Supporting Caregivers in Nursing Homes for Alzheimer's Disease Patients: A Technological Approach to Overnight Supervision

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Abstract. The reduction of public expenditure and investments in health care provisioning calls for new, sustainable models to transform the increasing aging population and dementia-related diseases incidence from global challenges into new opportunities. In this context, Information and Communication Technologies play a vital role, to both promote aging in place and home management of Patients with Dementia, and to provide new tools and solutions to facilitate the working conditions of the care staff in nursing homes, which remain an essential facility when cognitive-impaired patients cannot live at home anymore. Night staff in nursing homes are a vulnerable group, receiving less supervision and support than day staff, but with high levels of responsibility. Additionally, nighttime attendance of patients affected by dementia may be difficult, because of their incremented neuropsychiatric symptoms. This paper describes an integrated system for the night monitoring of patients with dementia in nursing homes, based on a product originally conceived for domestic use, but re-designed to provide support to nurses, by means of a set of sensors located in each patient's room, and suitable software applications to detect dangerous events and raise automatic alerts delivered to the nurses through mobile devices. The results obtained from the first experimental installation of the monitoring system proved the effectiveness of the proposed solution to support nurses during the night supervision of patients, and suggested suitable modifications and additional features to increase the nurses' compliance.

Keywords: Environmental sensors · Unobtrusive monitoring · Activity detection · Alarm notification · Behavioral analysis

1 Introduction

It is widely recognized that Information and Communication Technologies (ICT) have the potential to dramatically impact social and welfare systems in

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promoting new economically viable and sustainable models for healthcare delivery, especially when targeting the aging populations, and, among them, Patients with Dementia (PwDs) and their caregivers. By 2050, 22% of the world's population will be over 60 years of age [26], and both governments and the private sector need to mobilize innovation and research to transform this global challenge into an opportunity for new models of sustainable growth. Among the chronic diseases that mostly affect aging population, Dementia and Alzheimer's Disease (AD) have a prominent role [4]. ICT offers several opportunities to health services, specifically to PwDs and their caregivers, as discussed in a systematic review by Martínez-Alcalá et al. [22]. The paper shows that among the 26 studies that satisfied the inclusion criteria for the review, 16 were aimed at the PwDs, and 10 at the primary caregivers and/or family members. Basically, it means that the current literature almost neglects the opportunities ICT can offer to formal caregivers of PwDs, like professionals and healthcare operators, and to nurses working in the residential care sector. On the other hand, it is known since long time that professional caring of PwDs may have strong impacts on the carer's physical and mental health [12]; at the same time, improvements in nursing home residents' quality of life may be achieved by enhanced training and deployment of the care workers [33].

Staff working in care and nursing homes is typically undersized with respect to the real workload, because of budgetary restrictions on the amount of personnel that can be recruited, compared to the number of patients cared after. This results in a stressful working condition, as many tasks need to be carried out in a relatively short time. Since 2010, due to the global economic crisis, growth in public health spending came almost to a halt across the OECD (Organisation for Economic Cooperation and Development) members, with even reductions in many countries [28]. Anyway, despite the current trend of promoting elderly caring at home and aging in place, the role of nursing homes remains relevant, especially for PwDs or AD patients at an advanced stage, who cannot be assisted at home anymore. ICT should be more extensively exploited to facilitate the working conditions of the care staff dealing with PwDs, and to improve the quality of care, but the impact of technology on the underlying long-term established clinical work processes needs to be carefully evaluated and analysed. Possible blocks in the execution of routine procedures, due to the adoption of technology, tend to distract staff from care issues, and may lead to new errors. Typically, in reaction to this condition, nurses develop problem-solving behaviors that bypass the use of new technology, or adapt the work process so as to minimize disruption in traditionally executed procedures [5,13,20].

The so-called "sundown syndrome" in PwDs is characterized by the emergence or increment of neuropsychiatric symptoms such as agitation, confusion, anxiety, and aggressiveness in late afternoon, in the evening, or at night, probably due to impaired circadian rhythm, environmental and social factors, and compromised cognition [16]. Although night-time care forms a significant part of care provision in nursing homes, little research has focused on this. Night staff are a vulnerable group, receiving less training, supervision and support than day staff, but with high levels of responsibility [10]. Several ICT-based solutions have been proposed to facilitate home-caring of people affected by dementia or AD during the night hours. In fact, nighttime activity is a common occurrence in persons with dementia, which increases the risk for injury and unattended home exits, and impairs the sleep patterns of caregivers [17,18]. Technology has been applied to develop tools that alert caregivers of suspicious nighttime activity, to help prevent injuries and unattended exits [21,27,32]. Nighttime attendance of patients affected by dementia or AD may be difficult to manage also in nursing homes, especially because the number of nurses available is reduced, with respect to daily hours. As a consequence, it is of interest to evaluate the applicability of technology for night monitoring of AD patients in nursing homes, in order to assess the impact of technology on nurses' work flows, and on the quality of assistance provided to patients.

This paper describes an integrated system for the monitoring of AD patients, realized by evolving and updating an already existing product named UpTech [7]. The UpTech project focused on AD patients and their family caregivers; it was carried out as a multi-component randomized clinical trial (RCT), integrating previous evidence on the effectiveness of AD care strategies, in a comprehensive design, to reduce the burden of family caregivers of AD patients, and to maintain AD patients at home. Indeed, often the relatives who take care of AD patients are subjected to high levels of stress, that could also contribute to the onset of physical problems. The positive outcomes of the UpTech experimental phase [30], providing the use of technological devices as alternative or complementary form of support, have suggested its application in a different scenario, represented by the nursing homes. The aim of the new project, named UpTech RSA [24], is to support and help assistance of AD patients in nursing homes, during the night hours, by means of a set of sensors located in patients' rooms, and suitable software applications to detect dangerous events and raise alerts for the nurses.

When dealing with *monitoring* of people, this condition is often seen as violating the privacy of the user. Therefore, in order to satisfy the requirement of providing an unobtrusive monitoring, only simple environmental sensors have been employed in the UpTech RSA solution, that are less intrusive and more acceptable than other options, like wearable devices, or video cameras. Wireless sensors have been chosen and used: on one hand, this enables a simple installation, on the other hand, power consumption is a critical aspect, which has to be evaluated at the design stage.

The paper is organized as follows: the context of application of the proposed technology is discussed in Sect. 2, whereas Sect. 3 is focused on design and deployment issues. The field trial implementation is presented in Sect. 4, and the results gathered from the practical use of the technology in a real nursing home are discussed in Sect. 5, showing how the data collected from sensors may be translated into useful information for understanding the patients' needs and requirements. Finally, Sect. 6 concludes the paper and suggests possible future developments.

2 Context

Dementia is becoming increasingly prevalent worldwide and is today considered as one of the most burdensome disease for the developed societies. AD is the most common form of degenerative dementia. Generally, the onset of the illness occurs in the pre-senile age, however it could be even earlier. A person with dementia can live 20 years or more after diagnosis, during which he/she experiences a gradual change of the functional and clinical profile. As a consequence of the disease, a progressive loss of cognitive capacity is occurring, eventually leading to disability and to a severe deterioration of quality of life. During the so-called "dementia journey", the disease affects not only the patients but also their informal (e.g. families) and formal (e.g. care staff) caregivers, on whom the bulk of the care burden falls [8].

Up-to-date, there is no cure for dementia thus the attention to the symptomatic non-pharmacological treatment for the patients and their caregivers has become increasingly relevant, especially as the literature shows that these can be more effective that most of the available drugs [31]. Although home remains the preferred place for care delivery, a substantial number of patients need to access (permanently or temporarily) residential care facilities, when home care is no longer feasible. In the residential context, infrastructure and staffing levels are not always adequate to manage residents with dementia. Residential care services are indeed labour intensive and the quality of care here depends largely on the staffing level and characteristics [15,23]. As the ongoing financial crisis is reducing the budget available for residential care services, a detrimental effect on personnel standards might occur. This concrete risk of staff shortcomings might, in turn, lead to a substantial proportion of avoidable hospitalisations, use of emergency departments, increased carers' burden and stress, and inappropriate use of chemical and physical restraints (e.g. antipsychotics).

The literature suggests that education, training and support of available staff, supervision, and improvement of job satisfaction could be effective measures to increase quality of care in assisted care settings [14]. In addition, technologies and other environmental factors have been identified as the most promising measures to improve working conditions in the residential care setting, to reduce the care burden and to improve the overall quality of care [2,11]. The potentials of new technologies have been tested to reduce the need for continuous monitoring of dementia patients, and to increase their safety and well being within the residential setting.

Aloulou et al. [1] describe the development and deployment of an Ambient Assisted Living (AAL) system for nursing homes. They have tested the system, comprising a set of environmental sensors, devices to enable interaction and a centralized machine for each room, involving 8 patients and their caregivers, in a nursing home in Singapore. Field trials are extremely important: in this case for example, the installation outside a laboratory environment led to recognize problems derived from the real usage. Secondly, the first test phase conducted only with caregivers enabled a preliminary evaluation of the system and its refining without affecting the patients. Finally, the complete test provided an overall description of the system capabilities, its effectiveness, the benefits brought to the patients and the caregivers, the contribution to improve the quality of the assistance provided and to support the caregivers.

Several solutions can be found in the literature that adopt assistive technologies (ATs) to help PwDs at home, to perform the usual daily tasks and thus to maintain their independence. As for the type of ATs adopted, a mapping study have been conducted, based on literature and industrial (limited to UK market) surveys [3]. From this research, 5 main types of ATs have been identified: robotics, health monitoring, prompts and reminders, communication, software. Moreover, it seems that there is a gap between academic research and industrial products, since the literature mainly focuses on robotics and health monitoring, while the UK industry mainly develops health monitoring and software based technologies.

Other papers affirm that reminding technologies are an active area of research. Patterson et al. [29] provide an overview of works addressed to this topic, but they also find out that often the adherence to these reminders is not considered. They start from the principle that the user acknowledge is not sufficient to assess the real execution of the task following the reminder: therefore, they propose a prototype that integrates reminders and adherence detection, along with the possibility to inform a carer in case of non-compliance.

Despite the rich literature on the available technologies, there are a few studies that involve PwDs in determining the results of using ATs [9]. Most of them include people with mild and moderate dementia but often the stage of the disease is not specified. As for the assessment of the quality of life, a standard approach is necessary to carry out a significant comparison across studies.

3 Design and Deployment

The system described in this paper represents an evolution of a project named UpTech, aimed at improving the quality of life of both AD patients living at home and their family caregivers. This project involved nurses and social workers, who periodically went to the patients' houses, and included the installation of technological kits at the patients' homes. Each kit consisted of a network of wireless sensors installed in the house, for the monitoring of the patient. Data were processed by a central control unit and, in case of danger, a notification was sent to the caregiver. The new system, called UpTech RSA, targets the nursing home environment and has been devised primarily for the overnight monitoring of patients, when there is a lack of personnel in the building. Moreover, the main differences between the two systems concern the following aspects:

- number of users: in the nursing home, multiple patients are monitored at the same time. Thus, the central control unit is able to manage data coming from more than one set of sensors;
- sensors: different types of sensors are employed, due to the diversity of the physical environment;

- system architecture: the whole network can be seen as a set of sub-networks, one for each room;
- alarm management: the monitoring system is an aid for the nurses, the notifications are not sent to the remote caregiver as in the home-based system.

The project development stage carried out in the Laboratory was aimed first at the improvement of the previous UpTech kit, secondly at the design and implementation of the modules required for the new system. In particular, the radio transceivers firmware was re-designed, to implement an efficient data acquisition and transmission procedure. At the same time, particular attention was paid to the energy consumption exhibited by the transmission nodes, by taking into account the values of power absorption in the different operation phases, and implementing all the possible strategies for its reduction. As for the new components, the following modules have been designed: the structure of the database used to store the collected information, and the applications necessary to implement the decision algorithms, in charge of making actions depending on particular values of the acquired data.

The system requirements have been identified by collecting nurses' requests, thus the developed functionalities are related to the usual daily care procedures. Specifically, the set of sensors installed in each room enables the following functionalities:

- door opening detection;
- window opening detection;
- "French-window" opening detection;
- presence in bed detection;
- presence in the bathroom detection.

The door opening detection is achieved using a magnetic sensor, wireless connected by Sub-GHz technology at a frequency of 868 MHz to a gateway, by means of a properly designed electronic equipment.

Similarly, the detection of windows opening is obtained through the same technology (see Fig. 1[1]). The user's presence in the bathroom is detected by a self-powered Passive Infrared Sensor (PIR), which is connected to the radio transmitter module. For ease of installation, and to avoid damage to the fixtures of the building, these sensors have been placed on top of the entry doors of the bathrooms. A mat sensor has been adopted to detect the user's presence in bed; it is available in two versions, with and without self-calibration. The sensor without self-calibration is placed over the mattress, under the sheets, while the other one is placed under the mattress (Fig. 2), and therefore it results more comfortable for the patients and for the daily operations of bed maintenance. The gateway represents a central node that forwards data to a PC located at the nurses' station. Then, the application running on the PC filters the incoming information. Data related to events are saved in a local database (DB), while those referred to the operating status of the sensors are verified in order to monitor the correct operation of the technology kits.

[1] All figures in the paper are reproduced from [24].

Fig. 1. Magnetic sensors for windows opening detection.

Fig. 2. Self-calibrating mat sensor, for under-the-mattress positioning.

The electronic boards transmit an event to the central server every time there is a status change, that is, for example, activation/deactivation of the PIR sensor, or opening/closing the door. Accordingly, the data stored in the database contain the sensor information (id, gateway address, name and type), the date and time when the notified event occurred, and the status of the sensor represented in binary format as follows:

- activation: $state = 1$;
- deactivation: $state = 0$.

In addition, the server assigns a unique id to each DB row in order to implement a robust mechanism for transmitting information to the mobile interface. This allows the mobile device to identify one or more missing events, and to request them back from the server. In fact, a mobile Android application has been developed, running on a tablet or smartphone, and so easily portable. This allows the nursing staff to receive event notifications even when they are outside the nurses' station and cannot access the fixed desktop interface. Events data, properly processed, are displayed through not only mobile, but also desktop interfaces (Figs. 3 and 4). In the first case, the user can see a scrollable list of events identified by the name of the sensor that generated it and the room name, as shown in Fig. 3. Each event is tagged with a colored circle: depending

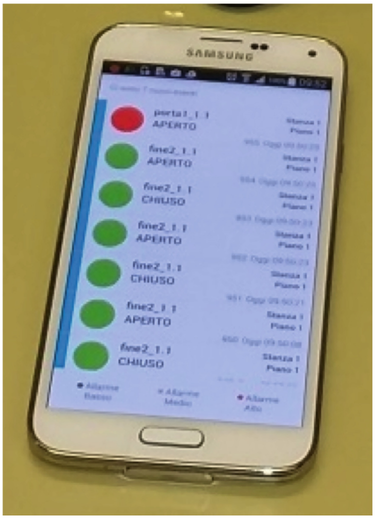


Fig. 3. Mobile interface running on a smartphone.

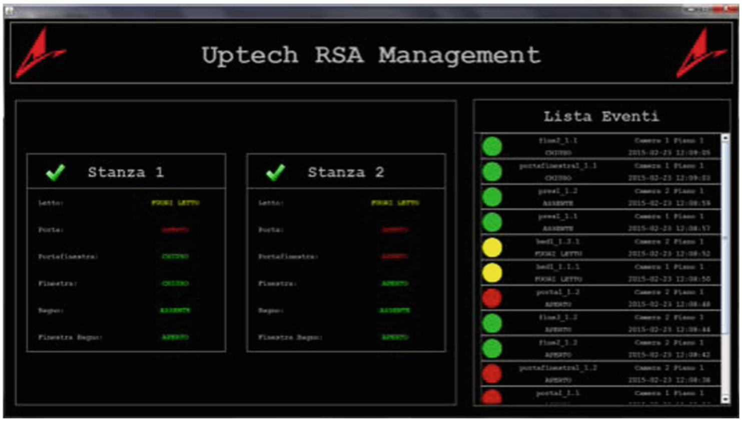


Fig. 4. Screenshot of the Desktop Interface, *two sections* version. (Color figure online)

on the associated level of alert, the circle may be green, yellow or red. In the latter case, two versions are available:

- a *two sections* version: the graphic interface is organised into two parts. On the right there is a scrollable list of the events acquired by the sensors, while on the left the status of the sensors in each room is shown. There is a top bar which becomes coloured and flashing when an event occurs;
- a *multi-user* version: the main screen shows all the rooms monitored. When an event occurs in one room, the corresponding frame becomes colored. By clicking on the box, it is possible to see the details of sensors state.

Given the wireless transmission mode of the sensor nodes and their battery supply, the monitoring of the sensors state itself becomes very important. Therefore, a procedure for the periodic sending of alive messages has been implemented in the sensors. They are constantly monitored by the central processing system, that generates alarm messages in the case of failure. Despite its importance, this procedure is extremely critical, because sending *alive* messages too frequently causes an increase in the batteries consumption. Otherwise, the transmission of the *alive* message at a lower frequency can give rise to long time intervals in which the sensor is not active, but the system is not informed about the failure. When an *alive* message does not reach the local server at the expected time, the latter notifies a malfunction of the sensor node to the nurse, who can promptly find out the problem and act accordingly.

4 Field Trial

4.1 Experimental Set-up

The system described in Sect. 3 is already available as a prototype. Following the initial development phase in the Laboratory, aimed to better adapt the technology to the emerged operational requirements, the prototype has been installed in the nursing home "Villa Cozza" in Macerata (Italy). In this phase, the supervision of two rooms (tagged as room 2 and room 3) has been implemented, while the final version of the system will be able to dynamically accept a plurality of rooms, depending on the operating requirements. Each room is equipped with a sensors kit consisting of three magnetic sensors (one applied onto the window, one onto the French window, and one onto the room front door), a PIR sensor in the bathroom, and a force sensor placed in the bed, as shown in Fig. 5. A single gateway device has been used to manage wireless communications with the sensors in the two rooms.

In room 2 two female patients are housed, only one suffering from AD. Her bed has been equipped with a force sensor. The other one is not autonomous and can move only by a wheelchair; consequently, the events generated by the different sensors can be originated only by the movement of the first patient. In room 3, instead, a single female patient is housed, also suffering from AD, but in this case she can not move autonomously. As the system represents a support tool for improving the safety of patients, it can be well-compared to an alarm system. Moreover, the type of sensors employed do not collect personal data of the two patients involved. According to the national laws, in this case the ethical approval is not required.

During the installation phase, it has been critical to enable the communication between the gateway, positioned in the corridor in front of the two rooms, and the central server, located in the nurses' station on the upper floor. Such a problem arises because the building where the nursing home is located is not equipped with a communication infrastructure (e.g. a Local Area Network): there are no network cables, or WiFi coverage. Moreover, the nursing home is hosted in a historic building and, as often happens in such cases, the walls are thick

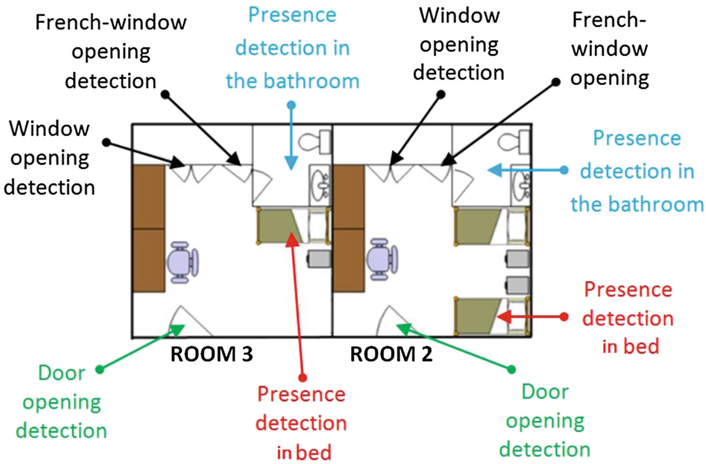


Fig. 5. Floor plan of the two rooms equipped with the UpTech RSA sensors in the nursing home "Villa Cozza", Macerata (Italy).

and made of concrete, thus making wireless communications very difficult. Both a Power Line Communication (PLC) and a mixed wireless infrastructure (WiFi and Hiperlan) have been experimented, finally selecting the wireless solution as the supporting communication architecture. In order to overcome obstacles like metal doors and thick walls, that limit signal propagation, multiple Access Points (APs) and links have been setup.

4.2 Evaluation Survey

Some weeks after the installation a survey for the evaluation of the system has been conducted over 18 nurses. Although some of them are not very familiar with the technology, the results are highly positive. In Table 1, some of the most significant questions and results are listed. The 100% of respondents believes the kit is easy to use and recommends it for the monitoring of AD patients in nursing homes during the night. All the nurses state the system has not been a source of stress for them. In fact, its introduction does not generate further work for the staff. They just carried on the usual activities, but with an additional monitoring tool. Only 6% of the nurses believes that it was stressful for patients. Indeed, operators have received some sporadic grumbles due to the discomfort produced by one of the bed sensors. As mentioned in Sect. 2, the bed force sensor without calibration must be placed between mattress and sheet: this may annoy the patient during sleep time, due to a difference in thickness. This leads us to conclude that the sensor with calibration is preferable, as it can be placed under the mattress, and will be consequently used in the subsequent installations. Apart from that, patients did not notice any change.

Moreover, the nurses stated that, during the trial period, there have been some dangerous episodes detected by the kit, such as the opening of a window

Table 1. The opinion of the nurses about the experimental deployment of the UpTech RSA technology at the nursing home "Villa Cozza".

Question	Yes	No	
Is the kit easy to use?	100%	0%	
Do you think that the patients monitored have suffered a stress?	6%	94%	
Do you think that the kit has been a source of stress for nurses?	0%	100%	
Would you recommend the use of this kit in nursing homes?	100%	0%	
Question	Positive	Medium	Negative
Overall opinion on the technological kit	89%	11%	0%
Question	Yes	Quite a lot	No
Do you think that the kit can improve the assistance provided in nursing homes?	61%	39%	0%

during the night, and a patient's fall out of the room. In both cases the system detected the alarming situation and the staff was able to intervene promptly. Despite the positive opinions, some problems were found, in particular due to the occurrence of false alarms. They were caused primarily by failures in the communication link, resulting in multiple sending of alarm events.

Still considering nurses' opinions, some ideas for improving the system were identified. First, false alarms must be avoided, as they can generate a feeling of distrust by operators against the entire system. Secondly, customizing different alarms for each user would be preferable, since each patient has different behavioural and health conditions. Finally, implementing an even more friendly user interface would encourage the adoption of the system by nurses unfamiliar with technology.

5 Data Analysis

5.1 Context Characterization

In addition to the real-time monitoring of patients, it is possible to perform several types of analysis on the data collected by UpTech RSA sensors over time, such as obtaining information on the patient's habits and, as a consequence, detecting any changes or unusual behaviours. In the following, some sample graphs are shown, representing selected daily activities of the monitored patients, obtained thanks to the events detected by the sensors. The analysis refers to data collected from May to June, 2015, by the sensors located in both the monitored rooms.

First of all, in order to give significance to the analysed data, some information about the patients and the daily activities conducted in the Alzheimer's ward are necessary. Table 2 represents a sort of daily diary. Patients remain within the ward during the day: they can stay together in the common areas, where they also have lunch and dinner, and can go in/out of the rooms whenever they want. The entry doors of the rooms are generally closed during the night. They are opened by the shift nurse who performs two inspection rounds per night, in order to verify that the patients are sleeping and do not need assistance.

Table 2. Diary of daily activities.

Time	Activity
7:30	Rooms cleaning
7:00–10:00	Patients get out of beds
Morning	Patients stay in the common areas, can go in/out of the rooms
11:30–12:30	Lunch in the dining room
Afternoon	Patients stay in the common areas, some of them have a rest
17:30–18:30	Dinner in the dining room
19:00–21:00	Patients go to bed
22:00	First nurses' check round
3:00	Second nurses' check round

In room 2 there are two patients: only one is monitored through a bed sensor, because she suffers from AD and often wakes up in the night and goes out of the room. The other patient moves by wheelchair and is not able to get off the bed on her own. The AD patient in room 3 has bed rails, so she can not get out of the bed autonomously during the night.

Although the system is able to monitor the patients throughout the entire day, the interesting events are those occurring during the night. In that period, in fact, the user is left alone for most of the time and thus the data acquired are more significant. The graphical visualization of the analysis output provided in the following sub-section has the ability to help the reader in recognizing and understanding a large amount of data, and in easily identifying anomalies and behavioural patterns that would not be obvious otherwise.

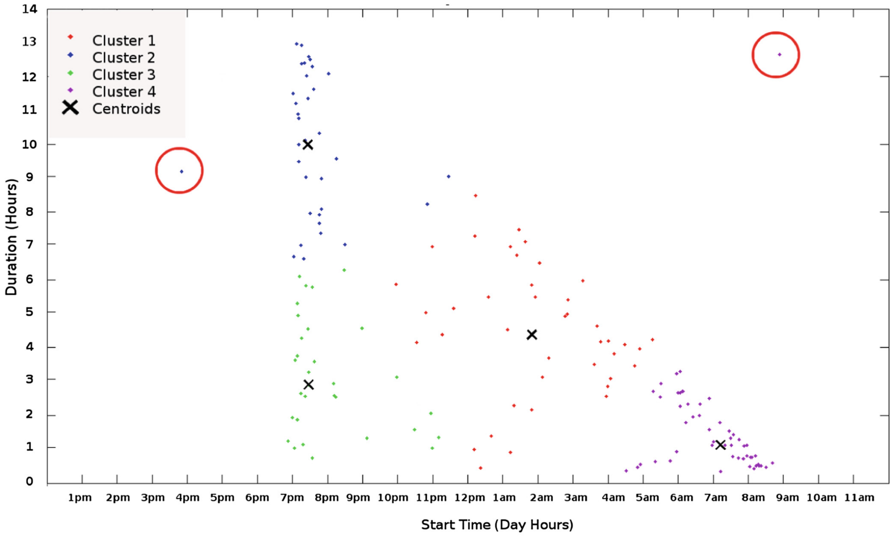
5.2 Data Representation and Analysis

The raw data collected by the sensors installed in the rooms are often difficult to interpret. Therefore, in order to carry out the data analysis, first of all it is necessary to find a representation allowing to understand them immediately. Lotfi et al. [19] affirm that, among the various representation methods presented in the literature, the start-time/duration is the most effective one for large data sets. The data acquired from each sensor can be seen as a binary signal, in which the value "1" is the activation and the value "0" is the deactivation. Representing information according to a start-time/duration method means converting the binary signal into two separate sequences of real numbers corresponding to the start-time and duration of each activity, respectively. Figure 6 shows the start-time/duration graphs of the activity detected by the bed sensor, i.e. presumably sleeping, for each room. Each point on the graph indicates a "sleep" and is characterized by a start-time (on the abscissa) and a duration (on the ordinate). All activities lasting less than 10 min have been ignored because they could indicate sensor activations and deactivations due to involuntary movements of the subject while asleep.

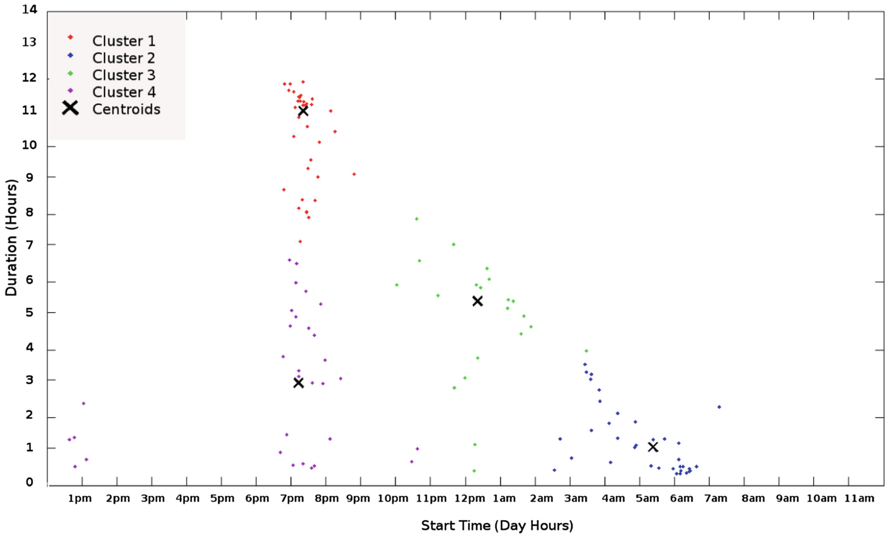
Looking at the charts it is easy to notice the triangular shape assumed by the set of points. This result was expected because life in the nursing home is scheduled by the daily diary and, thus, the sleeping activities are bounded by specific and almost fixed time constraints. Therefore, it seems plausible that patients never go to bed before 6:30 PM, and the sleep duration is inversely proportional to the start-time. The sparse distribution of points in the triangular-shape diagrams indicates that the monitored subject wakes up several times during the night. In Fig. 6(b) a group of points is located between 12:30 PM and 1:30 PM: this suggests that sometimes the patient has a rest after lunch. On the other hand, looking at Fig. 6(a), the presence of two outliers (highlighted by red circles) becomes immediately evident.

Analytically, a first detection of outliers is performed using clustering techniques. In the present case the K-means algorithm is applied [25], which allows condensing the data. Different techniques can be used to separate normal data and outliers [6]. In this case, a variation of the threshold filtering method has been chosen: it consists in both comparing a specific feature of the points with a threshold and excluding the outliers. Specifically, for each cluster identified, and for each point in the cluster, the considered feature is the euclidean distance between one point and the others belonging to the same cluster. Such distances are then compared against a threshold empirically chosen: all points whose distance exceeds the threshold are considered outliers. Moreover, to improve the clustering effect, another iteration of the algorithm is performed, by excluding the abnormalities found from the dataset. Clustering is employed as a preprocessing method, and it can be considered as the basic level of data analysis. It does not provide a definitive result, in fact its application to the dataset has the only aim to help understanding data by means of a graphical representation.

Another information that can be extrapolated by combining the data obtained from the bed sensor with those detected by other sensors, is the identification of the action carried out after the user came out of bed. This will enable the possibility to calculate the occurrences of predefined patterns of activities, instead of single ones. Such an analysis allows to identify potentially dangerous situations with respect to behaviours commonly exhibited by the subject, and not considered as alarms. Each point on the graphs in Fig. 7 indicates a "sleep" and is characterized by a start-time (on the abscissa) and an end-time (on the ordinate). As for the start-time/duration, the start-time/end-time representation requires the conversion of the binary signal in two separate sequences of real



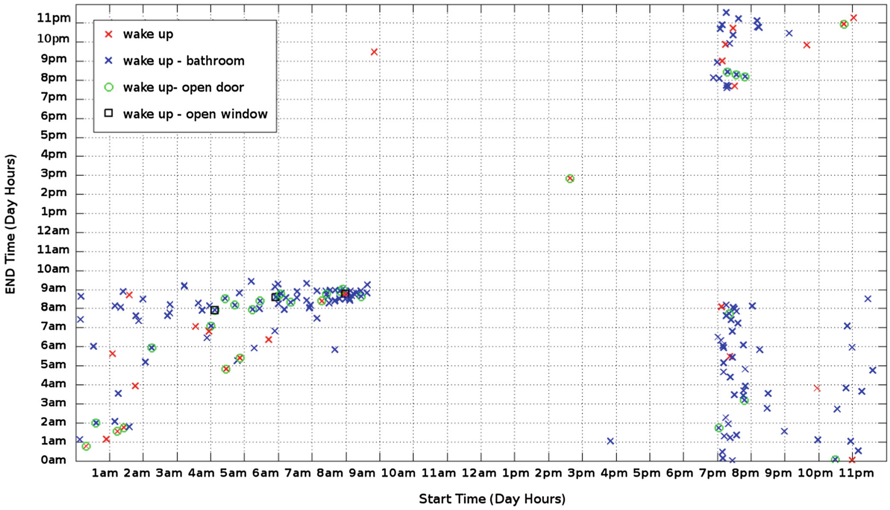
(a) Room 2



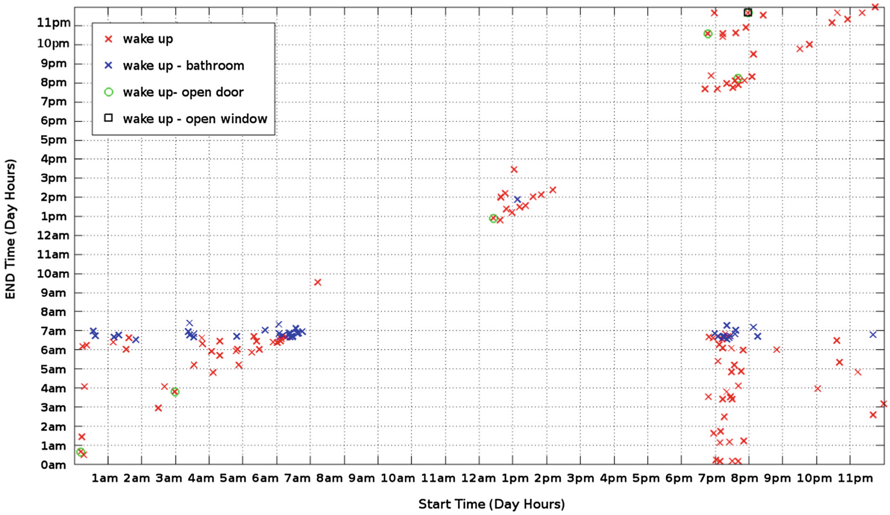
(b) Room 3

Fig. 6. Start-time/duration graphs of the "sleeping" activity detected from May to June 2015, respectively in (a) room 2, and (b) room 3. (Color figure online)

numbers which in this case correspond to the start-time and end-time of the activity. The type of activity shown is still the sleeping, but, according to the action carried out subsequently, the shape and colour of the marker changes.



(a) Room 2



(b) Room 3

Fig. 7. Start-time/end-time graphs representing the activities performed after waking up by the patients housed respectively in (a) room 2, and (b) room 3, from May to June 2015. (Color figure online)

In fact, the graphs show, for each room, the actions executed within 4 min after the patient got out from bed (end-time), i.e.:

- door opening (marked as a green circle);
- window opening (marked as a black square);

– presence in the bathroom (marked as a blue cross);
– no other activity (marked as a red cross).

This kind of representation has been chosen to emphasize, especially in Fig. 7(b), that some of the actions are performed only when the patient gets up at certain times. For example, the patient in room 3 enters the bathroom within 4 min after waking up only in the morning, i.e. only when nurses remove the rail from the bed. The other activations and deactivations occurring during the night could indicate that the subject has moved or was seated up on the bed, while the openings of the door or window are probably due to the presence of the medical staff.

Conversely, looking at Fig. 7(a), the observer can notice the patient very often goes to the bathroom or opens the door immediately after getting up. This agrees with the reports of the nurses concerning the fact that the monitored elder is very lively, and often gets up during the night.

In Table 3, the percent occurrence rates of each activity described above are given, limited to the night hours.

Table 3. Hit rate of the getting up action followed respectively by the action of entering the bathroom, opening/closing the door, or opening/closing the window, in the time slot between 09:00 PM and 06:00 AM.

Event detected after awakening	Room 2	Room3
Presence in the bathroom	76%	15%
Door opening	14%	2%
Window opening	0%	0.2%
None	10%	82.8%

The analysis described so far is just the very first step to identify the user's behavioural patterns and abnormal situations. Until now, we focused on the representation and visualization of data, extracting some preliminary information on the habits of two monitored patients. Nevertheless, there is still a long way to go. Although the detection of outliers can be very useful in this context, however, it is necessary to set up a predictive system able to identify in advance any anomalous situation to help the nursing home staff making the necessary arrangements. As already hinted, one of the aspects emerged during discussion with nurses is the need of alarm personalization. In fact, a situation may be potentially dangerous for a user, while it may be harmless for another one. This strongly depends on motor and cognitive skills of each patient. Although this can be done manually by nurses via graphical user interfaces, a significant contribution comes from the analysis of patients' habits. One of the future developments is to extend the behavioural analysis in the long term, aimed at recognizing unusual, and, therefore, potentially dangerous situations and notifying them to the staff, in a completely automatic way.

6 Conclusion

The comparison of the results obtained from the first experimental installation of the proposed monitoring system to the work already cited in [1], concerning the adoption of an assistive technological system in a nursing home, motivates a number of comments about the outcomes of the research herein presented. First, even if the solution presented in [1] is more complete than ours, we found some basic similarities that confirm the validity of our proposal, such as the choice of adopting wireless environmental sensors, and the usefulness of an overnight assistance. Second, the same referenced paper confirmed that data gathered from non-intrusive sensors can be exploited to perform a long-term analysis on the trend of the patient's conditions. Finally, we learned that before involving patients in the adoption of a new technology targeted to their assistance, this should be tested only with caregivers and nurses. This way, possible malfunctions or false alarms will not affect the patients and will be detected and solved beforehand. Nurses' compliance in using the proposed technology could grow even more by extending the pool of monitored patients, as being able to cover all of them increases the perceived benefit for the nurses and, above all, the degree of safety of the patients.

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