MULTI-MODAL PLATFORM FOR IN-HOME HEALTHCARE MONITORING (EMUTEM)

Wided Souidene, Dan Istrate, Hamid Medjahed
ESIGETEL – LRIT, 1,Rue du Port de Valvins, 77210 Avon, France

Jérôme Boudy, Jean-Louis Baldinger, Imad Belfeki, François Delavault
EPH/Telecom Sud Paris, 9, Rue Charles Fourier, 91011 Evry, France

François Steenkeste
INSERM U558 Toulouse France

Keywords: Telemedicine, Design and development methodologies for Healthcare IT, Interoperability, Semantic interoperability, Databases and datawarehousing, Datamining, Support for clinical decision-making, Wearable health informatics.

Abstract: This paper describes a multimodal platform dedicated to in-home healthcare monitoring. This platform consists in three heterogeneous and complementary systems which are designed to provide a sense of safety and connectedness for those being monitored. In this article we present a detailed description of the multiple sensors used to remotely monitor elderly or a patient health. These are: a set of microphones suitably placed in the home, a wearable device and a set of infrared sensors. This platform is remotely used by the medical staff in order to help them to take the right decision about the patient and/or elderly situation. It has a couple of great advantages. First, its good acceptance by the end-users since it is less intrusive than other healthcare systems. Second, it is reliable and robust since it performs the fusion of outputs of three complementary healthcare systems.

1 INTRODUCTION

The proportion of elderly is increasing in all societies throughout the world. As they are becoming older, they want to preserve their independence, autonomy and way of life. It is therefore our duty of scientists to provide the necessary devices to allow them to live at home while being safe and in good condition. Thus, several research teams have developed a number of systems for in-home healthcare monitoring and prevention towards day life risks. These systems are based on the deployment of several sensors in the care receiver home in order to prevent and/or detect critical situations. They offer the comfort and independence of staying at home, the security of daily monitoring and proper medical attention. However, there are few reliable systems capable of preventing critical situations of the elderly before it takes place. In particular, rare or not reliable are the systems which predict or detect the fall of the person with good sensitivity and good specifity.

To provide one answer to this problem, we assembled a group of researchers from different background within a consortium (QuoVADis Cf. Acknowledgment) in order to develop a platform for several uses and to meet the needs identified above. The platform developed within this project manages a system consisting in:

- A set of microphones disposed into the living rooms of the home of the elderly.
- A portable device that can measure ambulatory pulse heart rate, detect posture and possibly the fall of the person equipped.
- A set of infrared sensors that detect the presence of the person in a given home part

Souidene W., Istrate D., Medjahed H., Boudy J., Delavault F., Baldinger J., Belfeki I. and Steenkeste F. (2009).
MULTI-MODAL PLATFORM FOR IN-HOME HEALTHCARE MONITORING (EMUTEM).
In *Proceedings of the International Conference on Health Informatics*, pages 381-386
DOI: 10.5220/0001780603810386

and also the standing posture of the person in question.

The output of these three heterogeneous systems are collected, processed and fused through a multimodal platform (EMUTEM).

In this article, we propose a detailed description of the multimodal platform called EMUTEM which could have several uses among them Telemedicine, healthcare and monitoring. This platform provides a sense of safety and connectedness for those being monitored. It also reassures the care-receiver family and gives them some peace of mind. It could also be arguably less expensive than the cost of live-in helpers and caregivers. The proposed platform collects and analyses the output of three distinct systems and makes a fusion of 3 modalities in order to help medical staff to take the right decision about the monitored person situation.

In the following, we describe in section 2 the operation of each system above and we detail the configuration of the EMUTEM platform. In Section 3, we analyze the process of data acquisition. Finally, we present our findings and perspectives.

2 MULTI-MODAL PLATFORM FOR IN-HOME HEALTHCARE MONITORING

It was found that the fall is one of the major causes of death among the elderly. In France, people aged 65 and over are victims each year of 550 000 accidents with recourse to emergencies. They account for more than three-quarters to 20 000 deaths annually from Normal Day Life Accidents (NDLA). A large majority of these NDLAs are the result of falls.

Faced with this scourge identified as hazardous to health, safety and lives of the elderly, we tried to develop a system of in-home healthcare monitoring to prevent and detect a fall. We brought together the efforts of three teams to establish a multimodal platform. The platform manages three heterogeneous systems: a sound system, a portable device and infrared sensors. Figure 1 shows a proposed set of sensor to be installed at home.

In the following each one of these systems will be described and its contribution to the whole healthcare monitoring system will be emphasized.

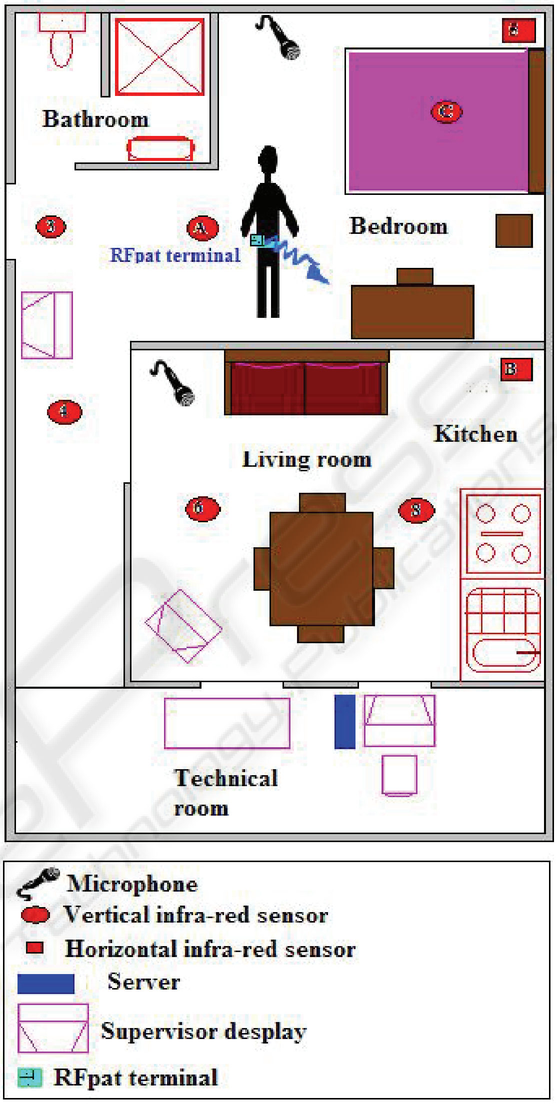

Figure 1: In-home sensor disposal.

2.1 The Wearable Device (RFPAT)

The wearable device named RFPAT consists in two fundamental elements (Figure 2):

- A mobile terminal: This is a waist wearable device that the patient or the elderly clips, for instance, to his belt all the time he is at home. It measures the person's vital data and transmits to a reception home station. In this article we will use the denominations wearable device, mobile device, mobile terminal indifferently to address the mobile terminal.
- A fixed reception base station: This is a receiver connected to a personal computer

(PC). It receives vital signals from the patient's mobile terminal,

All the data gathered from the different RFPAT sensors are processed within the wireless wearable device. To ensure an optimal autonomy for the latter, we designed it using low consumption electronic components. Namely, the circuit architecture is based on different micro-controllers devoted to acquisition, signal processing and emission. Hence, the mobile wearable terminal encapsulates several signal acquisition and processing modules:

- It records various physiological and actimetric signals
- It pre-processes the signals in order to reduce the impact of environmental noise or user-motion noise.

This latter point is an important issue for in-home healthcare monitoring. In fact, monitoring a person in ambulatory mode is a difficult task to achieve.

For the RFPAT system, we made the choice to come up with the noise problem in the acquisition stage. Then, some digital noise reduction filters and algorithms were implemented within the portable device. These filters and algorithms were applied respectively to all acquired signals: movement data, posture data and namely the pulse signal (heart rate).

Movement data describes the movement of the monitored person. It gives us information like: 'she is lying', 'she is immobile', 'she is sitting/standing up' etc. Movement data consists also in the percentage of movement, it computes the total duration of the movements of the monitored person for each time slot of 30 seconds (0 to 100% during 30 seconds). The posture data is information about the person posture: standing up / laying down.

The posture data is a quite interesting measurement which gives us useful information about the person's activity. Thanks to an actimetric system embedded in the portable device, we can detect the situations where the person is approaching the ground very quickly. This information is interpreted as a 'fall' when the acceleration goes through a certain threshold in a given situation.

The pulse signal is delivered by a photoplethysmographic sensor connected to the wearable device. After pre-conditioning and algorithmic denoising it gives us information about the heart rate every 30 seconds.

In the ambulatory mode, the challenging process consists in noise reduction. In (Baldinger, et al. 2004) we afford to reduce the variations of pulse measurement lower than 5% for one minute averaging, which remains in conformity with the recommendations of medical professionals.

Data gathered from the different sensors are transmitted, via an electronic signal conditioner, to low power microcontroller based computing unit, embedded in the mobile terminal.

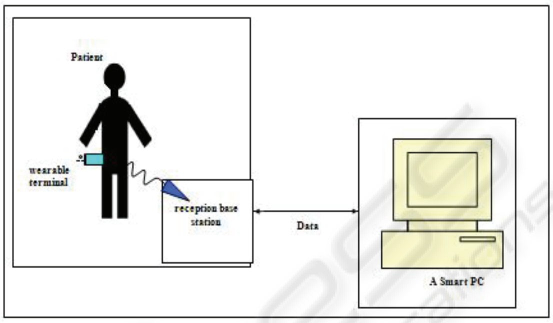

Figure 2: RFPAT module configuration.

Currently, a fall-impact detector is added to this system in order to make the detection of falls more specific.

2.2 The Smart Sound Sensor

In-home healthcare devices face a real problem of acceptance by end users and also caregivers. Sound sensors are easily accepted by care receivers and their family, they are considered are less intrusive then cameras, smart T-shirts, etc… In order to preserve the care-receiver privacy while ensuring his protection and safety, we propose to equip his house with some microphones. In this context, the environmental sound is not continuously recorded. This microphone array allows sound remote monitoring of the acoustical environment of the monitored person. The main advantage of this system consists in carrying in real time (Istrate, et al. 2006a). Hence, we continuously 'listen' to the sound environment in order to detect distress situations and distress calls. This smart sound sensor described in (Istrate, et al. 2006b) is made up four modules as depicted in Figure 3.

2.2.1 M1 Module: Sound Event Detection and Extraction

The first module M1 listens continuously to the sound environment in order to detect and extract useful sounds or speech. The signal extracted by the M1 module is processed by M2 module.

2.2.2 M2 Module: Sound/Speech Classification Module

The second module M2 is a low-stage classification one. It processes the sound received from module M1 in order to separate the speech signals from the sound ones.

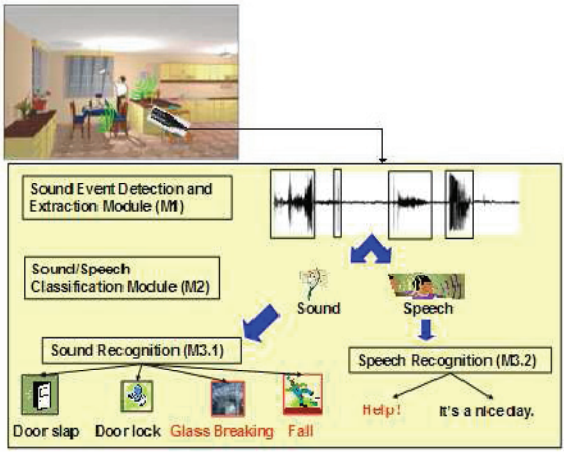

Figure 3: ANASON smart sensor.

2.2.3 M3 Module: High-stage Classification

This module operates within each class determined by the M2 module. It consists in two sub-modules. In the case of sound label attributed to the signal by module M2, the sound recognition sub-module M3.1 classifies the signal between eight predefined sound classes. In case of speech label, the extracted signal is analyzed by a speech recognition engine in order to detect distress sentences (M3.2 module).

For both cases, if an alarm situation is identified (the sound or the sentence is classified into an alarm class) this information is sent to the data fusion system. This is done in order to check whether the other sensors (RfPat and Gardien) detected or not an alarm.

2.3 The Infrared Motion Sensor (GARDIEN)

The in-home healthcare monitoring systems have to solve an important issue of privacy. When developing our multi-modal platform, we chose the monitoring modules such that they have the less intrusive incidence on the monitored elderly (Banerjee et al., 2003). We equipped our test apartment with infrared sensors which have two functionalities:

- Localize the person at home: the sensors are activated by the presence of the person in a certain room. Only the living rooms and the bedroom are equipped.
- Detect the vertical position of the person: A specific infra-red sensor is installed in the living room and/or the kitchen in order to detect whether the monitored person is standing up or not. Actually it detects movement in a fixed altitude of one meter and a half.

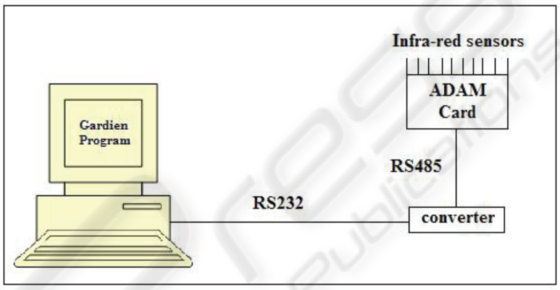

Figure 4: GARDIEN system.

The second functionality is quite useful in order to confirm or infirm a fall detection from the RFpat or the ANASON module. These sensors and the software and hardware which is used to perform the localization and the vertical position detection is called GARDIEN (Steenkeste. et al., 1999). Figure 4 represents the GARDIEN system.

2.4 General Interface of the Multimodal Platform (EMUTEM)

In order to configure and manage the three modalities above described, we developed a platform which has different functionalities and that could be easily used by a caregiver or even by several members of the monitored person family. Now, this platform is only used to control and synchronise the different data acquisition processes. The front panel of the developed platform is presented in Figure 5.

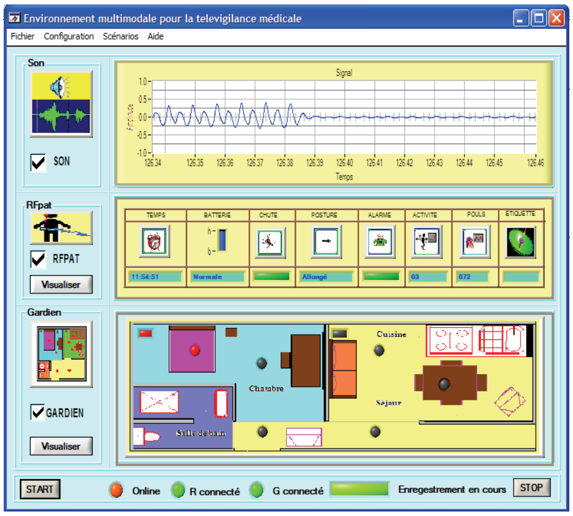

Figure 5: EMUTEM platform front panel.

Thanks to this platform, the platform manager can supervise the multimodal data acquisition stage.

The platform manager must first select the modality to record and then configure its parameters if needed. For RFpat and Gardien systems, we only need to specify the IP address and the TC/IP port number. For ANASON sensor, we need to select the sound card to be used for data analysis and recording (if several ones are available). We also specify the sampling rate and the location of the backup file. For a final target use, this configuration is only done once during the very first time the system is installed in the patient's or the elderly home.

3 DATA ACQUISITION

3.1 Data Acquisition Protocol

Data acquired using the different systems described below is stored on the embedded Master PC within a folder which has a specific name. For our case, we attribute to the folder a name which is an identification code number for the patient. Each recording consists in five files corresponding to the different modalities. These files are:

- A personal table named personnel.xml, contains the patient's identifier and some personal information like age, native language, usual drugs treatment...etc. All these data relative to the care-receiver are protected for his privacy and their use and transmission is let to his agreement.
- A descriptive file named scenario.xml, describes the reference scenario. This file is stored during the test phase of the platform. It is used further to analyse the performance of each modality.
- A sound file which contains sound data saved in real time, in a wav file with 16 bit of resolution and a sampling rate of 16 KHz, a frequency usually used for speech applications.
- A clinical data file which contains physiological and motion data acquired from RFpat. It stores information about patient's posture (laid down or upright/seated), his agitation (between 0% and 100%), his cardiac frequency, fall events and emergency calls. The acquisition sample rate is 0.03 Hz.
- A motion data file acquired every 500 ms by Gardien subsystem and saved in a separate text adapted file format. Each line of this file contains the infra-red sensors which are excited (they are represented by hexadecimal numbers from 1 to D) and also the corresponding date and hour.

As the acquired signals corresponding to the different modalities (ANASON, RFpat and Gardien) have different sample rates, we developed a synchronisation procedure in order to make the acquisition protocol synchronous. This operation is depicted on Figure 6. It uses the TCP/IP Protocol. The RFpat modality is launched first, because of his low acquisition rate. Then, supervisor software launches Gardien and Anason applications with TCP/IP commands (Figure 6).

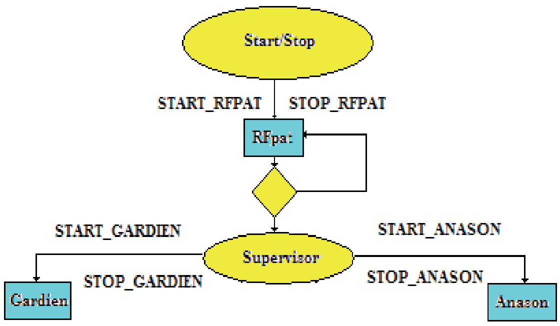

Figure 6: Synchronisation operation between our three proposed modalities.

3.2 EMUTEM Database Recording

In order to precisely evaluate the performance of EMUTEM platform, we first use it to record a multimodal medical database. Our multimodal database acquisition software described below provides a very helpful and well-targeted application to elaborate and assess the data fusion-based decision methods. The low level data recorded by our system will be useful for the development of each modality processing algorithms and their combination strategies.

In order to index our multimodal database, we have retained the SAM standard indexing file (Well, et al., 1992) generally used for Speech Databases descriptions. The SAM labelling of a sound file indicates information about the file and describes it by delimiting the useful part to be used for file content analysis and processing. For each modality of the database a corresponding indexation file is created, we have adapted this type of files to the specificity of each modality, and we have added another indexation file for the entire database. This conceptual indexation model is guided by a-priori knowledge and the reference scenarios. This aims to obtain the reference information for our Multimodal Database, and therefore to generate a novel type of database to validate different modality signal processing techniques and approaches of multimodal data fusion algorithms.

Nowadays, we have enriched our database with several scenarios played by actors. We already have the permission of a smart home designer to install our platform in his facilities which are apartments with elderly people living in. This will allow us to better evaluate our developed system and record real data.

4 CONCLUSIONS AND FUTURE WORK

During this first step of our collaborative research work, we developed a multimodal platform which performs in-home healthcare monitoring and especially distress situation detection and prediction. We put together three different modalities in order to ensure elderly person security in comfortable, non-intrusive way. We propose a wearable device able to acquire and process physiological signals, a smart sound sensor which analyses the environmental home sounds in order to detect distress situations and sentences and an infrared sensor array which localizes the person at home and detects her vertical position.

Nowadays, we are developing several techniques in order to fuse different inputs of these systems. Our ultimate target is to make this in-home healthcare system more robust towards false alarms and non detected hazardous situations. This platform could help medical staff to take the right decision about the person situation even if they are distant.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of French National Research Association (ANR), QuoVADis Project.

REFERENCES

Baldinger, J., Boudy, J., Dorizzi, Levrey, J., Andreao, R., Perpre, C., et al. (2004). Tele-surveillance system for patient at home: The medeville system. *ICCHP.*

Banerjee, S., Steenkeste, F., Couturier, P., Debray, M., & Franco, A. (2003). Telesurveillance of elderly patients by use of passive infra-red sensors in a smart home. *Telemed-Telecare.*

Istrate, D., Castelli, E., Vacher, M., Besacier, L., & Serignat, J. (2006a). Information extraction from sound for medical telemonitoring. *IEEE Trans. on Information Technology in Biomedecine*, (pp. 264-274).

Istrate, D., Vacher, M., & Serignat, F. (2006b). Generic implementation of a distress sound extraction system for elder care. *IEEE EMBS*, (pp. 3309-3312). New York.

Reynolds, D. (1995). Speaker identification and verification using gaussian mixture speeker models. *Speech Communications* , 91-108.

Schwarz, G. (1978). Estimating the dimension of a model. *Annals of statistics* , 461-464.

Steenkeste, F., Bocquet, H., Chan, M., & Vellas, B. (1999). Remote monitoring system for elders in a geriatric hospital. *International Conference on aging.* Arlington.

Well, D., Barry, J., Grice, W., Fourcin, M., & Gibbon, A. (1992). *SAM ESPRIT PROJECT2589-multilingual speech input/output assessment, methodology and standardization.* University College London: Final report. Technical Report SAM-UCLG004.