Telesurveillance of the Dependent Seniors Using Passive Infra-red Sensors in a Geriatric Hospital

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Abstract: To study the validity of a 'smart' system of telesurveillance in elderly patients, GARDIEN©, a passive infra-red sensor network, was connected to a computer placed at a remote site from the patient. It switched on automatically every day and remained active throughout the night. Data corresponding to movements within the room were collected twice per second. During the experimental period, the data file were analyzed manually and automatically; the results of the automatic processing were displayed in the form of a list with all movements noted together with the time and each movement's duration was stored in a patient file. GARDIEN showed the patient data either in the form of curves or as three-dimensional histograms. We studied the nocturnal activity of 23 Alzheimer patients, with or without cognitive impairment. Their activity profiles were different. Moreover, the nocturnal motor activity patterns permitted to identify pathological states.

1 Introduction

At present, elderly people consume a high proportion of health-care services and in future this proportion is likely to rise considerably. It is therefore evident that high-quality health care may in future be available universally if substantial savings can be made through the greater use of modern technology.[1] A major concern in supporting the sick, disabled and frail elderly people at home is the potential risks involved, such as falling on the ground and illness. An increasing effort has been made to develop systems to monitor people in their homes by the use of intelligent systems, for instance with the help of 'smart' sensors.

Most of the telemedicine technologies are concerned with the care of the elderly people living in the community, but there is also a distinct necessity of having a system of passive telealarm for the care of the elderly patients admitted in a geriatric hospital.[2, 3] Patients who are at-risk of suffering a fall, wandering out of their bedrooms, or have poor safety awareness like the demented, need a system of passive teleassistance in addition to the conventional system of summoning help through the use of bed-side or pendant alarms.

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With a view to improve the care of the elderly patients admitted in the hospital, we installed a system of telesurveillance consisting of a passive infra-red sensor network in a patient's bedroom of a geriatric hospital in Grenoble, France. The main purpose of our research was to study the validity of a 'smart' system of continuous telesurveillance of the elderly patients consisting of a passive infra-red sensor network in a hospital bedroom.[4] We also intended to monitor the nocturnal activities that took place inside a patient's room and eventually to find out any 'deviation' from the 'normal' pattern in case of a particular patient who happens to stay for a substantial period in the hospital. It was developed with the aim of remote monitoring and follow-up of chronic patients or elderly (or handicapped) people in order to prevent accidents and aggravation of the disease.

2 Method

2.1 Consent

We had obtained a written consent from each patient (or his or her relatives in cases where the patient was unable to provide a written consent) before he or she could participate in the research.

2.2 Sensors and Network

A hospital bedroom (3m by 3m) for a single patient was selected for the purpose of study in Grenoble. Nine passive infra-red sensors were installed in the patient's bedroom; 8 of them were fixed vertically, at the ceiling level, in the different walls and inside the toilet, the ninth (number 5) was screwed horizontally into the wall, at 1.2 meter above the ground. The plan of the room with the position of the sensors is depicted in Fig. 1. These sensors are activated by human movements taking place in the field of capture of the sensors, which is in the shape of a rectangular pyramid covering approximately 1m by 2m area on the floor. The field of capture of the ninth sensor covers horizontally entire room; its aim is to improve fall's detection. The field of capture or range of the other sensors can be narrowed down with the use of masks if required in certain cases, so that they can only detect the passage of human beings while passing just below a sensor. We used masks to reduce the field of detection in cases of the door (both inside and outside) and the toilet sensors. These sensors were connected through cables to an I/O parallel card, which in turn was connected to a Pentium III, 64 MB RAM computer kept in another observation room (Fig. 2).

2.3 Registration of movements during the night

The computer automatically captured and registered data obtained from the different sensors every day from 10 a.m. till 8 a.m. in the next morning with the help of a program known as GARDIEN©. Data corresponding to movements were collected twice per second, and stored with indication of time when they differed. That is when a different sensor or a different combination of sensors was activated due to the movements of the patient, it was registered sequentially in that order, until the sensor(s) came back to the original inactivated state, which was again registered indicating the time in every instance. GARDIEN© registered movements made by the single patient (along with occasional visits by the personnel or relatives) in the bedroom during this span of 22 hours and saved them in a file with an extension name '.dat'. The artificial intelligence program analysed the data at the end of the surveillance period and then generated a report showing a list of the activities[5] taking place in the room with indication of the time of start and end of each movement as well as the type of movement, like 'Getting up and movement in room', 'Agitation in the bed' and so on.

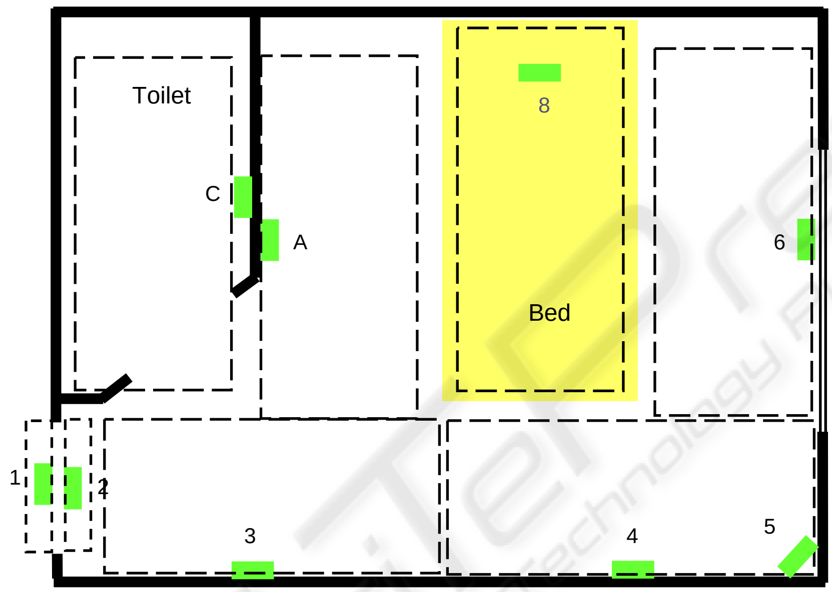

Fig. 1. Figure showing the different locations of the sensors inside the room. The dashed lines represent the field of capture of the vertically set sensors

2.4 Document sheet maintained by the night personnel

In addition, the patient's room was always visited by the personnel during the night. This resulted in more than one person being present in the room during the period of visit by the personnel. GARDIEN© was programmed in such a way that it could differentiate the entry and exit of a personnel from that made by the patient. The night personnel were given a document sheet to note their time of entry into the room, number of persons entering the room, duration of stay and special remarks.

2.5 Analysis of the file and its comparison with the report generated by GARDIEN©

Every file that was created during the day was opened with a word processor the following day and printed. A portion of a file is shown in Fig. 3. This print-out was analysed manually and thoroughly by an expert to find out all the activities that took place in the bedroom during the night taking into account the document sheet filled by the night personnel. The method of analysis is described as follows: at first, the file to be analysed was divided into successive different sequences of valid movements (or displacements) according to the rules described in the latter part of this section. Next, within each sequence, each sensor denoted by a number, was noted with respect to the previous sensor(s) registered in the file. In this manner, the 'pattern' of sensors appearing in a sequence was noted one after another just as analysing a raw data obtained from a discrete signal. The resulting analysed sequence was then compared with the entry of the night personnel if noted in the document sheet and then a proper movement name, like "Visit by the personnel, or Movement in the bathroom, etc.", was assigned to that particular analysed sequence, taken from a list of 24 movements. Other sequences were also analysed in the same manner. The utility of the document sheet by the night personnel was to confirm the presence of a visitor (more than one person) in the room or the patient leaving the room, etc. when the same was found on manual analysis. Following this, it was compared with the report generated by GARDIEN©, which was programmed to analyse the sequences automatically and independently by an intelligent algorithm and then put it in the form of a report (Fig 4) containing a series of activities (with reference to time) taking place during the night, *i.e.*, each movement analysed manually was compared with each movement reported by GARDIEN© to find out if they matched with one another.

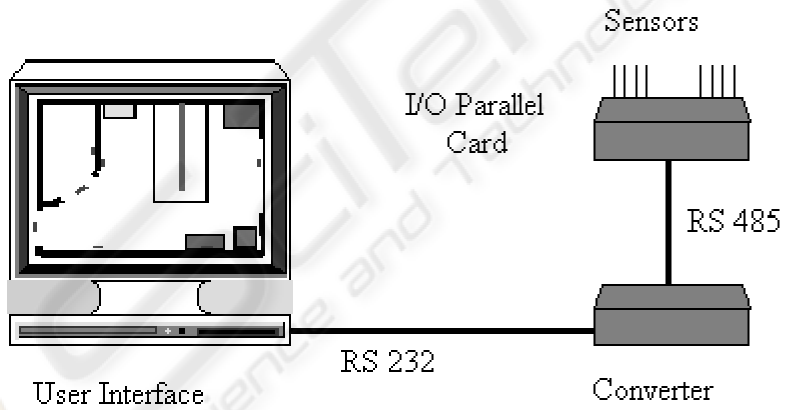

Fig. 2. The GARDIEN© system

Certain conditions were applied while analysing the print-outs manually and comparing them with the reports produced by GARDIEN©. The determination of a displacement, whether by manual analysis or automatic treatment by GARDIEN©, is based on two criteria: Interval I (in seconds) separating two consecutive data (lines) and D number of data (minimum number) lines of activation of sensors in a sequence) was corresponding to a state of activation of the sensor network. When a sensor is activated by the passage of a person underneath, it remains activated as long

4 6	Fri Mar 07 10:49:14 2003
4	Fri Mar 07 10:49:14 2003
34	Fri Mar 07 10:49:17 2003
3	Fri Mar 07 10:49:17 2003
23	Fri Mar 07 10:49:19 2003
2	Fri Mar 07 10:49:20 2003
	Fri Mar 07 10:49:22 2003
2	Fri Mar 07 10:49:23 2003
	Fri Mar 07 10:49:23 2003
2	Fri Mar 07 10:49:24 2003
	Fri Mar 07 10:49:26 2003
C	Fri Mar 07 10:49:28 2003
	Fri Mar 07 10:49:29 2003
C	Fri Mar 07 10:49:34 2003

Fig 3 This sequence was analyzed as “Movement in the room and in the toilet”

ACTIMETRIE DEAMBULATOIRE

Nuit du : 15 Mar 2003 au : 16 Mar 2003

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Nota : Les agitations au lit, de moins de 3 mouvements, ne sont pas notées.
Les déplacements sont séparés par des temps de repos d’au moins 30 secondes.

Déplacement		
Début	Fin	Commentaires
21 :00 :59	21 :03 :10	Plusieurs personnes dans la chambre
21 :03 :35	21 :04 :20	Recoucher du patient accompagné par le personnel
21 :07 :30	21 :09 :53	Lever, Déplacements dans la chambre et recoucher
21 :19 :31	21 :23 :05	Lever, Déplacements dans la chambre et recoucher
22 :58 :01	23 :00 :46	Lever, Déplacements dans la chambre et recoucher
23 :44 :08	23 :44 :33	Lever et Déplacements dans la chambre
23 :57 :44	23 :58 :51	Lever du patient et sortie de la chambre
00 :01 :27	00 :03 :31	Recoucher du patient accompagné par le personnel
00 :04 :06	00 :04 :42	Agitation au lit
01 :03 :21	01 :03 :22	Ronde du personnel
01 :13 :00	01 :14 :08	Lever du patient et sortie de la chambre
01 :15 :54	01 :16 :36	Retour et sortie du patient
01 :17 :27	01 :19 :37	Retour du patient et recoucher
05 :20 :49	05 :22 :25	Lever du patient et sortie de la chambre
05 :22 :56	05 :24 :29	Retour du patient et recoucher

Fig 4 A report of nocturnal activities

as there is movement under that particular sensor and for an additional duration of 0.5 second after the cessation of the movement. At that instance, the state of the sensor network is modified (inactive state), which is registered with indication of time. If a new change of state appears during the interval I following it, the movement which provoked this change of state is considered to belong to the same displacement.

Whereas, if there is movement producing a change of state after the interval I, it is considered to be a new set of data for the next displacement. In order to be considered a significant movement, a displacement must consist of D data (lines) in accordance with the above criterion. In our experiment, we had fixed I = 30 seconds and D = 5. This means that if there is a movement causing activation of the sensor after 30 seconds of inactivity, it will be considered to be a part of the following displacement. In addition, there has to be at least five data (lines) in a displacement in order to consider significant. GARDIEN© is provided with a facility to alter these thresholds, with I being 60 seconds and D as 20 maximum.

In the same time, a counter was increased by the duration of the movement; there was a counter for each kind of movement (bed activity, room activity, …). Each quarter of an hour, the activation's duration of each sensor was calculated too. When GARDIEN© finished analyzing the data file, patient's references (name, address .) were asked to the medical user and then the report was printed, the movement's counters and the sensors counters were stored in a patient file with an extension name '.reu', together with the date. This file was used by the Graphical User Interface to display in the form of curves, the duration of each kind of movement per night (Fig 5) and in the form of three-dimensional histograms the duration's activation of sensors in each part of the room per quarter of an hour (Fig 6).

3 Results

During the technical evaluation period, we detected 1637 valid sequences [6] of movements taking place in the room by analysing manually. Of these, 10 movements were not detected by GARDIEN© (*i.e.*, 1627 movements were detected). In addition, 1450 movements, *i.e.*, 88.6% of the movements, analysed manually by the expert were interpreted in the same manner by GARDIEN©.

The total number of entries made by the night personnel entering the room was found to be 341, of which GARDIEN© was able to pick-up 332 times (97.4%) that there was an external person visiting the room, which indicates the 'sensitivity' of the system to detect any reported event. The nine instances when these events remained undetected could be either due to the passage of the night personnel in the corridor passing 'near' the patient's room without actually entering 'inside' or due to the faulty noting of the 'time of entry' by the night personnel.

The clinical evaluation period of GARDIEN© continued during 486 days. 23 Alzheimer patients occupied the room during this time; 16 of them had cognitive impairment and a MMS (Mini Mental State) score lower than 25, the others had a MMS score higher than 25 but no cognitive problems. The median motor activity was stable during the without cognitive impairment patient's stay. On the other hand, this activity was more important at the beginning of the stay and decreased during the observation period of the patients with cognitive disease (Fig 7).

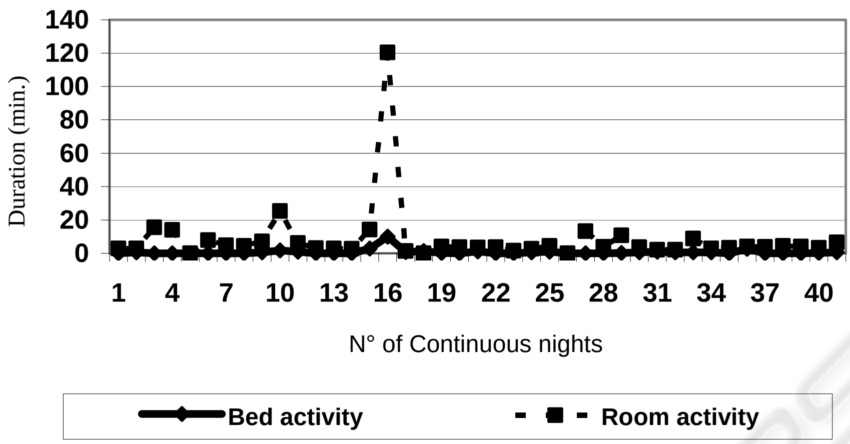

Fig 5 Nocturnal activity in an 77-year-old patient with hyperactivity in room on the 16th night

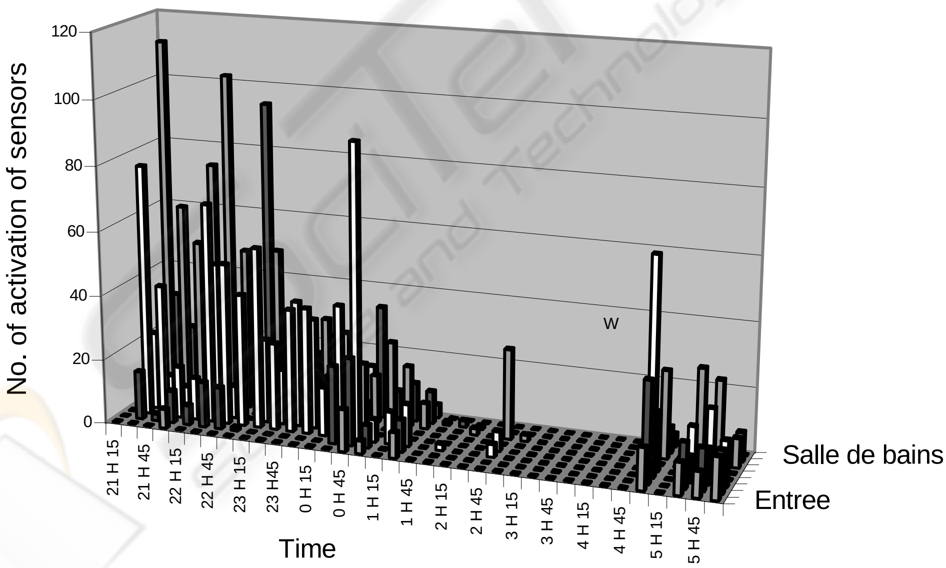

Fig. 6 Activity in the room during one particular night when the patient was excessively agitated initially followed by a period of sleep and finally waking up at five o'clock in the next morning

Although, all the patients were Alzheimer patients, their nocturnal motor activity patterns were different and we found three kind of pattern:

- acute nocturnal agitation,
- chronic nocturnal hyperactivity
- mental confusion.

These features are illustrated by three patients. In the first case, the patient was 77 year-old male patient. His was admitted in the geriatric department for agitation, aggressiveness and violence against his wife at home. He was observed for 41 nights. On the 12th day, he complained of shortness of breath and abdominal pain. On the 16th night (Fig 5), he moved excessively in the room as well as in the corridor (this fact was noted by the night personnel). On the basis of previous complaints and excessive activity, a pulmonary Scintigraphy and Echo-Doppler study were performed. The scintigraphy showed a strong possibility of Pulmonary Embolism. An anticoagulant therapy was started, the nocturnal motor activity became less important and the patient recovered fully after treatment.

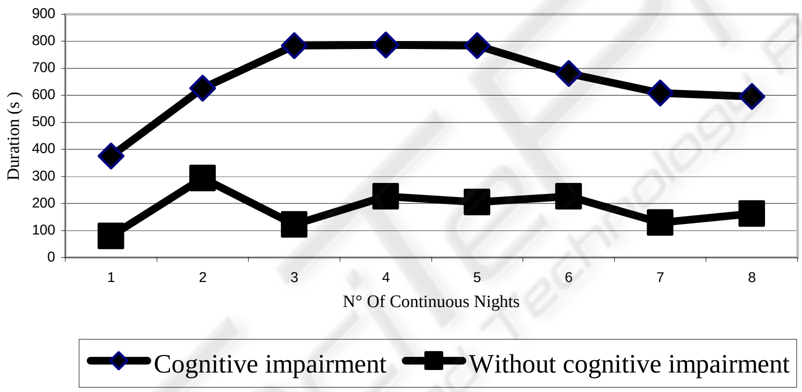

Fig 7 Influence of cognitive problems on nocturnal motor activity

The second case was an 87 year-old female patient. She was admitted in the geriatric unit for rehabilitation after a rib fracture. During her entire stay, she never presented with agitation or an episode of fugue. She frequently suffered from spatio-temporal disorientation. Her room activity chart (Fig 8) showed irregular fluctuations but we did not know precise cause. We found only that she slept several times during small intervals interrupted by motor activity sequences. She stayed for 63 days in the geriatric department.

The third patient was a 93 year-old man. He was admitted for agitation, aggressiveness and violence against his wife. He stayed 38 days in the department. This patient was very calm during the day but his nocturnal motor activity was important. On the 14th day, the treating physician changed therapy in order to reduce the patient's daytime somnolence and restore sleep during the night. The therapeutic change had effect about one week later and the nocturnal motor activity of this patient decreased progressively (Fig 9).

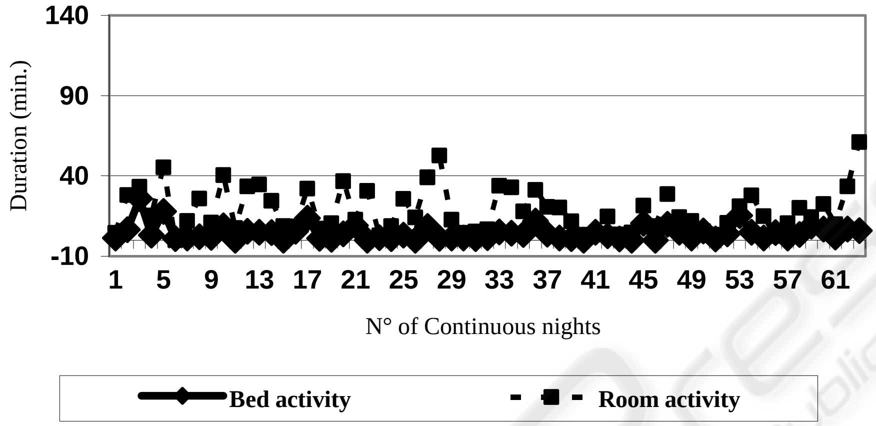

Fig 8 Example of chronic nocturnal hyperactivity

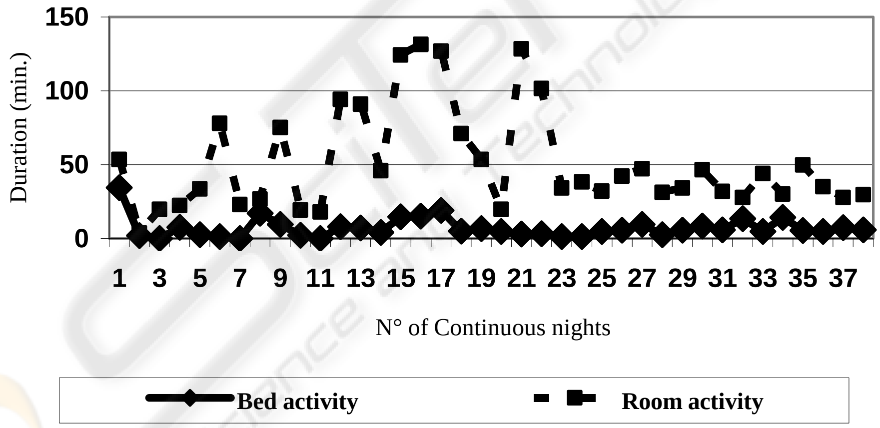

Fig 9 Example of mental confusion superimposed on chronic hyperactivity

4 Discussion

We found that the most important step in determining the accuracy or reliability of the system was to find out how the program (algorithm) treated or analysed the data thus obtained. That is whether GARDIEN© was able to interpret the data in the same manner as it would have appeared to the expert analysing the data manually. This accuracy (88.6%) was consistent throughout the period of observation that is there was not significant fluctuation in the day to day results obtained. However, 10 movements (out of a total of 1637 movements) were undetected by the system. We found that all the movements that were not detected were actually of very short sequence (5 or 6 sensors). The reason was due to failure of the treatment of data stored in the .dat file by the program.

The system is generally capable of detecting all major movements in the room. But in the event, when the patient happens to stand near the door, but not causing movement for a long period without actually leaving the room, will be detected as 'patient leaving the room', since the last sensor to be activated will be the outside door sensor. Similarly, the system couldn't tell where the patient is lying in the room if he or she is stationary for a long period, either on the bed or on the floor, since the infra-red sensors will become inactive due to the absence of movement. But if the patient falls and stirs on the floor, his movement is detected by the vertical sensors but it is not detected by the ninth sensor (horizontal). In this case, GARDIEN© can sound an alarm. Since the ninth sensor is working, GARDIEN© and the caregivers did not note a patient fall; consequently, we can't conclude yet about the efficiency of this sensor.

Most of the telesurveillance systems that have been developed or tested until now, used a system of multisensors in which infra-red sensors were used along with other types of environmental sensors or wearable sensors (fall sensor for example). [7-10] In all these cases, the data obtained from different sources were combined by 'fusion of data' regarding activity of a person within an intelligent habitat. The installation of a multisensor system increases the complexity of the habitat in addition to increasing the expenditure. Moreover, the infra-red sensors that were used in all these cases, only detected the presence or absence of a person by noting the movements within the room.

GARDIEN©, on the other hand, was developed only with passive infra-red sensors, which due to its intelligent algorithm could not only detect the presence or absence of a person, but also detected the type of activities done by the person within the room including his or her exit from the room. This is an important aspect of the system since it permits distinction between the entry and exit of night personnel with that of the patient. This feature could well, in future, be combined with a system of passive telealarm that can alert the caregivers in real-time whenever the patient tries to leave the room, which are many times associated with falls or getting injured in the corridor. The simplicity of installation of infra-red sensors within a room is a plus point, since no other type of sensor is required.

Another important feature of the system is that nocturnal actimetry of the persons living in the room is possible. The activity inside the room during one night is shown in Fig. 6. In this figure, one can note that the patient was extremely agitated from 21.15 till 01.30 hours in the next morning. Following which, there was a period of sleep lasting till 05.00 hours, when activity due to waking up was noted. For patients staying for a longer period, it may serve as a means of identifying motor activity trends that can provide data to the physicians to monitor the patient and attribute deviations in the activity trend to various therapeutic interventions.

Studying behaviour trends in relation to treatment may help planning therapy and follow-up of the patients. In addition, sleep patterns may be discovered in patients suffering from insomnia. A patient with a known seizure disorder showing excessive agitation in the bed on a particular night could signal a convulsion and in turn may be programmed to activate the alarm, although further studies are necessary to accept the reliability of the system in alerting the health personnel in such emergency conditions. On the other hand, diminished motor activity in the bed in a bed-ridden patient could forewarn the onset of bed-sores.

As GARDIEN© is an environmental sensor, it is compatible to be used simultaneously with any other medical or body-attached sensors providing complementary data on the patient, like devices measuring heart rate, ECG, blood pressure, or fall detectors (accelerometers).

At last, the patients who stayed in the room during the period of observation did not feel any discomfort with the system, but further study is necessary to establish its acceptability in the community.

References :

1 Doughty K, Cameron K, Garner P. Three generations of the telecare of the elderly. J Telemed Telecare 1996; 2(2): 71-80

2 Tyrrell J. Evaluation of Telemedicine: Patient needs and perceived benefits of an innovative communication system in a geriatric rehabilitation unit. European Commission : Training and Mobility of Researchers Programme 1998

3 Couturier P, Tyrrell J, Banerjee S, Debray M, Moulin P, Franco A. Téléassistance en milieu gériatrique : besoin du patient et réponses technologiques. Aides techniques et matériel d'assistance en gériatrie (édition: Masson), 2002: 63-73

4 Steenkeste F, Bocquet H, Chan M, Campo E. La mise en place d'une technologie pour observer le comportement nocturne des personnes âgées en institution. ITBM-RBM 2001; 22: 25-30

5 Steenkeste F., Banerjee S., Couturier P., Franco A. GARDIEN: un système de telesurveillance pour personnes âgées dépendantes. Proc. of Les Nouvelles Technologies dans la Cité Rennes 11 décembre 2003

6 Banerjee S., Steenkeste F., Couturier P., Debray M., Franco A. Telesurveillance of elderly patients by use of passive infra-red sensors in a 'smart room'. J Telemed Telecare 2003; 9; 23-29

7 Coyle G, Boydell L, Brown L. Home telecare for the elderly. J Telemed Telecare 1995; 1: 183-184

8 Ogawa M, Togawa T. Monitoring daily Activities and behaviors at home by using brief sensors. Proc. of the 1st Annual International IEEE-EMBS Special Topic Conference on Microtechnologies in Medicine and Biology 2000

9 Chan M, Bocquet H, Campo E, Val T, Estève D, Pous J. . Multisensor system and artificial intelligence in housing for the elderly. Gerontechnology, IOS Press, 1998: 145-149

10 Rialle V, Lauvernay N, Franco A, Piquard JF, Couturier P. A smart room for hospitalised elderly people: essay of modelling and first steps of an experiment. Technol and Health Care 1999; 7(5): 343-357

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