Detecting abnormal behaviour by real-time monitoring of patients

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Abstract

This paper deals with a follow-up system that passively observes elderly people moving about in a hospital setting and records automatically various patterns of activity. The aim is to propose a support tool to help the medical staff make decisions. The system is based on a sensor network connected to a processing unit. The software developed automatically follows the patient's behaviour and plots statistical curves related to a number of characteristics such as getting up, going to bed, going to the bathroom, etc, ... Thus real-time monitoring can be displayed on a graphical interface for the medical staff. Experimental platform using this system is presented along with examples of behaviour monitored during the night.

Introduction

Monitoring elderly people in health care units is one of the most important problems in our society. Population is constantly ageing, leading to ever increasing medical costs. Thus, to reduce these costs and provide the best quality of life, the elderly should be maintained at home (Sixsmith 1994) and solutions are needed to follow these patients particularly if the person lives alone and has experienced a loss of autonomy. Based on this, many smart surveillance and tracking systems have been developed with a host of software and hardware architectures that make up the so-called "Intelligent home" (Rialle et al. 2001). Indeed, the increasing maturity of algorithms and techniques makes it possible to apply this technology to this sector (Tang and Venables 2000), (Ogawa and Togawa 2000), (Rialle et al. 1999), (Togawa et al. 1998), (Celler et al. 1994). Other studies propose video images primarily with the view of detecting a person standing still or moving with others (Haritaoglu, Darwood, and Davis 2000), (Ricquebourg and Bouthemy 2000). However, these systems raise ethical issues. Indeed, technical aids must be efficient, reliable, and conform to medical ethics (Fisk 1997), (McShane, Hope, and Wilkinson 1994).

Thus, the objective of this paper is to present a monitoring system for the elderly using expert systems. The originality of the approach lies in tracking people and monitoring their activities through use of low cost positioning sensors. The system records and learns the patient's movements and their whereabouts. It is non-intrusive system: no camera, pendant or bracelet (Chan et al. 1999a).

This study contributes to the definition of an advanced monitoring system for the elderly by proposing a solution to keep people at home based on multisensor data acquisition, communication and processing. The system presented provides statistical descriptions of the night (getting up, going to bed, going to the bathroom, wandering...) for a period of time that can be adjusted by the user. This differed time analysis is intended to help doctors detect unusual events, by spotting activities that differ greatly from normal patterns, e.g. particular movement that differs from normal nocturnal observations.

In the following sections, we describe our tracking method, then outline our system for monitoring activities over night by simply observing people moving. Some results collected in-situ through experiments in a hospital setting are shown.

Material platform

The monitoring network consists of four basic parts (Chan et al. 1999b):

- a set of thermal infrared (IR) moving sensors distributed in the room on the ceiling. They are housed in a small box form and fitted out with a Fresnel lens, to allow each zone to be monitored as shown in Fig. 1.

The sensors work in binary mode (0 or 1) and cover specific zones (about 1 or 2 m^2). The sensor is triggered by motion and data is sent to a database in a computer.

- a PC using C++ language software (data acquisition and processing). It allows integration of the data transmitted by the sensor network (2 Hz periodical polling), filtering, then processing automatically by specific software based on expert systems. The system aims to provide statistical analysis (by use of rules) of all data and a real-time diagnosis of the situation so as to set off an alarm in case of emergency.
- a communication network based on a RS485 bus linking all elements of the system.

- a communication interface, for the medical staff, which allows real-time observation of motion, display of the previous night's data and record of all alarms detected by the system.

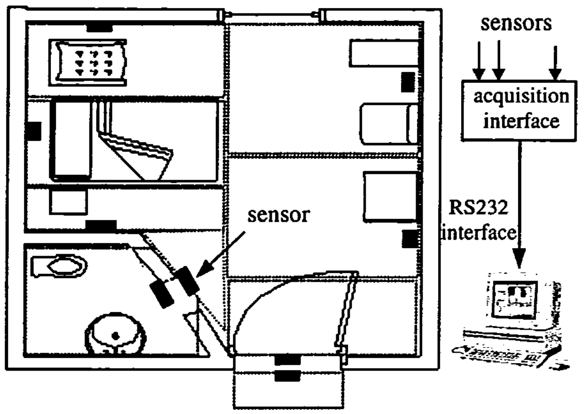

Figure 1. Material platform of the experimental room.

The platform presented is built on a wire hardware configuration using logical acquisition modules and a RS485/RS232 bridge to the PC. Wireless hardware architecture has been also successfully tested in laboratory and will be soon implemented in experimental site. The hardware system must allow reliable data representative of the patient's status to be collected. The originality lies in how the system learns the patient's behavioural habits.

Experimental sites

Patients monitored

Alzheimer's disease is the leading cause of cognitive impairment in old age. Wandering of the elderly is a symptom of Alzheimer's disease that causes considerable management problems for caregivers with risks of falls, injury or death. Alzheimer's disease and other organic mental disorders affect one out of ten elderly persons in the community (Evans et al. 1989). It has been estimated that nearly half the people 85 or over are afflicted with the disease. So, this category of people requires a lot of attention. The patients monitored range from 65 to 85 and exhibit different stages of the disease.

Experiments were conducted in long-stay and short-stay units in geriatric hospitals in France and involved the use of actimeters recording the patients' movements during several nights. As a matter of fact, a great deal of equipment is needed to prevent risks during the night: digicode for doors, barring windows, surrounding beds with barriers, ID labels worn by patients. Our system could be an automatic monitoring aid for nurses.

Events recorded by the nursing staff

The main events recorded by the nurses (about 60 were interviewed) are listed in Table 1, for the two sites.
Clearly, in both units, falls and wandering are the main cause of risks for patients (more than 70 %). Restlessness is a symptom of wandering.

Events	Long-stay unit	Short-stay unit
1) running away	4	6
2) falls (or prevention)	12	10
3) wandering	10	6
4) restlessness/ aggressiveness	6	10
5) discomfort	1	

Table 1. Nurses' response to events caused by patients.

Figure 2 shows the fall profile of patients (182 falls listed over 2 years). Moreover, on 82 patients, 32 have fallen more than one time. It is commonly accepted that a patient suffering 2 falls or more is at great risk of falling again.

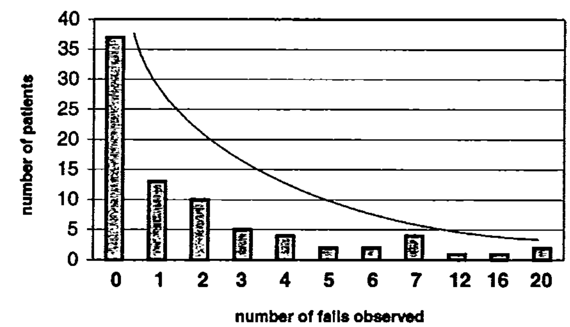

Figure 2. Profile of patients' falls (in long-stay unit).

So, the population considered exhibits a high probability of risks particularly as the stage of the disease is advanced. A smart system, capable of monitoring all discrepancies and preventing such risks is so valuable. Movements have to be monitored particularly when the patient gets up, wanders in his room (65% of activities), as shown in Table 2.

Activity at the time of the fall	Number of falls	Percentage (%)
gets up	58	31.9
going to bed	8	4.4
going to eat	2	1.1
wandering	61	33.5
going to the toilets	14	7.7
other activity	39	21.4
Total	182	100

Table 2. Activity of patient at the time of the fall.

Results

Parameters

The different parameters considered and plotted have been determined by data processing. Each event has been defined and thresholds were set for such conditions as agitation or a quiet night in bed, running away... Thresholds could be adjusted by comparing several series of measurement obtained from either the system or direct observation by nurses.

Experiments

17 patients have been monitored in the short-stay unit from 2 to 15 nights and a total of 83 nights, 13 had the Alzheimer's disease. To illustrate how the system works, we will describe the patient's follow up over 13 consecutive nights (D1 to D13). The selected patient suffered Alzheimer's disease. The medical staff doesn't diagnose behaviour disorders. The patient is administered a soporific during the night. The accurateness of the results obtained can be ascertained with the records of the nursing staff.

On the whole, a very good agreement has been found between the system's analysis and the data collected in-situ by the night nurses during their rounds (Chan, Campo, and Esteve 2002).

The system's results from 9 pm to 6 am are plotted in Figs. 3 and 4 with such parameters as duration of getting up, outing, visiting the washroom or staying in bed with agitation. The number of each activity is too available.

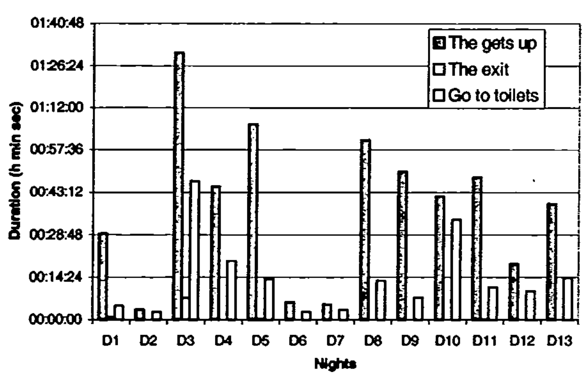

Figure 3. Patient's activity over 13 consecutive nights.

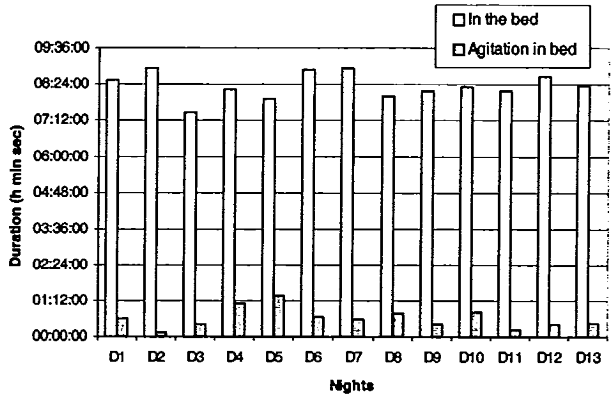

Figure 4. Patient's agitation in bed over 13 consecutive nights.

Figure 5 shows the distance covered by the patient each day over 13 consecutive days. This distance was assumed to be equal one meter when the patient walks from one detection area to another. We can observe that the patient exhibits a mobility decrease at the end of the hospitalisation period (D6 to D13). The patient was agitated in the beginning of the observation period. During the night, the patient got up, went to the bathroom several times, left his room and then wandered about in his room. His behaviour seemed to have calmed down at the end of hospitalisation.

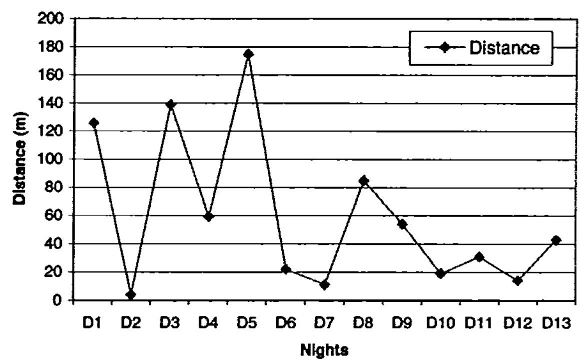

Figure 5. Evolution of the patient's mobility over 13 consecutive nights.

Although the study focused on a night period (D1-D13), Figs. 6 and 7 give an example of the patient's night activity (from 9 pm to 6 am). Each activity is recorded over a 15-min interval.

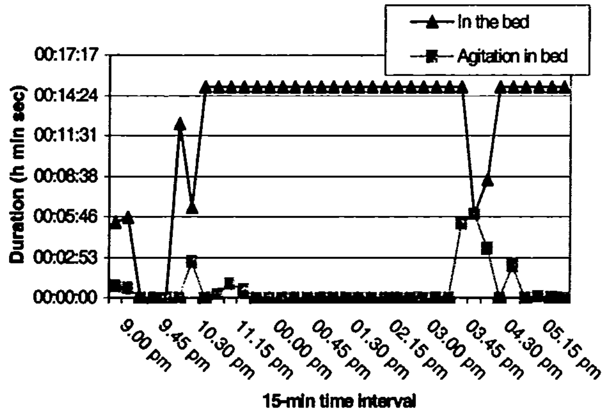

Figure 6. Evolution of the patient's condition in bed during D3 night.

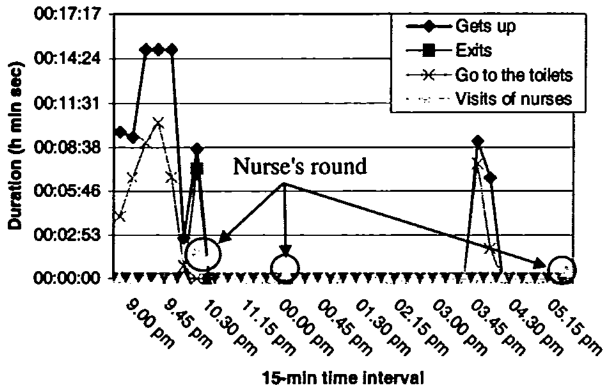

Figure 7. Evolution of the patient's activity during D3 night.

From 10.30 pm to 3.45 am, the system found the patient very quiet in his bed corresponding to a threshold ts = 5 minutes without motion detected by the bed sensor. The patient got up twice between 3.45 am and 4.00 am to go to the toilets. However, as the nurse was not present at the time, this information could not be recorded. Only one exit was noted at 10.00 pm as shown in Fig. 7. We can notice at 00.00 pm and 05.45 pm that the nursing staff came in the room quickly because the time noted by the system was of a few seconds (respectively 18 and 28 seconds). Figure 8 records the staff visits that tend to decrease by the end of the stay; the minimum amount of visits corresponding to the D12 day with a minimum distance covered by the patient and the minimum time spent up.

In this work, we can compare objectively only the entrance/exit in the rooms noted by the personnel from the entrance/exit obtained automatically by the system. We constated that the results were similar. Sometimes, the system find entrance/exit not mentioned by the staff or an hour different because the nurse has noted the fact when she has finished his round (several minutes after). So, the nurse can't observe the exits of patients unless this occurs during their rounds. The same goes for the getting up and wandering where only the system can observe these activities.

In daily clinical use, such an analysis would have allowed us to warn nurses of an increased risk of fall or a decrease in mobility. Also, it would assist them in making decisions about what to prescribe or whether additional surveillance was needed for a patient.

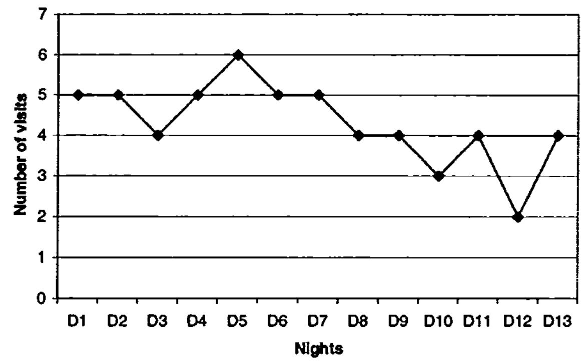

Figure 8. Evolution of the nurse's visit over the 13 consecutive nights.

Interface

The software architecture operates as an automation and computes the patient's position in real-time and more with difficulty those of the personal in function of the activated sensor. The position thus computed is plotted (in different colours) as shown in Fig. 9 where the main interface window has been developed for the nursing staff. Statistics can be automatically displayed as shown previously or the patient's behaviour can be followed in real-time. The interface can accommodate other room configurations or modified existing configurations. It can also monitor many rooms.

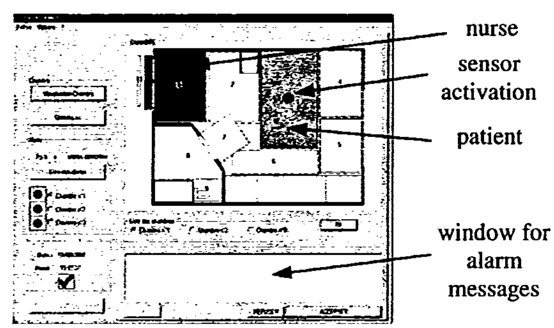

Figure 9. Main window on the nursing staff interface.

From principles enounced in previous studies (Chan et al. 1999b) and simulated in laboratory, a new functionality (in progress) will allow alarm messages to be transmitted to the nurse pager in real-time and on the PC screen with a light indication and alarm motive. To execute this function, two types of alarm will need to be implemented: one alarm when immobility is found during patient's activity, and one alarm when the patient's usual behaviour deviates from his behaviour observed in real-time.

Conclusion

The work presented in this paper describes an experimental platform for monitoring the elderly so as to measure behaviour patterns through mobility and to discover unusual behaviour. Qualitative and quantitative analysis of motion can be used in many areas of medicine such as Alzheimer's disease, nocturnal behaviour, wandering... in a hospital setting.

This system has been successfully tested and the principles used validated in geriatric care units. Thanks to the expert systems, it operates on it own without involving the patient.

Thus, series of measurements have been carried out on different patients with motion disorders. The system calculates mobility parameters (duration and frequency) over variable time intervals selected by the user. Thus, the patient's follow up history can be obtained (number of time he gets up, goes back to bed, visits the toilets, leaves his room) along with the distance covered during the night. It is also possible to display the cumulated frequency of different activities over variable periods of time. All the data can help the medical staff monitor efficiently the patient during the night and understand him better with the view of adapting the treatment or increasing monitoring. Ongoing work is focused on adding real-time diagnosis thru use of a real-time comparison between the patient's real behaviour and the learned patient's normal behaviour. This function is designed to detect those anomalies and disorders (decreased mobility, unusual situation) likely to lead to falls or get away situations and to transmit alarms to the nursing staff.

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