A Multimodal Corpus Recorded in a Health nursing home


* LEGRAND, DIST Research Departement, Limoges France
  Toufik.Guettari@legrand.fr, Pascal.Dore@legrand.fr
** Institut Mines Telecom, EPH Department, Evry, France
  jerome.boudy@telecom-sudparis.eu, jean-louis.baldinger@telecom-sudparis.eu, badr-eddine.benkelfat@telecom-sudparis.eu
*** ESIGETEL, Villejuif, France
  dan.istrate@esigetel.fr

Abstract. In the last few years, a series of technological developments has given some new options for health monitoring system. Internet-based solutions are becoming available that allow caregivers to keep an unobtrusive, high-tech eye on elderly, ensuring that they’re safe, healthy and well cared for\(^1\). In this article, we start by categorizing supervision systems and highlighting some implemented systems. Next, we describe the equipped rooms in the nursing home in which we recorded our multimodal data base so we depict PERvision platform (hardware and software part) installed in our trial site called GIS Madonah\(^2\). In the next section, we expose our study of methods to clean and filter data stored trough PERvision platform and exhibit our approach to extract useful information from this recorded data. Finally, we describe a supervision system which exploits information generated by anonymous, binary sensors, particularly those employed by security systems such as motion. This monitoring software consists in analyzing human behaviors and looking for changes in their habit.

Keywords: Monitoring System, Actimetry, Healthcare, Binary Sensor, Unobtrusive Sensor, Non-Intrusive System.

\(^2\) http://www.bourges.univ-orleans.fr/madonah/

Studia Informatica Universalis.
1. Introduction

As the will is to keep the elderly population well-being and socially connected, while reducing the strain on healthcare infrastructure, the demand of indoor Location-Based Services increases and a number of solutions are proposed by scientific community in order to address the localization issue inside a building. A growing interest in developing an accurate tracking system appears recently and rapid advances in both sensor and telecommunication technology promote monitoring systems which become increasingly popular in recent years. Unobtrusive supervision systems have been made feasible by a reduction of the size of monitoring sensor and recorded/transmitting hardware. Diver supervision systems have been implemented utilizing these hardware developments which are coupled with many wired and wireless telecommunication options now available [KPG03].

A monitoring platform is composed of two parts: hardware part and software part. We have classified monitoring sensors (hardware) into three categories: installation sensors corresponding to sensors which can be incorporated in electrical installation such as motion sensor, contact sensor; wearable sensors correspond to sensors which can be wearied by care receiver such as watch, neck, Rfpat (Belt) ... Mobile sensors correspond to sensors which cannot be wearied permanently by care receiver and cannot be incorporated on electrical installation such as blood pressure, balance, oximeter, robot...

We have also classified supervision application (software) into two classes: passive supervision application is a software witch extract macro data and relay on an ergonomic interface in order to aid the care-

![Figure 1: Monitoring models and hardware and software classification](image-url)
giver to interpret the data; active supervision application is a software witch relay on decisional model (expert system or statistical model) in order to produce explicit information toward caregivers.

2. Previous Work

Based on preceding and related works released through multiplicity of researches and a variety of approaches, numerous laboratory teams are currently working on health monitoring subject.

As mentioned ahead, we distinct two software categories (passive and active software) and three hardware platform classes (installation, wearable, and mobile sensors). In stat of the art, the researchers started by using installation sensors in order to implement a passive software.

In 1994, the first supervision system using binaries sensors to estimate care receiver’s mobility was implemented by Celler.B.G etal. [CHEI94] at the University of N.S.W., Sydney, Australia. This system relay on infrared sensor and magnetic switch contact to localize a specific area of the room in which the observed patient was. Fusion with sonor signal permitted to determine the activity type of the care receiver. Power-line communication is used to collect data and the telephony network enables the platform to transmit the gathered data generated by different sensors toward the end users.

In 1995, Chan et al. have developed a system in which hardware part exploit passive/active infrared sensors to monitor presence/absence and mobility of the observed person. Concerning the software part, it relay on An Artificial Neural Network (ANN) to make a right decision in case a major discrepancy occurs relative to care receiver’s habit. In this study, it has been assumed that the elderly lives alone in his/her bedroom with repetitive and identifiable habits that form the basis of the diagnosis.

In 1997, japans team [YOTT98] has utilized infrared sensors to retrace daily person’s displacement and exploited physiological sensors as CO2 level to determine a subject’s presence/absence in the room.

Combining hardware classes with software categories, divers monitoring systems have been implemented using a variety of monitoring
devices and sensors. These supervision platforms have been classified by Korhonen et al. into two models the wellness & disease management model and the independent living & remote monitoring. The first class covers systems in which caregivers actively participate in the measurement and supervision of their condition and the medical personnel play a supporting role.

As chronically ill patients are out of scope, except the elderly surfing from Alzheimer’s disease and cognitive deficiency, our supervision system takes part of the second model according to Korhonen’s classification, so the platform minimizes user’s intervention for measurements and does not use medical equipment.

3. Sensor Choice and Software Option

Our objective is to set up a non-intrusive supervision platform using minimally sensors which are already installed and easily incorporated on electric installation of resident. Therefore we use anonymous, binary sensors, particularly those employed by security systems. According to Korhonen et al. classification our monitoring system takes part of the fist model.

The Software which is under development offer two options, the first one consist to post filtered data in order to help end user to take judicious decision. This option consider deferent forms to access and represent data so the software attribute for each end user a specific profile which permit him to navigate and consult needed information. This aspect allows distinguishing between end user’s qualifications and interest. The second option of the software consists to generate instantly a right decision in case of emergency.

4. Description of the equipped flats in nursing home

We have used two rooms in Embazac nursing home, first one "Ch101“ is occupied by a men having more than 80 years old and the second one "Ch102“ is in use by a women having more than 73 years old.
The two flats have the same architecture, composed of bedroom and bathroom and it shares a one technical room in which we have installed our recorder and monitoring computer.

We have installed three infrared sensors in the bedroom: ‘Lit haut’, ‘Lit droit’ and ‘Lit gauche’ infrared. One infrared is installed on ceiling in the bathroom: ‘WC’ infrared and a ‘SAS’ infrared fixed just at the entrance of the flat.
5. **Sensors installation**

'Lit haut' infrared sensor is installed to detect a person’s movement when the subject is standing.
6. Acquired corpus

We have developed software to generate an "Ambulatrogram" of the daily infrared database recorded in both flat. This application allows us to visualize the time series generated by infrared sensors per flat each day.

7. Annotation

As we have not been allowed to install a camera, we have used a microphone in order to label our infrared database. Manually, we have described all activities produced in the two flat during a day and a night.
8. Methodologies

In order to detect alarm or prevent emergency, our approach relay on different levels of treatment. Then we opt for four software levels, each level is composed of at least one module.

9. Data preprocessing level

This level is composed of one module which clean and prepare data. We have integrated open source software usually used in Business Intelligence (BI) field which is Pantaho Data Integration (PDI). This software called ETL tool permit us to Extract, Transform and Loading data on a clean database. PDI is configurable and we have easily incorporated our own rules in order to choose useful data.
As we use this level consists to eliminate all errors generated by hardware installation.

10. Filtering data level

The problem of person tracking is addressed at this level. Using infrared sensor to localize the CR, it is difficult task when there is more than one person at home. The Bayesian filter used by Wilson requires a score of infrared installed on ceiling in order to raise a granularity of infrared’s mesh. As we are interested by localizing and tracking person in nursing home, we have a considerable overlap between infrared’s area, except bath room’s infrared. Therefore we have chosen to start using a method based on activity level in order to discriminate between two classes: one person in room class or more than one person class. The second step consists to track the subject alone in the room.
As we want to implement an unsupervised and an adaptive algorithm, we have chosen to use a k-means classifier and k-nearest neighbor (KNN).

11. Modeling and pattern identification

Once we have filtered our database, we proceed to identify a pattern of resident’s displacement in this level. Therefore we have used a transition matrix to learn a model of person’s displacement.

\[
M = \begin{pmatrix}
    p_{11} & p_{12} & p_{13} & \cdots & p_{1j} \\
    p_{21} & p_{22} & p_{23} & \cdots & p_{2j} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    p_{i1} & p_{i2} & p_{i3} & \cdots & p_{ij}
\end{pmatrix}
\]  

(1)

M is the transition matrix.

The main step of the algorithm are presented in the following.

Initialization

In order to initialize the transition matrix, we consider the hypotheses H1, H1: transition probabilities between regions (zones) are inde-
Figure 14: Different activities deducted using manually sounds files recorded

Figure 15: Different levels which compose monitoring software

Pendent with regard to the time. Therefore if the transition between two zones $i$ and $j$ is possible without passing by another zone, then the probability is upper than zero.

$$M(i,j) = P_{ij} = \frac{1}{Q \sum_{j=0}^{Q} Nearest\_Area_j}$$  \hspace{1cm} (2)

where $Nearest\_Area_j$ has a binary value

\begin{align*}
\{ 1 & \quad \text{if the Area}'t' \text{ is situated on border of the area } j \\
0 & \quad \text{otherwise}
\end{align*}

and $Q$ is the total number of areas.
Learning

In order to learn a transition matrix we have estimated its elements $P_{ij}$.

\[
\hat{P}_{ij} = \frac{\text{Transition from } S_i \text{ to } S_j}{\text{Transition from } S_i} = \frac{\sum_{k=1}^{K} \sum_{t=1}^{T-1} (s_k^t, S_i)(s_{k+1}^t, S_j)}{\sum_{k=1}^{K} \sum_{t=1}^{T-1} (s_k^t, S_i)} \quad (3)
\]
Once we have learned the transition matrix, we can predict care receiver’s displacement. A difference between infrared localization and area predicted will be used to detect an abnormal behavior.

12. Conclusion and Perspectives

As we have not a lot of area in ‘101’ room in Ambazac’s nursing home, we have used our system to detect unary infection. For that we need to use 3x3 matrix transition. Once our matrix was learned we can detect an abnormal displacement between three areas: SAS area, Bed area and bathroom area.

Toufik Guettari, is a Ph.D. student in signal processing at Télécom SudParis, Evry, France. He has defended his Master 2 degree at Université de Versailles Saint-Quentin-en-Yvelines in collaboration with Conservatoire National des Arts et Métier Paris and Télécom et Management SudParis, Evry in 2009. He is with the Research Laboratory at LEGRAND/DIST/Recherche, Limoges, France. His main domain of research is multimodal data fusion. He has participated into the National project QuoVADis (TecSan2008) and the European project CompanionAble (FP7) as Research Engineer in Télécom SudParis, Evry.

Jerome Boudy, (PhD 1988, Uni. Nice, area: Adaptive Filtering for Underwater Acoustics Signal Processing). In 1988, he joined the Speech Processing Department of Matra Nortel Communications in 1988 where he has worked on Speech Recognition area and adaptive filtering.
applied to hands-free communications. On February 2001, he joined the Telecom branch of Philips Group in Le Mans, for RD on Speech recognition. In January 2002, he joined Telecom SudParis as associate professor in Signal processing for the Electronic and Physics Department: he was actively involved in French ANR TecSan-funded projects on remote Healthcare vigilance projects (TelePat, TANDEM, and QuoVadis) for Elderly persons where biomedical signal processing, pattern recognition and multichannel data fusion are his main research areas of interest. He is also involved in the current IST-FP7 CompanionAble project (IP) since January 2008 (combined concept of CompanionRobot and smart Home sensors network for Elderly persons).

Dan Istrate, received his Habilitation to supervise PhD Students (HDR) in 2011 from University of Evry Val d’Essonne and he has defended his Ph.D. degree in signal processing from the Institut National Polytechnique Grenoble (INPG), Grenoble, France, in 2003. He is the Research Laboratory Head (16 researchers) at Ecole Supérieure d’Informatique et Génie des Télécommunications (ESIGETEL), Fontainebleau, France, responsible also of the embedded system for e-Health teaching specialty. He is involved in embedded systems for sound analysis and processing (sound recognition) and in multimodal data fusion. He has participated to 5 National, 1 European and 2 International Projects like: CompanionAble (FP7), QuoVADis (TecSan2008) and Sweet-Home (VERSO2009). He supervises 4 PhD students.

Jean Louis Baldinger, is electronics engineer and obtained his degree at ENSEA school (Cergy-Pontoise, France), specializing in telecommunications, in 1976. He assumed responsibility for regional facilities and maintenance of radio transmitters for paging, then took responsibility for a team of research and development for public radio networks and provided the technical responsibility of a management service of frequencies for private radio networks to the Direction of Externals Telecommunications Networks (General Direction of Telecommunications) until 1983. It is then responsible for teaching and research (Associate Professor) in electronics and signal processing in the Department of Electronics and Physics (Telecom SudParis - Institut Telecom) since 1983. Since 2002, he assumes especially responsibility for development of very low power embedded solutions (embedded electronics and algorithms) for remote monitoring of patients at home. He has contributed and taken responsibility for sub-projects in French national projects (Mdiville, TIPat, Tandem, QuoVadis) and European (CompanionAble).

Pascal Doré, né en 1960 Maîtrise EEA (Université d’Orléans), il est entré chez Legrand en 1990. Après avoir exercé différentes fonctions au sein d’une unité de production de produits électroniques, il rejoint l’équipe Recherche technologique du groupe Legrand. Ses investigations initiales portent sur l’innovation dans l’installation électrique par l’intégration
d’électronique dans ses composants de base. Elles évoluent ensuite vers l’assistance à l’autonomie. Cela consiste à mettre en œuvre et utiliser les technologies de l’installation électrique et des réseaux de communication pour procurer de la sécurité, du confort et du lien social aux personnes âgées ou à des personnes fragiles. Cette activité s’exerce essentiellement via la participation voire le montage de différents projets de Recherche collaboratifs portés par le pôle de compétitivité S2E2 dont il est membre du CA depuis 2005.

References

