in Fig. 1 was chosen, which is detailed in the bar chart in Fig. 2, where we can see that the system is divided into three clearly defined subsystems: the central module, the detection module and the user devices.

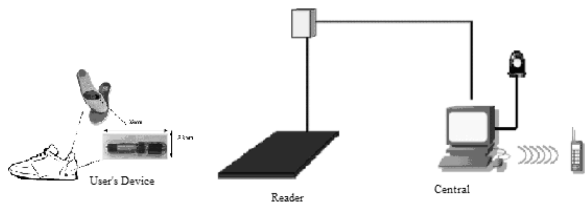

Fig. 1. System architecture

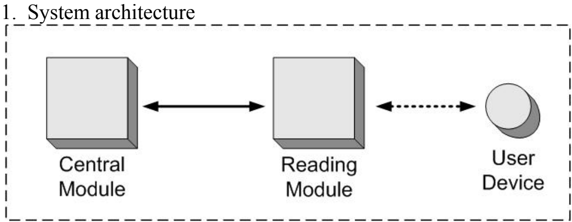

Fig. 2 Bar chart

The various system elements are detailed below:

A. Central Module

The central module consists of the elements necessary to allow interaction with its users as well as with the rest of the system elements.

Fig. 3 is a diagram of the central module, made up of monitoring equipment (a), and controlled by means of a PC. The specifically made to measure application permits the operator to set up the system and store all the information necessary for the identification of the people to be monitored and monitored areas. The system may then monitor the multiple detection devices located in the various areas in order to survey the home, by means of the serial communication module (d), which communicates with the reading modules by means of an ASCII protocol and series communications RS-232-422-485 [2]. The system also allows the storage of the information and management of the rest of the components including the following: GSM modem (Global system for mobile communication) (c), for the remote notification of the events to mobile telephones, and the alarm control module (b), which activates an alarm (e), or light signals (f). All the events are carried out in real time.

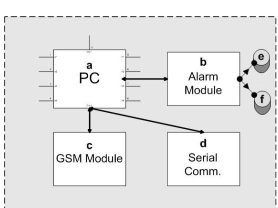

Fig. 3 Central Module

All the central module's functions will be accessible by means of a visual application based on forms and contextual menus, designed and made to measure.

The main functions of the monitoring unit are the following:

– Gathering and storing all the events.
– Managing the detection system.
– Configuring all the system parameters.
– Monitoring the notification System.
– Managing and configuring the data associated both with the home's staff as well as the users included in the project.
– Ensuring the confidentiality of the stored data.
– To be made up of modules and be extendable to a large number of control ports.

The development language used has been the ".NET" language, due to the relevant characteristics that this language has for the generation of the visual applications and database management. For the storage of all the events and other data of interest, postgresql as database has been used.

Fig. 4. Application window

To the left of the screen is the main panel of buttons through which the user can access the various application options.

– ***Residents***: Management of all the data related to the residents that will be included in the system (name, alias, type, etc.)
– ***Terminals***: Management of all the data regarding the mobile telephones used for the notification of alarms (registering and deregistering of numbers, activation and deactivation, etc.)
– ***Events***: All the events produced in the system can be accessed via this section, such as closed cases as well as those still open and all the data associated with said events
– ***Reports***: This option allows the generation of various types of reports, in order to obtain information from the system and of the events carried out.
– **Maintenance**: System configuration tool.

Apart from the functions described, in addition to triggering the alarms as previously mentioned, the system also prompts an alarm screen showing the identification details and location of the sensor detection.

Another feature of the application is a self-protection system which notifies the operator of any errors detected in the system itself.

B. Detection module

Fig. 5 shows a generic scheme of what a detection module is, made up of a microprocessor (a), which manages the other components, including an RF (Radio Frequency) transmitter / receiver (b) connected to an aerial (d) specifically designed to take into account the needs of the physical area to be monitored. All the information received is sent to the central unit by means of the communications module (c), a serial interface that can communicate with the central module via cable or wirelessly.

The detection devices are model RI-CTL-MB6A of 'Texas Instruments' 2000 series [2]. These readers operate on the same frequency as the user devices (134.2 KHz), allowing dozens of readings per second, along with identifying the user device numbers and providing a communication interface with the central module. It should be highlighted that as many readers as necessary can be connected to the central module.

The aerial (d) is designed to match the specific needs of its location and is made of copper cable. They have been designed as mats to be placed underfoot, in such a way that the radiation diagram is perpendicular to the floor, and in order not to generate obstructions at the healthcare premises that may hinder the access of the elderly people or vehicles such as ambulances.

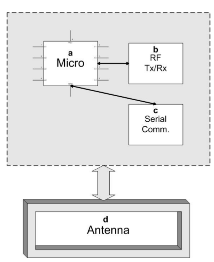

Fig. 5. Detection Module

C. User Devices

The identification device is made up of a micro-aerial and a small chip allowing the storage of a unique identification number, necessary for later matching it with the element to be monitored.

The device has to be as simple as possible in order to facilitate its maintenance and allow it to be low cost [13]. Thus a very small passive device (32 mm) has been chosen which costs less than 2$ each; it also had to be completely waterproof and resistant to chemical substances such as alcohol, hydrogen peroxide, etc.., as well as resistant to possible impacts and knocks. A Texas Instrument glass transponder has been chosen [2], allowing a maximum reading distance of approximately 70 cms.

These devices, following the recommendations given by the home professionals, are placed in an insert in the shoe specially designed to fit in a reinforced cavity in the arch of the foot. Fitting the device to an ankle strap is also possible, as long as it is close enough to the floor where the sensors located. Concealing the device in the shoes ensures that the distance between the sensor and the tag will always be within the limits and also prevents the residents from identifying it., favouring its acceptability.

The overall operation of the system can be seen below:

The first stage is assigning the identification device and entering its details with those of its user into the system software to allow the system to match the device to an entry in its database the instant it passes a monitoring device. It will be possible to assign various devices belonging to the same user.

The areas subject to monitoring have a detection system allowing the monitoring of any user carrying a device. At the moment when a person subject to monitoring passes a sensor it picks up the identification number of the device by means of a RF module, and sends it to the central module through the communication system.

When the central module receives the information that a user has gone through a monitored area, this will prompt the appropriate action, amongst which we can highlight the alarm notification - both locally and remotely - whereby an on-screen alarm is generated, the acoustic-light alarm devices are activated, and SMS messages are sent by the GSM modem to all those mobile phones that have previously been configured in the system.

In the notification the person who has gone through the area is indicated, as well as the area and the time, although the notification is in real time. Apart from the notifications, the system stores all the information for a later examination and use of the same.

When the situation has been resolved, the person responsible will close the case through the application installed in the central module, and all the alarms will be deactivated, apart from sending a new SMS to the remote telephones to indicate that the incident has been resolved.

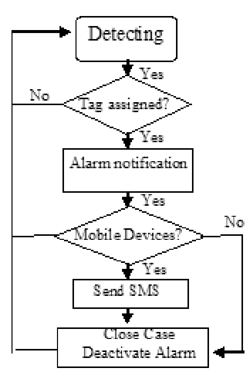

Fig. 6. Algorithm. Flow Chart

III. IMPLEMENTATION AND VALIDATION

The implementation and validation process has been carried out in 3 stages:

A. Stage 1: validation at laboratory.

Multiple system trials were carried out on a laboratory prototype in order to assess the system's technical characteristics and reliability, as it has to operate efficiently for 24 hours a day given the service it provides (ensuring the safety of its users). Amongst these we can highlight the *average time between failures* which is approximately one month, the *average maximum reading distance* which is about 35 cms, and the *percentage of success* in the detection of the tags, higher than 95%.

B. Stage 2: Practical testing.

Due to the positive results obtained in the laboratory tests, the system was installed in a home as a pilot scheme for a period of approximately 1 month, allowing its real use by the residents and professionals. This period proved extremely informative in terms of feedback from its users which led to modifications to its operation whilst leaving the system architecture almost untouched.

Many tests were carried out to ensure a correct working of the system. In the beginning, a professional wore a user device to test the reliability, and he was able to check that every time he went through a monitored area, the system reacted. Finally, about seven elders were provided with tags, and under the watchful eye of the professionals, the system was validate due to the percentage of success in detecting when elders went through was 100%.

C. Stage 3: Volume Implementation.

After the practical testing period, the system was installed in 18 elderly people's homes belonging to the Andalusian government, monitoring more than 70 areas, and over 100 users with spatial disorientation problems.

The system has been in operation for over a year in some of the homes with more than 200 detections in control areas, thus avoiding the risks incurred by the possible straying of people with a lower physical-spatial awareness.

The system has been monitored closely since it was installed and only few times a not working incidence has been reported, and most of them have been due to power cuts, or simultaneous readings. Some problems were detected with interferences generated by some devices, as industrial washing machines, that worked in the same frequency as the reader. The effect was that the reading distance decreased depending on the distance between the reader and the device. This problem was solved filtering the noise in the transmitter device.

Anyway, taking account this incidences the average of success is higher than 95%, notifying more than 200 events in all homes.

IV. CONCLUSIONS

Having analysed the tests carried out, and the results obtained in those homes where the system has been installed, such as the percentage of success that is higher than 95% in the detection of the tags, the reading distance which is higher than 30 cms, and a great reliability, that ensure a correct working of the system for at least one month. We can state that, even knowing that the system can be improved avoiding interferences and providing it with UPS (uninterrupted power supply), the use of the system provides a series of advantages that by increasing safety it allows an improvement in the quality of life of dependant people, their family and carers. Technically, the system has been found to be efficient, detecting a high percentage of the movements, and has proven sufficiently independent to operate correctly without being supervised. The system has also proven to be user-friendly. Therefore, the system is being assessed in a favourable way by external institutions to include it in their elderly people's homes.

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