Help with monitoring of elderly by using physical activities criteria

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***Abstract*— This article presents the deployment of a continuous monitoring system for the elderly. The persons concerned live in a medicalized retirement home in a rural area. This study is part of a national experiment using satellite communication links for remote monitoring. After a brief description of the infrastructure, the paper exposes the first results obtained for help with medical diagnosis based on the subject's activity through learning his lifestyle. Some time slots are highlighted in which normality thresholds of behavior are defined. The excess of these thresholds allows reporting of a deviant behavior or a high risk situation for the subject.**

I. Introduction

DEPENDENT people in industrialized countries all over the world are increasing in number. Improving the quality of life for elderly and disabled persons is becoming an essential task for society today. To maintain these people as much as possible at home with a high quality of life, many past or current researchers have lead with the principal objective of proposing assistive technological solutions based on the life activities measurements and danger situations [1-7]. Many indexes are used to measure the autonomy state, as, for example, the Activities Daily Living (ADL) score [8]. These scales evaluate as correctly as possible the degree of dependence to assess the autonomy centered on the person and to evaluate the cost of dependence. When dependence exists, we need to continuously monitor all deviances and risk situations and try to avoid dramatic issues [9]. Falls, wandering, running away, sleep agitation, and prolonged duration in places need to be monitored because they can identify changes in functional health status. In all cases, it is important to automatically prompt appropriate, timely and cost-effective medical intervention. In rural areas or isolated regions, telemonitoring is considered as a tool that could exert a more positive impact on health care services delivery [10]. For example, although the system is not meant as an emergency prompt system, the caregiver may receive alerts or urgent notifications in case of sudden accidents indicating changes.

Manuscript received April 30, 2008. The work presented in this paper has been possible thanks to the experimentation conducted in OURSES project which is supported by the French Ministry of Industry and by EDF R&D Company.

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In this work, an activity monitoring system has been deployed to continuously monitor the activity pattern for the elderly who are living alone in a Host Institution for Dependent Elderly. Indeed, because of the low number of caregivers, especially during nights, there is need for a technological aid. One problem in these institutions is the isolation of the medicine and physician. Thanks to satellite communication, the relationship between the patient and his physician will remain active [11]. Moreover, it reduces the consequences of the digital divide and allows continuity in the monitoring of fragile people.

After a description of the material architecture of the platform developed, we describe the methodology used, which is based on specific activities criteria such as speed of motion, distance covered and time spent in given zones of a living environment for monitoring physical capacities. Using the appropriate data analysis tools, important observations can be made from the activity data generated by the monitored individual. These observations include physical behaviour, activity levels and deviance calculation. These observations may yield early indicators of the onset of a deficient motor behaviour or disease. Additionally, a sudden change of activity (or inactivity) can indicate an incident.

II. Material and Methodology

A. *Architecture components*

The material architecture of the experiment consists of:

- Wireless infrared movement sensors (PIR) operating at ISM frequency band and with characteristics adapted: response time, standing time, bidirectional RF communication, remote configuration, autonomy of more than two years. These sensors implement a low data rate proprietary protocol.
- An ISM RF transceiver supplied by a transformer and connected to the computer by RS232 serial link. The range of radio transmission is up to 30m in the indoor configuration.
- An analysis computer to manage the sensors' network and to ensure the transmission of information to a remote physician's computer via internet protocol.
- Webcams embedded on the local and physician's computer. They allow to the nurse and doctor to establish a dialogue through a video/audio link.
- A Divona TW3 satellite access point (2024 kbps/ 512 kbps) was used during the on-site tests.

The configuration is shown in Fig. 1.

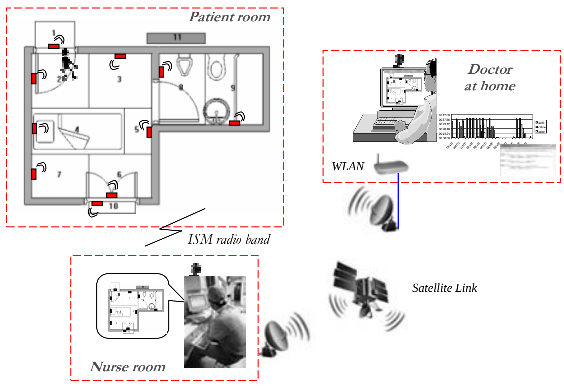

Fig. 1. Global scheme of behaviour telemonitoring using satellite link.

B. *Principle of monitoring*

The principle is to ensure a remote automated continuous monitoring. The main function concerns the behavior monitoring by following up actimetry which is representative of the health status of individuals. To do this, we used a low-cost and non-invasive wireless movement sensor network, described previously. The sensors are distributed on the ceiling of the living room of a subject in a medical institution [12]. These sensors define 10 detection zones to cover the life space (bedroom and bathroom) and provide digital output whenever the subject moves. They are connected to a local monitoring station to collect the patient's motion in real-time.

Processing algorithms based on statistical analysis allow modelling of the usual behavior of the subject and calculation of the threshold levels. These statistical analyses are based on past data from the sensors and are stored automatically. So, diagnosis of the situation can be established [13]: lack or changes of activities. The general approach is the following: if the time periods of lack or excess of activities in areas are over the threshold values, an alarm is set off for care providers. Software tools can also generate reports of activity indicators and establish the well-being of the individual. Moreover, the system will provide a confirmation of activity levels, thereby encouraging reality-based decision-making.

The central processing station localized at the local nurses' station is connected via satellite link to a remote doctor in charge of collecting alarms and associated data from home or from his medical practice.

C. *Method and analysis technique*

Elaboration of the habits model contains two distinct stages: a temporal classification of activities for the day coupled with a local division permitting a descriptive analysis of activities criteria. This division is performed by an automated analysis of an historical impulse log (sensor activation) from the last 30 days before the analysis.

The method of temporal activity classification uses a genetic algorithm combined with a descriptive statistical analysis that delivers temporal bands that characterize the lifestyle of the user. The algorithm is based on the evolutionary model of ranking type [14]. A performance function is defined as a representative of the adequacy of calculated time bands compared to the sensors' detection histogram recorded as historical data of 30 days [Fig. 2].

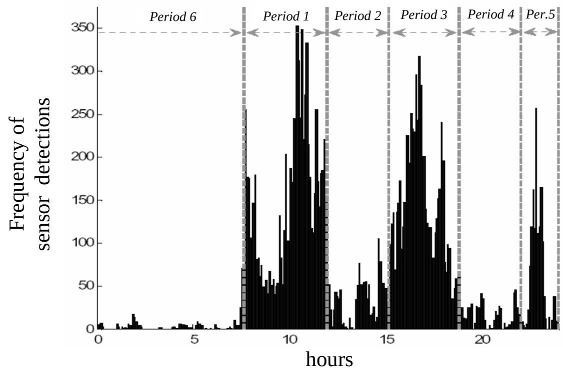

Fig. 2. Temporal division of a day.

This initial classification of temporal habits coupled to a local decomposition makes it possible to calculate, for each time of day and every area of the room, estimators corresponding to the different criteria [15]. These criteria are represented by a threshold's couple (maximum and minimum value) characterizing the normal activity. These values are used by the system to serve as a reference for help with medical diagnosis and incident detection.

D. *Diagnostic criteria*

The criteria are the interpretations that it is possible to make from only the movement information. Initially, the PROSAFE system [16] exploited immobility, agitation and presence criteria for detecting dangers. Here, we operate more with the time spent in areas, the speed of motion and the distance covered, testifying of the physical capacity of the individual.

Immobility is a criterion based on the lack of movement of the user in an area of his life space. We make the assumption that prolonged immobility of the user may be a sign of a fall, not well-being, and so on. Immobility is characterized by the difference between the time of the last sensor activation and current time.

Time spent criterion corresponds to the time spent by the user in an area of his dwelling. The presence time characterizes the occupational habits of each place of the living environment. It is defined as the moment when the user arrives in an area and the moment when he leaves it.

Agitation is based on the number of movement detections recorded in a ten minute period.

To measure distance covered by the user, at first all displacements of the user for each trajectory of 3 distinct areas (for example trajectory: "Zone 2 → Zone 3 → Zone 5" in Fig. 1) in a given period of time (30 days) are identified considering the speed of motion as constant (1m/s). The speed of motion is an interesting criterion because it reflects the physical capacity of the user. The speed of motion for a given trajectory can be calculated when the estimated distance is known.

E. *Detection thresholds*

To detect unusual behavior we are proposing to define the thresholds for two distinct classes: "usual" behaviour and "unusual" behaviour. The idea is to treat each area of the dwelling independently and to work on as many thresholds as areas. This provides more precision. For each diagnosis, the threshold values are calculated from the history of the 30 past days and filtered to improve statistical analysis. From this data sample, we deduce the parameters of a distribution following the Weibull law representing the probability density, and then calculate the minimum and maximum thresholds relating to the average.

III. RESULTS

A. *Incident detection*

The analysis of the results based on the criterion of immobility is presented in Fig. 3. Immobility durations of less than 2 minutes are excluded from the sample because only prolonged immobility plays a role in the detection of incidents, especially a fall. Fig. 3 presents the maximum calculated (horizontal segments) for one day from immobility observed in the preceding 30 days (light spots) and the observed immobility during the current day (black spots).

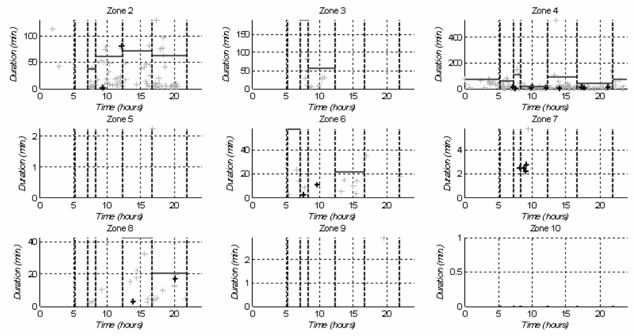

Fig. 3. Immobility time by temporal bands and for each area.

We note that all events are below the thresholds (horizontal bars) except for areas 4 and 10.

An example of statistical analysis based on the presence time is shown Fig. 4. The durations of stay less than 1.5 minutes are ignored in order to not take into account the low duration due to user movements. Fig. 4 shows the upper limit calculated (horizontal segments) for one day from presence durations observed in the previous 30 last days (light spots) and the duration of stay recorded during the current day (black spots).

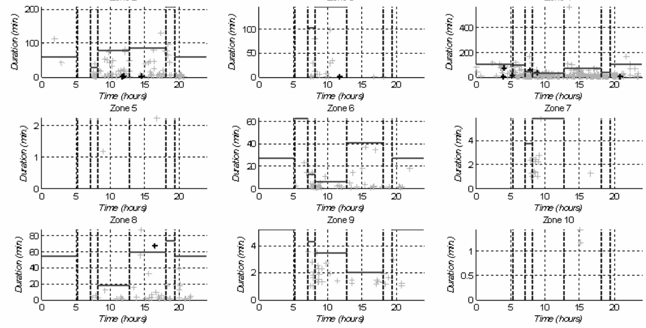

Fig. 4. Presence time by temporal bands and for each area.

In this example, we note that only 4 events exceed the threshold reference for a few minutes while the set of values remains lower and very close to the threshold.

Statistical analysis using agitation criterion is presented in Fig. 5. The agitation values of less than 5% are ignored because only the high values come into consideration in incident detection. Fig. 5 shows the upper threshold calculated (horizontal segments) for one day from agitation variations observed in the 30 previous days (light spots) and the agitation values observed during the current day (black spots).

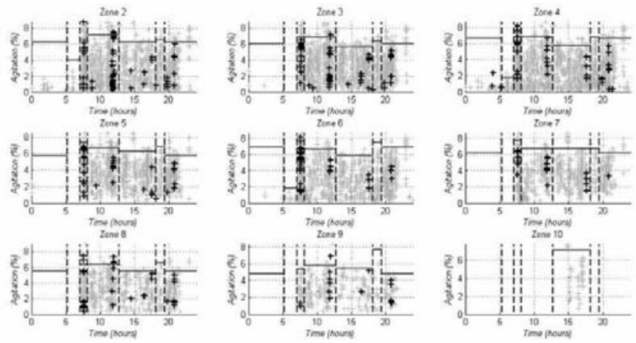

Fig. 5. Agitation level by temporal bands and for each area.

If the set of values are below the reference thresholds (many are superior to most areas between 12h and 14h), it's probably coming from caregivers daily involved with this person. These values could be filtered with an identification device.

Statistical analysis based on the relative distance criterion is shown in Fig. 6. Relative distances covered by the user combine all the displacements made by the user. Fig. 6 shows the minimum and maximum thresholds (horizontal segments) calculated for the current day from the relative distances calculated for the 30 previous days (bar graphs) and also the relative distances covered by the user throughout the current day (first vertical bar graphs).

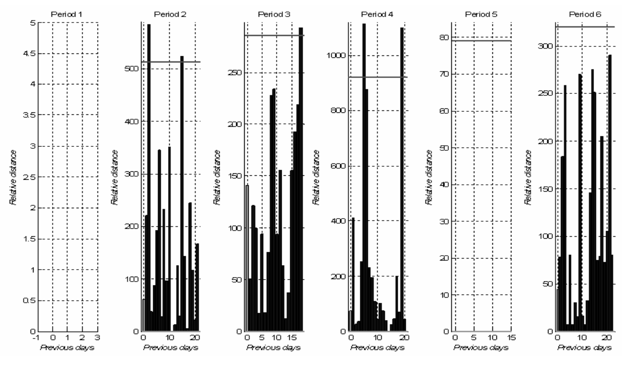

Fig. 6. Relative distance by temporal bands.

Distances are homogeneous and reference thresholds are in line with the limit values observed.

An example of statistical analysis according to the relative speed criterion of the user is shown in Fig. 7. It presents minimum and maximum thresholds (horizontal segments) calculated for one day from the mean relative speed calculated for the 30 previous days (light spots) and the relative speed performed by the user during the current day (black spots).

Except between 12h and 14h as a result of visits from aid caregivers, speed values are located in normal areas.

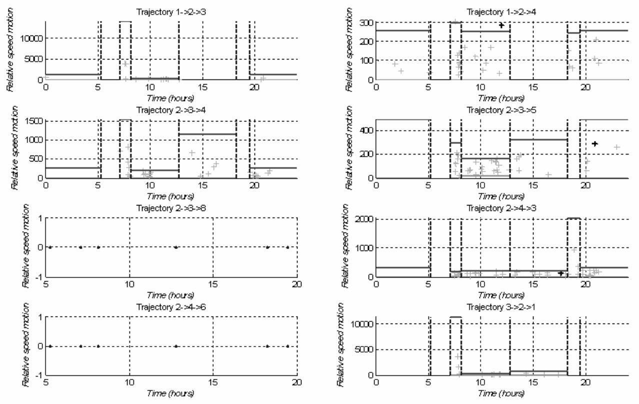

Fig. 7. Relative speed of motion by temporal bands and in function of trajectories.

B. *Help with medical diagnosis*

Based on new criteria incorporated into a fine modeling of habits to detect incidents in real-time, the telemonitoring system implemented is also a tool to help make relevant decisions in any medical diagnosis, preventive or therapeutic act. It proposes objective metrics (without interpretation, without uncertainty) focused on the continuous monitoring of patient’s activities. The patient's health condition may be described more precisely and behavioural disorders and deviance better characterized.

On the same principle, we offer a quantification of deviance allowing the deviance magnitude to be evaluated. This measure can help the make the doctor’s interpretation of the change in an elderly person’s physical state easier. We offer a uniform representation of deviance by a quantification of the abnormality concept based on the deviation from the threshold. Fig. 8 illustrates a case greater than a reference threshold for two activity criteria: presence of time and immobility.

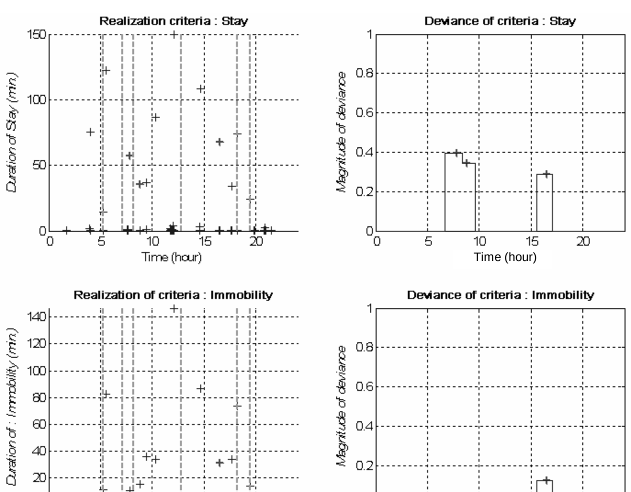

Fig. 8. Duration of presence and immobility for all the zones and deviance calculation in relation of time.

The concept of deviance is normalized and the larger the gap in relation to the habits, the more deviance tends towards 1.

The diagnosis of certain diseases or physical decline due to aging is realized by an analysis of the activites criteria over the long term (week, month, year), whose evolution and gravity are evaluated by the doctor. A regular analysis of the daily activities of a patient allows the physician to monitor the evolution of physical ability and to establish reliable diagnostics and follow the prescription of therapeutics. Fig. 9 shows the evolution of the activity criteria averaged per day over a period of 86 days. The evolution of the activities criteria of immobility, agitation, presence time and distance are represented by a significant trend. For example, the distance covered decreased over time.

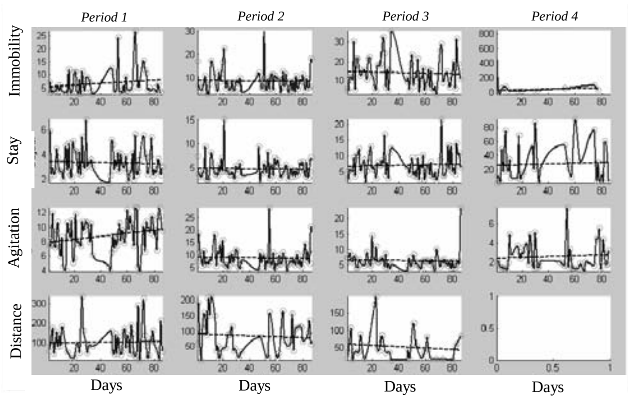

Fig. 9. Evolution of activities criteria over 86 days.

IV. Discussion

Two kinds of results have been obtained in this work. The first is the validation of real-time remote monitoring from the doctor’s computer: patient’s activities, video links between the institution and the doctor, alarms when incidents are detected by the central PC. The second result is a description of the normal activities of the patient from statistical analysis of data collected over the last 30 days. Several criteria were used: relative speed, distance covered, time spent by area, duration of immobility by area, agitation. These criteria are used as indicators of the physical condition of the person. Here we have presented some examples of results showing current situations in relation to past situations and the thresholds defined. Any excess when compared to thresholds sends an alarm to the staff. This alarm is shown on a graphical interface in visual, aural and textual form and notes the type of incident detected. The expertise of medical staff helps to corroborate these results. This expertise is in progress.

V. Conclusion

Our work is focused on a precise characterisation of habits, via location and time bands, to establish diagnoses concerning changes in individual behaviour. Relevant analysis criteria, the user’s relative speed and the distance covered, enhance these diagnoses. Modelization of the life activities of the individual tracked is more precise because one normality threshold for each criterion is automatically calculated for each daily temporal band. This multicriteria analysis has been implemented in a platform consisting of remote monitoring of dependent elderly people via satellite communication links in rural areas. It is now being studied in an attempt to improve fall detection by merging data.

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