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As the number of older adults increases, and with it the demand for dedicated care, geriatric residences face a shortage of caregivers, who themselves experience work overload, stress and burden. We conducted a long-term field study in three geriatric residences to understand the work conditions of caregivers with the aim of developing technologies to assist them in their work and help them deal with their burden. From this study we designed, implemented and evaluated two prototypes for supporting caregivers' tasks (e.g. electronic logging and elders monitoring). The evaluation, conducted in-situ for a period of four weeks and, the data collected from six months of use, motivated the design of a predictive schedule, acting as a proxy between residents and caregivers. Such design was iteratively improved and evaluated in participative sessions with caregivers. PRESENCE, the predictive schedule we propose, triggers real-time alerts of risky situations (e.g. falls, entering off-limits areas such as the infirmary or the kitchen) and, informs caregivers of routine tasks that need to be performed (e.g. medication administration, diaper change, etc.). Moreover, PRESENCE helps caregivers to record caring tasks (such as diaper changes or medication) and wellbeing assessments (such as the mood), which are difficult to automatize. This facilitates caregiver's shift handover, and can help to train new caregivers by suggesting routine tasks and by sending reminders and timely information about the residents. It can be seen as a tool to reduce the workload of caregivers and medical staff. Instead of trying to substitute the caregiver with an automatic caring system, as proposed by others, we propose the design of our predictive schedule system that blends caregiver's assessments and measurements from sensors. We show the feasibility of predicting caregiver's tasks and a formative evaluation with caregivers that provides preliminary evidence of its utility.

Categories and Subject Descriptors: **J.3 [Life and Medical Sciences]**: Health

General Terms: Design, Human Factors, Measurement

Additional Key Words and Phrases: Assistive living systems, Activities of daily living (ADL), Elderly care

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1. INTRODUCTION

The world's population is aging and, as a consequence, the number of older adults has experienced a sharp increase in recent years, increasing with it the demand for dedicated care (World Health Organization 2012). The elders, by their own, or via their closest relatives decide to move to geriatric centers, also called residences or nursing homes (Hossain 2014), which are places designed according to the needs of older adults (*residents*) with specialized personnel to take care of them (Silva et al. 2013).

Despite the specialized services offered, the capacity of geriatric care centers is limited (Bardram 2008), and very often, residents greatly outnumber caregivers attending capacity (Fennell et al. 2010). The staff is constantly under work pressure and stress (Yedidia & Tiedemann 2008) due to emotional wear, rotating shifts, the need for specialized training (Rosenberg et al. 2009) to treat and attend each resident, etc. Moreover, caregivers are required to record the activities performed by the residents of the nursing home. For this, they rely on conventional tools, such as pen and paper (Archer et al. 2011); frequently these records are not up-to-date due to heavy workloads (Blumenthal & Tavenner 2010). As a consequence all the staff (caregivers, doctors, nurses, etc.) act upon incomplete information (UNFPA 2012). As personnel rotation occurs, newcomers rely on more experienced members in order to get valuable information from them to better perform their jobs. Thus, there is a lot of implicit knowledge in the care of elders, the methods to capture such knowledge are unreliable and error-prone, and knowledge transmission is not systematic.

No attempt has been made, so far, to incorporate valuable information from caregivers into assistive technology to support elders' care processes in residences. This is not an easy task. For a perfect understanding of the care process and, the elders and staff needs, it is necessary to propose an appropriate technology. The grand view of this work is to extract and systematize the essential knowledge behind caring elders, to learn the methods and techniques used by caregivers, and to detect weaknesses and improvement opportunities in nursing homes. Therefore, we conducted a field study to develop suitable assistive applications based on the principal characteristics found in naturalistic environments. This paper discusses the process guiding the design of ad-hoc applications developed to assist elders' without losing sight from caregivers' burden and assessments. The result of our study is the design of a predictive schedule that will help caregivers in their daily activities to diminish burden, as well as a tool to transmit information during shifts in a discreet, transparent and orderly manner.

Our principal finding is the need for an assistive technology able to present a holistic view of the care needs of each resident, without consuming the ever scarce time of the caregivers. Moreover, due to the routine nature of caring, the adequate tool would be a predictive schedule. That is, a regular schedule with some inference mechanisms to suggest tasks, receive timely reminders, monitor elders' location passively, trigger alerts and alarms from risky situations, and a few other abilities like electronic logging and reports.

The above design was possible after a long-term study, the design and implementation of two prototypes, their corresponding evaluation and several rounds of participative design sessions. The two implemented prototypes (SSAMI and SMAMI), the former for sending notifications about risky situations and the later for recording annotations from caregivers and sensor readings, were evaluated and used by the caregivers and the medical staff. Then the users suggested enhancements in subsequent participative design sessions, which lead to the design of the predictive schedule. This paper discusses the process guiding the design, the insights acquired, and how they were incorporated in successive iterations of the predictive schedule named PRESENCE.

The rest of this paper is organized as follows. Section 2 discusses related work. Section 3 presents our research methodology. Section 4, shows the iterative design process that guides the implementation of two functional prototypes. In section 5 we present the design of PRESENCE as a result after the in-situ evaluation. Section 6 presents a discussion of our results and we conclude in Section 7 with some remarks.

2. RELATED WORK

In recent years, many assistive technologies have been proposed to assist elders and caregivers to: advise about their nutritional habits (Lázaro et al. 2010), monitor risk behaviors (Kaluža et al. 2011), measure muscle strength with videogames (Zavala-Ibarra & Favela 2012), socialize and exercise (Cornejo et al. 2012), track activities (BeClose 2013). Others are focused on the improvement of the care process by providing: electronic health records (Kim & Kim 2010), remote medical attention (Havasi & Kiss 2008), and intelligent vital signs monitor (Megalingam et al. 2012). Among these assistive technologies, there are Ambient Assisted Living (AAL) systems (Sun et al. 2010) that analyze different data sources from sensors to generate timely information useful for both older adults and the staff working in geriatric centers. This data can be analyzed to identify individual and group patterns from which it can be inferred situations requiring the attention of the caregiver (Fatima et al. 2013). That is, it is possible to generate additional knowledge about the resident from the data collected and sensed (Fayyad et al. 1996). Also, deviations in the behavior of the elderly have been analyzed to detect health risks (Botia et al. 2012) and situations that may require attention (Shin et al. 2011).

Using sensors, it is possible to infer elders' health, by monitoring the level of physical activity performed (Kaluža et al. 2012), as an indicator of their frailty (Bravata et al. 2007). Monitoring and assessing the performance of daily activities is relevant for the continuous assessment of elders' health and independence (Onyimadu et al. 2011). Promising results have been obtained with the combination of sensor and medical data using diverse techniques to determine the level of wellbeing in older adults while performing their daily activities (Suryadevara et al. 2012).

Virtual caregivers have also been proposed to assist the human caregiver in taking basic decisions, asking for human intervention when necessary (Hossain & Ahmed 2012). In most of the above-mentioned work, the analysis of heterogeneous sensor sources is used to make inferences. However, based on the classification of digital sources proposed in (Zhang et al. 2012), sensor data are only part of the static sensing infrastructure, and it focused on inferring a single type of behavior, e.g. mobility patterns. The challenge is in including more context data sources and combining them to improve inferences. In (Rodríguez et al. 2014) an information fusion approach was proposed as a multi-agent system, which manages data from sensors and processes them to infer the activities of residents. The focus of this last work is in presenting statistics from location sensors, and based on the statistics the authors suggest the creation of patterns. Statistics are valuable information to make decisions but, they are not the best form to present and visualize information for fast decision making by caregivers (Skiba 2014).

Another alternative to provide care to older adults is with robotic caregivers (Borenstein & Pearson 2010)(Sorell & Draper 2014). Certainly, robotic caregivers are an approach intended to substitute human caregivers (Parks 2010), to encourage elder's cognitive skills (Coeckelbergh 2010), or to avoid isolation as a partner of an elder (Sparrow & Sparrow 2006). Although there are advantages on the robotic caregivers there are still some elements that limit their adoption as a viable approach for caring older adults (Decker 2008)(Vallor 2011)(Misselhorn et al. 2013).

Moreover, robotic caregivers surely represent an option to reduce or even eliminate burden on human caregivers, even though human caregivers will not be replaced by robots in the near future. Our approach considers using caregivers' observations as an input to a prediction model and combine them with data from sensors to provide predictions based on mixed context information. On the other hand, the assistive technology aims to reduce caregivers' burden through simplifying the care processes and tasks (Silva et al. 2013)(Aloulou et al. 2013) (Piau et al. 2014). In this way, technology helps to increase the quality and efficiency of care [Lexis 2013] of older adults. We believe that the predictive schedule would be another mechanism that will help to diminish the caregivers' burden and stress, by the anticipation in registering elders' activities. The time saved enables caregivers to program others kinds of activities with elders (such as, games, chats, hand crafts, etc.) which will impact elders' mood and wellbeing (Shankar et al. 2014).

3. RESEARCH METHODOLOGY

The methodology used in this work was iterative and user-centered (Norman & Draper 1986), and it describes the steps we followed to design the predictive schedule. The methodology consists of the following five phases (see Fig. 1), each one is explained in detail next and developed in the following sections:

1. *Initial context comprehension*. This step includes acquiring empirical knowledge from the application field to understand and establish roles, artifacts, tasks, activities, and processes. Qualitative techniques were used such as structured and semi-structured interviews, non-participative observations, shadowing, and process engineering. The above techniques enabled empirical data collection for later analysis and to construct valid theory from qualitative data.
2. *Context data analysis*. The data acquired in phase 1 were analyzed. All the interviews, observations and annotations were transcribed to execute an iterative analysis seeking for concepts and categories. This process enabled us to identify insights, needs and requirements within a specific context.

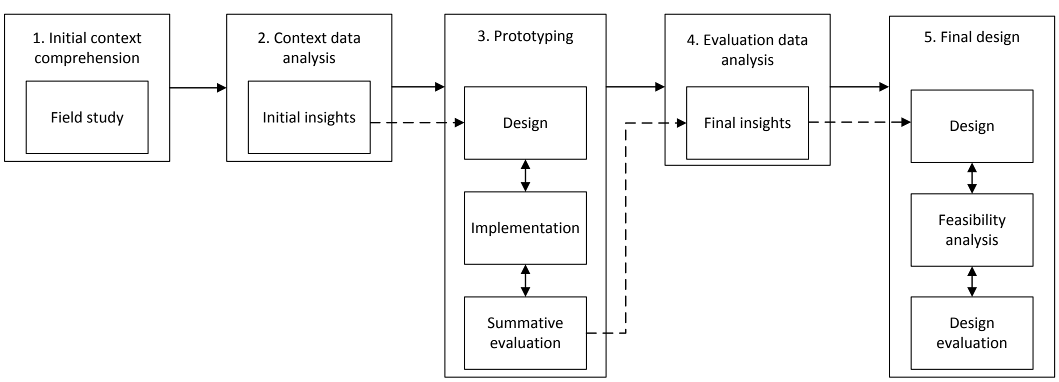


Fig. 1. Research methodology diagram.

3. *Prototyping*. Previously to the final design, two prototypes for recording activities (SSAMI) and for sending alerts about risky situations and sensor readings were designed (SMAMI), implemented and evaluated

based on the insights defined formerly. All design decisions aimed at solving the problems identified in previous stages. The prototypes were designed as tools to improve the care of residents and the awareness of the caregivers about the residents. The implementation included the development of tools and applications around the prototypes. Finally the prototypes were evaluated *in-situ*. This type of evaluation is hard because controlling variables and subjects implies foreseeing all possible situations; which may not be achievable in a bounded amount of time. An *in-situ* evaluation is, however, a good source of reliable information and adds value to research. When the prototypes were installed and tested *in-situ* some unpredicted situations may arise, and the design and structure of the prototypes can be changed within an iterative cycle to make the necessary adjustments.

4. *Evaluation data analysis*. The data obtained from the evaluation of the prototypes were analyzed. The perceptions and technicalities about the users of SSAMI and SMAMI were studied to find gaps, which were considered to get the final insights.
5. *Final design*. With the *in-situ* evaluation of the preliminary prototypes final insights were obtained. We designed the predictive scheduling system considering them. We also explored the viability of the predictive schedule in a geriatric residence, for this reason we conducted a participative design session with caregivers and medical staff. We present the analysis of the main results that gave us evidence about the utility of the predictive schedule for caregivers.

4. DESIGN PROCESS

The following sections detail the methodology we used to collect, analyze and process data from personnel and residents of the geriatric residences. With a non-participatory observation (Section 4.1) we determined the features to be monitored (Section 4.2), and from that we designed and developed prototypes (Section 4.3).

4.1 Initial context comprehension

We conducted a field study to investigate the caring needs of residents of geriatric centers, and to learn the methods and procedures used for the care of older adults. The field study took place in three different institutions in the state of Baja California in the northwest of Mexico, two of them private and one public. We conducted a non-participatory observation (180 hours), and a total of 19 semi structured interviews with caregivers and residents of the three institutions. Residents came from different socioeconomic strata; had different levels of support from their social network and also variable levels of health and physical and mental fitness. This implies a variety of specialized care needs to be met on an individual basis. From the data gathered, we performed an analysis to obtain a classification of the main activities of both the residents and the caregivers. This analysis included a thorough and comprehensive review of the observation logs and interviews using methodologies such as grounded theory (Glaser & Strauss 2012) and sequential analysis (Wald 2004), and process engineering (Davenport 1993) covering quantitative and qualitative perspectives.

We transcribed manually 19 semi-structured interviews conducted in the different residences. Using some techniques of grounded theory (open and axial coding) we found the main activities performed by caregivers and residents. Then the activities were classified according to the Activities of Daily Living (ADL) classification and their relevance for caregivers, and we formed groups of activities and tagged them. Next we present the definition and classification of these activities.

- *Information management*. Activities related to the collection and consultation of relevant information to the process of elders' care. It covers filling and updating reports hourly by hand, one by each shift, and reporting eventualities, if any. It includes accessing information from the medical record, filling in nursing sheets, and monitoring and registering information about meals, excretions, urination and eventualities in the notebooks.
- *Coordination*. Activities related to staff management, *e.g.* the meetings for planning and assigning work tasks, planning special diets, inventory control, operational meetings, collecting and verifying medications for the elders, talks between the staff and reviews about general aspects.
- *Care*. Activities related to maintaining the wellbeing of the elders. Care activities are divided into:
    - Medical attention. Taking vital signs, medication intake, medical consultations and visits, and preparing medications or some medical devices in the nursing station.
    - Hygiene. Bathing, assisting in the bathroom, changing clothes, changing diapers and grooming (haircut, cutting nails, brushing teeth, washing the face, etc.)
    - Recreation. Walking in the garden, watching movies or the T.V., playing games in the living room, listening to music and going out of the residence with family or friends.
    - Feeding. Feeding or providing food to the elders.
    - Service. Getting elders out of bed, talking with the elders, checking elders' status, awakening, and responding bell calls.
    - Rest. Residents resting in their room or sleeping.
- *Support*. The support activities are those additional activities supporting the maintenance, cleanliness and order of the residence. Washing, drying and folding laundry; ordering things in the kitchen or cupboard; preparing meals; receiving family and visitors; maintenance of the facilities; residence cleaning; answering the phone; and opening or closing the door of the residence.
- *Personal time*. It covers personal and informal chats between caregivers or staff, checking their mobile phone, time for eating, and taking personal calls.

Once, identified the main activities, we proceeded to model the care process. The methodology we used was *process engineering* (Curtis et al. 1992) from which we built a rich picture (Checkland 1989) with the general view of the process. A rich picture gives a comprehensive and useful view of the process it models. This picture (see Fig. 2) conceptualizes a general view of the process, its inputs, outputs, roles and the relationships among them. For instance, the caregivers change clothes of the resident (process), s/he needs the clothes (inputs) and contact with the resident (relationships) to put them on. With the above procedure we obtained qualitative, valuable information for the managers of the residence. We also transcribed the 180 hours of observations gathered and performed a quantitative analysis using sequential analysis of the activities. All these results led to the design of the assistive technology for the residents and caregivers.

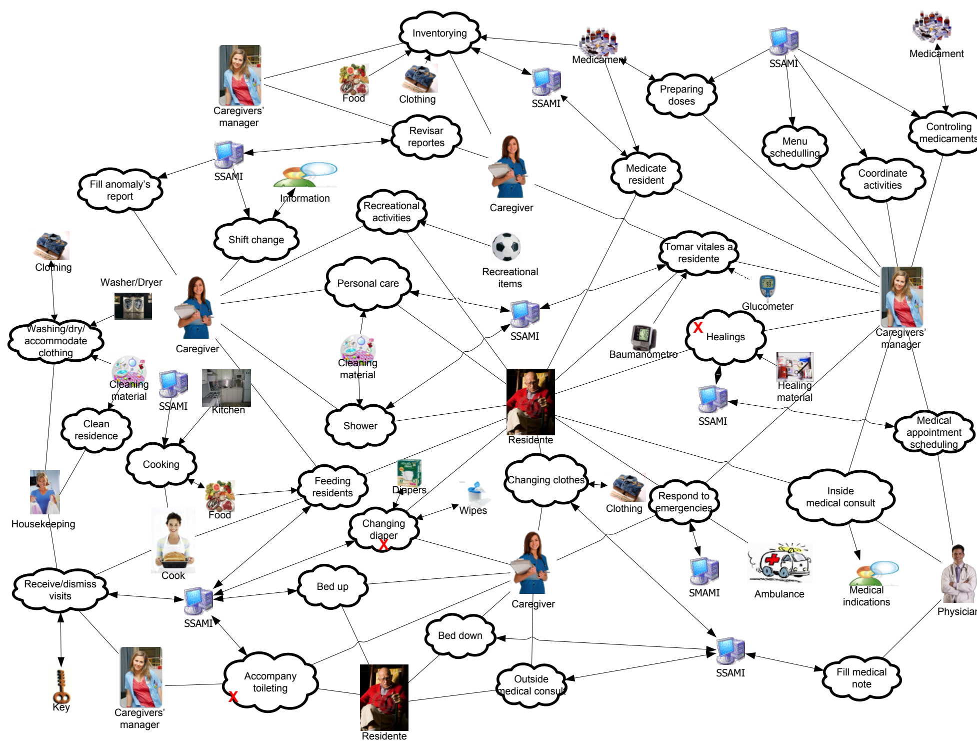


Fig. 2. Rich picture of the care process followed in the geriatric centers studied.

4.2 Data analysis

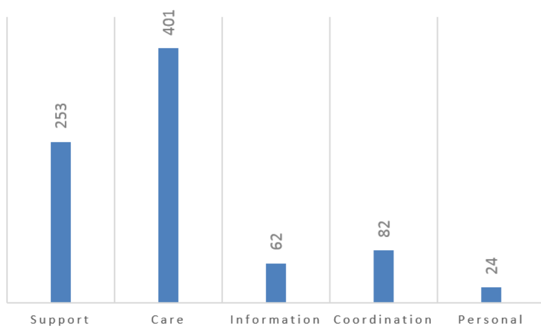
Next, we present the list of design insights, technical requirements, and their rationale, obtained from the results of our analysis presented in the previous section.

> *Insight #1.* It is important to provide awareness to the caregiver about pending tasks and risky situations, without interrupting the current task.

> *Technical requirement #1.1.* The user interface and the mode of interaction of the system should compromise between alerting and distracting. For example, alerts should be easily lifted, without disappearing from the roster.

> *Technical requirement #1.2.* The system should detect when the caregiver is busy.

In the field study, we found that more than one third of the caregivers' time is dedicated directly to the resident's care (37%). The time a caregiver spends with a resident depends on his/her general health and physical condition. While some of them can be very independent, others may be in need of more care and attention due to its medical conditions (e.g. Alzheimer, Parkinson). We observed that sometimes caregivers spent a considerable amount of time with a single resident, letting others waiting for attention; hence it is essential to find new ways to increase direct contact with all the residents. The numbers above the bars in Fig. 3a indicate the number of times that caregivers perform each type of activity, and Fig. 3b shows the number of hours that caregivers dedicate to a specific activity (as defined above in 4.1) and the percentage of the total time that each activity represents.



a)

	Time (in hours)	Percentage
Support	21:43	37%
Care	21:26	37%
Information	6:52	12%
Coordination	4:06	7%
Personal	4:29	8%

b)

Fig. 3. Frequency, total time and percentage of activities considering the time of the caregivers.

Insight #2. Caregivers must know at all times in which area of the residence elders are and what they are doing.

Technical requirement #2.1. A real-time indoors location module should be included to determine each elder whereabouts.

Technical requirement #2.2. A real-time activity recognition mechanism should be included to know what the elders are doing.

Data analysis revealed that caregivers spend an arbitrary amount of time with each resident, depending on the level of care required. Since the number of caregivers is limited the above implies loosing direct contact with residents under their responsibility.

Insight #3. It is necessary to provide a signal of alert for a busy caregiver within seconds of a risky situation to prevent a compromise to the elders' health.

Technical requirement #3.1. An alarm signal should be sent to all the staff when an elder is detected in a risky situation to maximize the chances of timely attention to the elder's condition.

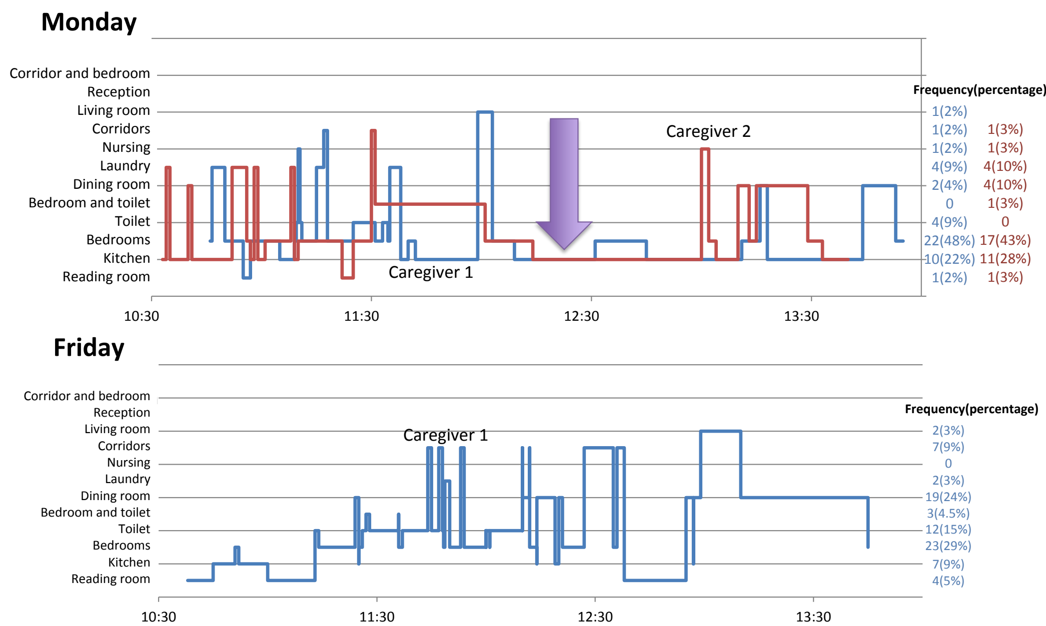
We found that some activities of the residents were not perceived by the caregivers. For example, it is almost impossible to follow all the time an elder who is wandering without assigning one dedicated caregiver to this task. This is particularly sensitive if the caregiver does not notice when a resident enters an off limits or dangerous area such as the kitchen or the infirmary. Moreover an elder might fall without a caregiver noticing, which is risky.

> *Insight #4.* Due to economic restrictions, care centers will most likely be understaffed. Therefore, there is a need to provide tools to support this situation, in particular concerning the care needs.
>
> *Technical requirement #4.1.* The design should plan for understaffing. Care time should be administered and prioritized by care needs.

Due to the diversity of activities that caregivers perform within the residence, on some days the workload exceeds their response capabilities. This situation can be seen as an understaffing problem; nevertheless, even in the hypothetical case of having one caregiver per resident it is possible that at some moment (perhaps for a few seconds), the caregiver can lose eye contact with the resident and a fall might occur. Hiring more personnel can be a solution, however it would increase the costs of care. Hence, there exists a tradeoff between those alternatives. In our study we found that caregivers perform all sort of activities, for instance, from our case study, Fig. 4 shows the workload of two caregivers on two separate days. In one of them (Monday) the absence of kitchen staff compromised care activities when preparing lunch.

> *Insight #5.* A planning tool and means to measure the degree of completion of planned tasks should be incorporated. The residents in geriatric institutions have routines and the staff plans on this routines, which be carried out.
>
> *Technical requirement #5.1.* A module to detect repetitive patterns and a planning tool need to be included in the design. It also should include a tool to measure the degree of adherence to the scheduled program.

During the time we observed residents and caregivers within the residence, we could establish that their activities have low variability or, complementarily, high repeatability. Moreover, caregivers and residents followed a repetitive program of activities, i.e. every day the residents followed the same set of activities and they rarely varied that routine. This characteristic of periodicity enables, in principle, detecting when residents deviate from their usual routine.



Note: Caregiver 1 represented by the blue line and Caregiver 2 represented by the red line. In Friday, Caregiver 2 was outside of the residence.

Fig. 4. Workload distribution of the caregivers.

> *Insight #6.* A mechanism to exploit the correlation between the time and locations where activities are being performed is needed, together with the inference of activities given time and location.

> *Technical requirement #6.1.* The system should include an inference module to predict the activity, given the location of the elder and the time of the day.

We also noticed that the activities of the residents have a high correlation with their location. In some cases, location and time of the day are enough to infer the activity. For example, changing clothes (within care activities) of a resident at morning is usually performed inside the bedroom (see Fig. 5).

> *Insight #7.* It is necessary to automate the activity records, at the present they are in paper and they are redundant.

> *Technical requirement #7.1.* Daily activities should be logged using an electronic system capable of performing historical searches.

Information management consisted in recording by hand all the activities residents did during the day. The caregivers must write on paper hour by hour the recent activity of each resident. They had an hour-by-hour register and a notebook of anomalies. At the end of each shift caregivers should send a report with the same information written on the register. Sometimes the caregivers spent a few minutes after the end of the shift just to complete or correct the records. No electronic record was implemented before, all the records were written in paper and the same information had to be filled in, in up to three different formats. It is clearly a waste of time to invest valuable resources in this kind of repetitive task.

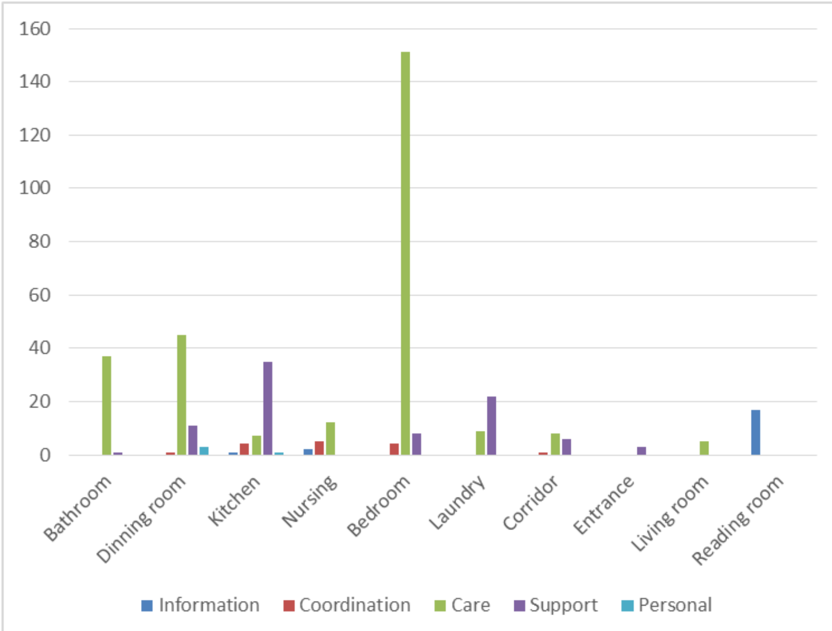


Fig. 5. Frequent places where activities are performed.

> *Insight #8.* The privacy of residents and their data are principal concerns that should be taken into consideration.
>
> *Technical requirement #8.1.* A module managing privacy with hierarchical methods, user profiles and clearance levels, using formally proofed to protect the elders data should be included.

We observed in the residence that the caregivers and staff were responsible for the information of the residents. The control of information was performed manually and the records were available to all staff members and whoever entered the area. The residents and family signed a consent agreement about the residents' information and care. The residence has the responsibility over both the data and the wellbeing of each resident, the storage and management of information should be done in a reliable, safe and systematic way.

The previous analysis gave us all the relevant elements considered for designing supportive technologies. In the next section we present the development of prototypes that cover the necessities established with the insights.

4.3 Prototyping

After the field study, we used the extracted technical requirements for building two prototype systems. During the development and implementation of the prototypes, the design decisions aimed at solving the problems stated in the previous section. Both prototypes were designed to have a small cognitive load, and a friendly interface to avoid overwhelming caregivers (Insight #1, Technical requirement #1.1) because usually the number of residents exceeded the capabilities of the staff in elderly care centers. Moreover, the use of electronic records could reduce the time of information management (Kim & Kim 2010)(Su & Yude 2012); as a consequence, the time remaining could be redirected to increase the quality of the care.

We developed two prototype applications SSAMI (Sistema de Seguimiento de Adultos Mayores Institucionalizados, spanish acronym for Journaling System for Residents) and SMAMI (Sistema de Monitoreo de Adultos Mayores Institucionalizados, spanish acronym for Monitoring System for Residents). They were designed to run on Android smartphones that caregivers carried at all time, and in all places in the residence. The prototypes are described below.

4.3.1 Prototype 1. SSAMI.

Purpose.

The objective of this prototype was to provide a tool that enables caregivers to manage and register information about residents' daily activities (presented in section 4.1).

Functional services.

This mobile application enables caregivers to have an inventory control, medication intake alerts, and to register as well as consult daily activities (feeding, hygiene, etc.).

A desktop application enables general staff to manage the elders' care process including the scheduled medication, meals, and recreational activities. Also the application allows sending messages to specific users for specific tasks. Physicians have the historic electronic medical records integrated in one application.

Non-functional services.

Daily activities logs of each resident are stored in a data base.

For security reasons, we proposed the use of roles (Insight #8, Technical requirement #8.1); depending on the role, management and retrieval of information can be granted or denied. In this application, managers, caregivers, geriatricians, physicians and nurses can have a personal account to access the system.

Implementation details.

This prototype is intended to be unobtrusive, proactive and requiring a small cognitive load (Insight #1).

The mobile application was installed in an android smartphone; with this the caregiver can record the activities performed by each resident using Near Field Communications (NFC) tags or a single touch. The caregivers receive notifications on the device (Insight #3, Technical requirement #3.1), as a reminder, if a resident should be medicated.

The desktop application was developed in Java and it was installed in a touch display computer.

Advantages.

SSAMI was used for registering the activities of the residents (Technical requirement #7.1) instead of paper records. It was designed to interact with NFC tags (see Fig. 6a). Those tags were placed all around the residence to reduce the time of interaction with the device. This way the caregivers were creating an activity log with the activities of each resident (see Fig. 6b). For instance, when a resident went to the infirmary to have his/her blood pressure checked, the nurse would scan one of the tags in the wall to record this activity. In this manner, registering information becomes simple, fast and in real-time.

a)

b)

Fig. 6. NFC tags placed in the residence a) and a view of the SSAMI application b).

4.3.2 Prototype 2. SMAMI.

Purpose.

The principal objective of SMAMI was to monitor residents whereabouts and inform caregivers in real-time.

Functional services.

This prototype was designed for continuously monitoring residents' mobility, to determine their location, and for sending real-time notifications to caregivers. The data from location sensors and accelerometers were collected in a central server. From the collected data it was possible to detect risky locations (Insight #2, Technical requirement #2.1) and from the motion sensors data, a possible fall can be detected (Technical requirement #2.2, Insight #3, and Technical requirement #3.1).

A Wireless Sensor Network (WSN) is part of SMAMI. A large number of fixed sensors (*fixed nodes*) need to be installed in strategic areas of the residence to sense residents. The residents wear a sensor (*mobile nodes*) with wireless communication placed at the waist and some engagement techniques were needed to encourage residents to use the technology. The *fixed nodes* determine the location of *mobile nodes* and retransmit data. The mobile nodes have an inertial unit composed by three-axis accelerometer; these data also travel through the network to the *base node* in the server. The server processes the received data and recognizes the activities processing the accelerometer data using the well-known decision tree algorithm (Jeong et al. 2007). Furthermore, the recognized activities and location are combined in the server to detect risky situations, and immediately send notifications to caregivers, for example, when residents entered restricted areas (*e.g.* the kitchen or the infirmary) or in case they suffered a fall (see Fig. 7). The notifications service works with mobility, places, duration and the hour of the day. Also, a decision tree (Rokach & Maimon 2008) is used to decide when to send notifications and inform caregivers about the risky situations.

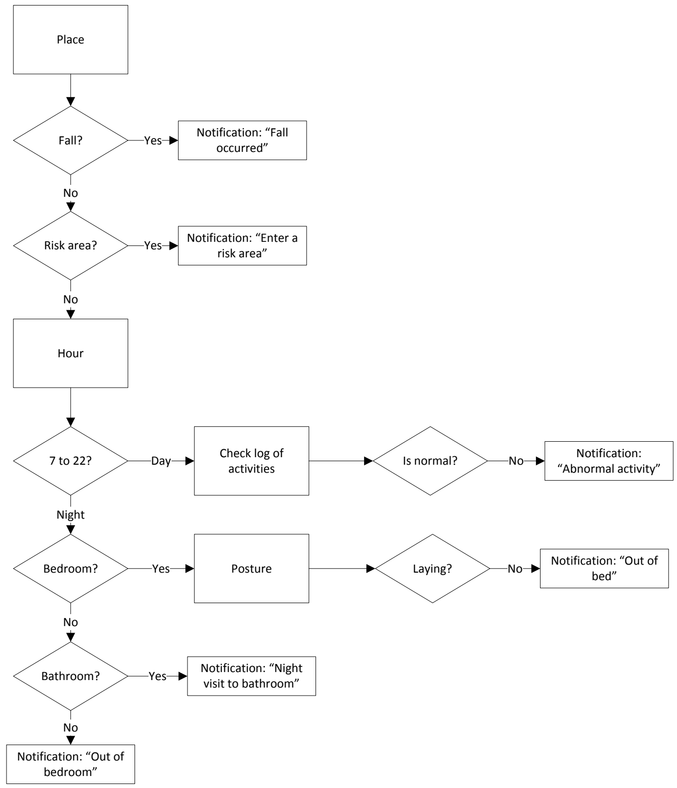
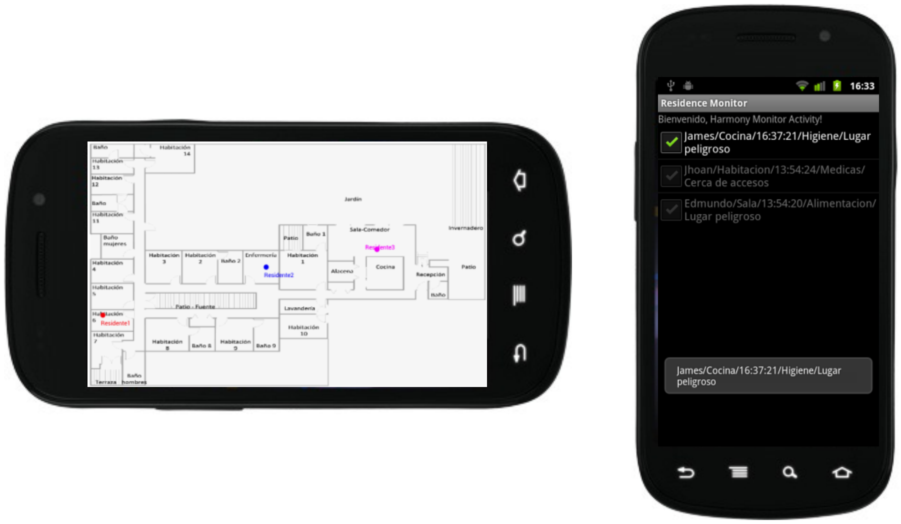


Fig. 7. Decision tree used to send notifications to caregivers.

An android application was developed to show to the caregivers the location of the residents in real time (Fig. 8a), and also to alert them when a dangerous situation occurred (Fig. 8b). The notifications should be provided just in time, because time is an important element when a fall occurs, for example.

Non-functional services.

The data from location sensors and accelerometers was collected in a central server and a mechanism to improve the accuracy of the locations in real-time was developed. The accelerometer data was fed to a process recognizing postures and launching notifications.



a) b)

Fig. 8. SMAMI system showing: a) location of residents and b) notifications.

Implementation details.

An indoor location system was deployed, based on radiofrequency triangulation with a sensor network. Also, accelerometry data was used to infer elders' activities (sitting, lay down, etc.). Both location and activities were reported to an Android device available to the caregiver.

Fig. 9. Residents and caregivers using the SSAMI and the SMAMI systems.

Advantages.

Before using the prototypes, elders' monitoring had to be done by following them at all times. SMAMI was a surrogate "follower", informing the caregivers of the whereabouts of the residents at all times, notifying them in case of a risky situation.

The architecture of both prototypes was based on the client-server and publisher-subscriber paradigms, enabling complete functionality for real-time notifications and up-to-date information in the server side.

4.3.3 Evaluation

Both prototypes were evaluated in one of the residences during four weeks. They were used daily by the caregivers for five months after de evaluation. Fig. 9 illustrates residents wearing sensors and caregivers using the mobile application.

The evaluation of the prototypes was conducted in one of the three geriatric homes. The *in-situ* evaluation was designed to measure the efficiency and effectiveness by monitoring 12 residents, the perception of use of the applications and their usefulness was evaluated with 11 caregivers. Furthermore, we assessed the effectiveness of the notifications that served as alarms and reminders for the caregivers. The acquired and reported data were corroborated by means of 12 hours of observation, 11 interviews and 2 focus groups. This evaluation provided complementary information on some aspects not covered in detail in the initial design of the prototypes. Also, it fed the design of a new application with a clearer view of the components that a system for elders care in nursing homes should contain.

From the *in-situ* evaluation we assessed the adoption, usability and utility of the above prototypes. The experiences, comments and opinions from the interviews and focus group of caregivers were analyzed using open coding. The above analysis was used for establishing additional requirements for a new version of the systems.

> *Insight #9.* A large number of notifications could be annoying and stressful for caregivers when they are performing other task, there should be a small number of relevant notifications.
>
> *Technical requirement #9.1.* A module to arbitrage notifications and alerts in real-time should be included.
>
> *Technical requirement #9.2.* The system should detect when the caregiver is busy.

One observation was that constant notifications are annoying; a mechanism for prioritizing and controlling the number and frequency of notifications was needed. *"The notifications were obnoxious because they were constantly ringing" [Caregiver 7].*

> *Insight #10.* A system that informs caregivers increases the awareness of residents and caregivers perceived improvements on the care process.
>
> *Technical requirement #10.1.* The interface should include different formats to inform caregivers about complex information for each resident with an appropriate metaphor.

Through the evaluation of the systems, we confirmed the system usefulness and ease of use, the caregivers were more aware of what the residents were doing and where they were at any given moment. "*If she (the resident) was wearing that tracking device we just go to that map where they show they are and you look over there and it's easy to track them*" *[Caregiver 4].* In the focus group this feature was consistently perceived as enabling better care of residents.

> *Insight #11.* A failure detection module is needed.

> *Technical requirement #11.1.* The system should recover automatically from failures. A failure detection module should monitor battery, connection status, and the reactivity of the actual application.
>
> *Insight #12.* Data sources should be diversified and redundant to make the system reliable.
>
> *Technical requirement #12.1.* The system should include a module to interpolate lost data from historical records, redundant sources, etc.

During the evaluation there were some technical issues presented, such as miscommunication between the wearable sensors and the server, and between the mobile phones and the server. *"This system could fail, all systems fail, and we don't know when it will be back and don't know how to restart it. All this will imply a large setback in our job" [Caregiver 11].* We also found that the physical infrastructure of the residence was not conductive for a good performance of the devices. *"We (the caring staff) need technical support, if the system fails who is going to restart it" [Caregiver 10].* As a consequence of the technical infrastructure problems confronted during the evaluation, there were some missing data that cause having some incomplete records. It is important to consider these common errors in the design of real care systems, where reliable data are important because they are the basis to extract and infer further information.

> *Insight #13.* A mechanism to avoid the constantly text input by caregivers is needed.
>
> *Technical requirement #13.1.* The system need to be design to diminish the caregiver constant registering.

Even if the systems aimed at helping caregivers the perceptions were disparate about the usefulness of the system. One opinion was *"It is easier than searching in paper" [Caregiver 11]*, while others did not perceive a substantial advantage between paper and electronic logging. *"It is more difficult for me (the system usage) because in the notebook (referring to the paper logs) it was just writing, it is essentially the same, but using technology" [Caregiver 8].*

By means of the *in-situ* evaluation we collected data about the residents and caregivers. The data recorded during the evaluation consisted of the activity logs of the residents, notes from caregivers, location and accelerometers from wearable and environmental sensors. Also, we obtained a list of socio-technical issues which result useful when conducting naturalistic long-term evaluations (Soto-Mendoza & Garcia-Macias 2014). Next we focus on the design of PRESENCE.

5. PRESENCE, A RESULT FROM THE EVALUATION

Our work of monitoring and collection of elders' data, naturally lead us to envisage a more challenging objective, a predictive scheduling system.

5.1 Designing of PRESENCE, a predictive schedule

From the results obtained from the analysis of the data gathered from the collected activity logs, data from sensors, caregivers' notes, interviews, observations and focus group sessions, the *in-situ* evaluation, and with the new insights obtained, we designed a new system merging the previous prototypes and adding new features. The final application turned into a predictive schedule (Technical requirement #13.1) for caregivers that we called PRESENCE. The predictive schedule is a front-end application and for its optimal operation different elements are needed. The description and functionalities of each component, and the general view of the predictive system is described below.

Sending notifications to caregivers was an important characteristic of the previous prototypes (Insight #10). However, a big number of notifications are overwhelming for caregivers (Insight #9). Therefore the design of the proposed system has an arbitrage algorithm to prioritize notifications to avoid increasing the stress of caregivers at work (Insight #13), only urgent notifications would be forwarded to nurses or caregivers.

The design of PRESENCE includes a new module for the analysis of activities in greater detail (Technical requirement #12.1). The analysis aims at giving a higher level of abstraction on the state of a resident. One extreme example would be to say, "*Mr. Robert is OK*". As the abstraction level becomes higher, the work of the caregiver becomes simpler; but it may not be easy to implement. We need to compromise between functionality, design requirements and the ability to implement them. We found a compromise where the caregivers do not have to record everything manually, and the system will recommend the next activity to follow; waiting for the manual input of the caregiver agreeing or not with one touch.

The prototype called SSAMI (section 4.3) includes a roles' manager to use the application. However, considering roles to access to the system is not enough, the design of PRESENCE establishes that there should be access policies to the data at different levels, taking into account the data types, so that external entities, such as the residents' external physicians, have a secure access to the residents' information (Insight #8, Technical requirement #8.1).

The design of the system has an error recovery and fails support mechanism, as described (Insight #11, Technical requirement #11.1). For this reason, we consider improving location algorithms, falls detection and activity recognition. Moreover, the caregivers' assessments must be incorporated to have more accurate measures. The predictions will be more reliable and can be assessed with the help of the caregivers' annotations (Technical requirement #12.1).

5.1.1 PRESENCE architecture

In Fig. 10, the general architecture of PRESENCE is presented. It is a three-tier architecture: server, client, and source. The server contains the principal functions: the services and data manager component to cope with the data and information received from the different sources of data, and to organize the diverse services offered by the system (e.g. notifications); the inferences engine is responsible for the data analysis, and will perform data fusion when they come from different sources; it is also natural to include pattern discovery in this component. The component for controlling the emission of notifications is also depicted. The privacy component will manage all the privacy policies; the incorporation of dissimilar data sources could increase the complexity of the data privacy policies, for this reason a semantic knowledge component was proposed as a part of the system with the data stored in a semantic repository. Concerning the sources, different elements, sensors or applications can be incorporated; all sources should be part of the data repository. Finally, all the user interfaces and mobile applications will be found in the client side.

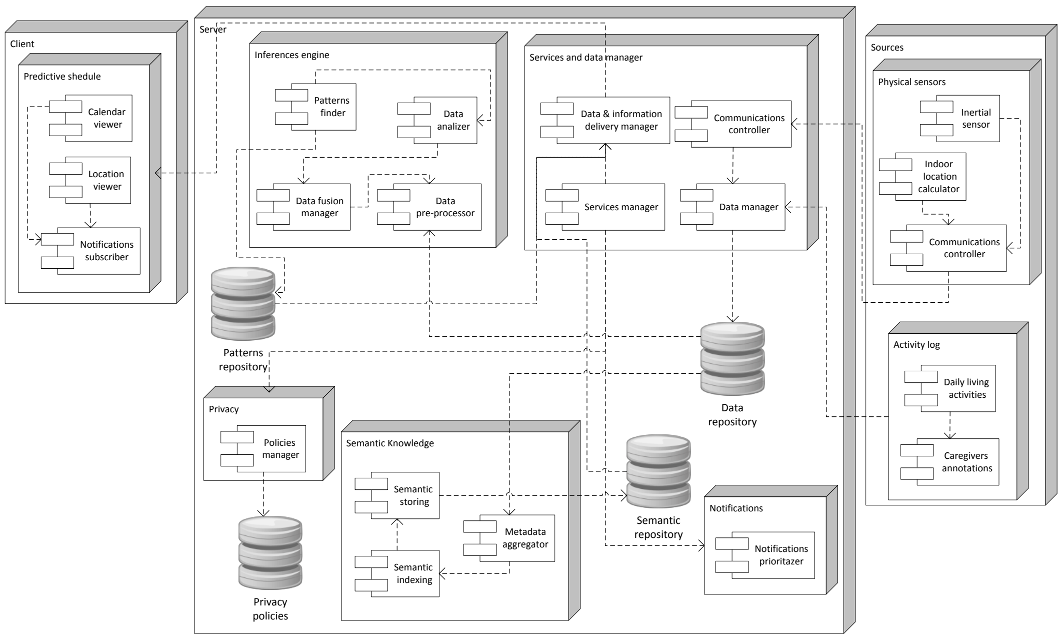


Fig. 10. Architecture diagram of PRESENCE.

Other modules could be added in the previous schema, this poses a scalability challenge to the *data manager,* which should be capable of recognizing, analyzing, generalizing and establishing data privacy policies to a new data source. This can be crucial when a large amount of data is stored and ready to be processed for making inferences, reporting messages and in general to be of use. For instance, when each resident wears a small device to monitor the activity level (e.g. a Shimmer motion unit); the single data source of this device should be multiplied by the number of residents, the number of devices and, the sample rate.

The *data fusion manager* will use the degree of confidence of each data source to output the most reliable reading. For example, it is advisable to give a strong confidence to a caregiver annotation if the data represents the mood of a resident; but a sensor is more reliable to verify the heart rate or the temperature of a resident. The data fusion manager will construct a data warehouse by selecting and aggregating data (data pre-processing) coming from different sources (sensors or caregivers) and stored in the data repository. To do this, ETL techniques (Extract, Transform, Load) can be used. There exist open source tools like the one proposed by Talend[1] that may facilitate this task.

The *services manager* was proposed to control the flow of each input or output service (e.g. sensors, notifications). When a notification emerged the services manager uses the *notifications prioritizer* to know the urgency of the message. This module is also responsible for data reliability, with subroutines handling communication protocols, such as CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport) which have more tolerance to communication faults and latency. Uninterruptable power sources are provided to support static sensing infrastructure.

Caregivers will continue registering residents' activities. The *data repository* will store both: activities logs and sensor data. The *inference engine* will take the data from the repository and process it to provide structure. The *data fusion* will mix the data sources to *analyze* and *discover patterns* in the activities. The patterns found will be stored in the *patterns repository*.

Additionally, the data management and control module should be supervised by the *privacy policies* to enforce physical devices and personnel to respect the privacy agreement of the data. Preserving privacy of residents is very relevant because data collected by PRESENCE is very sensitive. It is important to establish a personal privacy policy for each resident (helped by the corresponding tutor) that should be preserved by the schedule. Such policies will describe which data is collected, whom can access them, for what purposes they are collected, for how long they will be stored (data should not be stored forever), etc. Policies will follow well-known guidelines and legislations as the ones proposed by the OECD[2] (Organisation for Economic Co-operation and Development), by the CNIL[3] (National Commission on Informatics and Liberty), or by HIPAA[4] (Health Insurance Portability and Accountability Act).

The data collected during a long period of time could be analyzed in different manners; therefore the results of the analysis will be diverse and will have a lot of applications. The data acquired and processed could represent complex concepts, hence we propose a complete representation through semantic technologies. The relationships and causalities could be modeled using ontologies. The relationship between data and entities is modeled with RDF (Resource Description Framework); the same could be used for the interactions with smart objects. These concepts come from the Internet of Things (IoT) and semantic web, in the proposed system they are contained in the *semantic knowledge* module to be combined with the machine learning techniques used inside the *inference engine*.

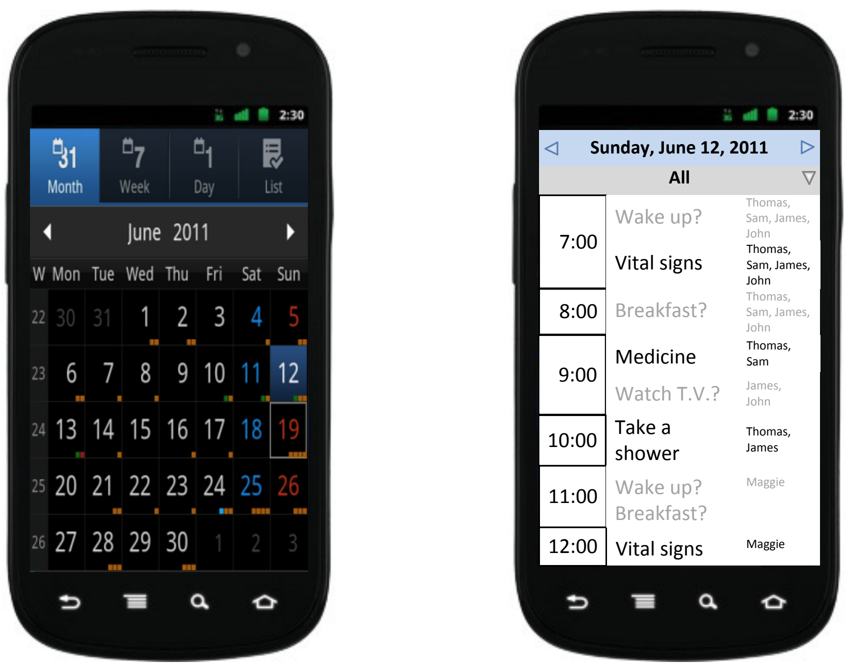
In the client side we propose a component to manage all the user interfaces of the system, namely desktop and mobile applications. Our mobile application, the predictive schedule, would be part of this node and it will show caregivers the

[1] Talend Open Studio for Data Integration (http://www.talend.com/download?qt-download_landing=3#qt-download_landing)
[2](http://www.oecd.org/internet/ieconomy/oecdguidelinesontheprotectionofprivacyandtransborderflowsofpersonaldata.htm)
[3] http://www.cnil.fr/english/
[4] https://www.privacyrights.org/content/health-privacy-hipaa-basics

digested data resulting from the inference analysis, the activities and location as the initial prototypes did.

5.1.2 Appearance and functionality

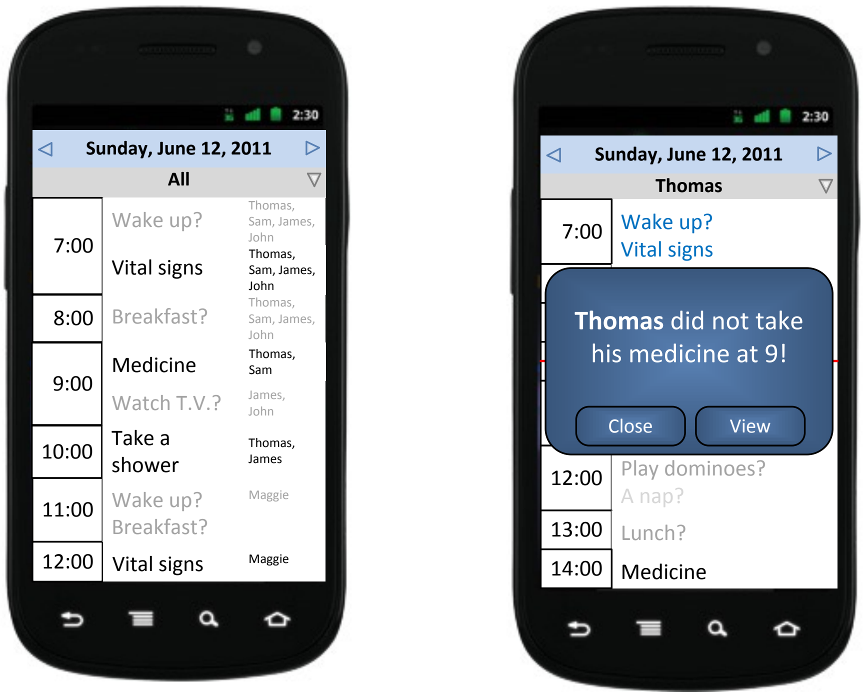
The predictive schedule looks mostly as a common calendar (see Fig. 11a). The calendar is fed with two types of information; on the one hand the actions from the medical protocol (medication, therapy, activities, etc.) are inserted as mandatory (see Fig. 11b); on the other hand it is fed with the information generated from the inference module, the complementary actions following a mandatory task are suggested. In this way, caregivers would know what tasks are pending and the tentative deadlines for them. The task will be considered as "executed" when the caregiver clicks on it. Caregivers can visualize the activities or tasks scheduled in a month, week or day basis. Also the application enables caregivers to consult the activities of all residents per day, or filtering the activities by resident. The predictive schedule is dynamic, meaning that if a series of events deviate from the usual, predictions will be recomputed and the schedule will be updated accordingly.



a) b)

Fig. 11. (a) Appearance of the predictive schedule and (b) the information it presents.

Each prediction has its proper level of importance. Actions from the medical protocol are mandatory and have the highest level of importance; for example not giving some medicine to a resident has not the same level of importance than a resident who does not receive visits one day. The mandatory part of the schedule and the optional complements are blended in the interface. We assigned priorities to each prediction related with an activity. As time goes by, the schedule evaluates and contrasts the expected activities with those that have occurred. Finding a perfect match indicates that everything is according to the schedule. When a mismatch is detected the application notifies caregivers about the deviation of the plan (see Fig. 12a). Depending on the importance of the deviation the caregiver will receive a silent, normal or urgent notification. This is to avoid annoying the caregiver with unimportant updates. However, if the caregiver wants to check for a particular resident, all the notifications will be there for him/her to peruse. Urgent notifications, for example when a vital medicine was not given to a resident (see Fig. 12b), will not go away until they are attended.



a) b)

Fig. 12. (a) List of suggestions and (b) notifications presented by the predictive schedule.

The data collected from the *in-situ* evaluation of the prototypes was manually mined and processed to find usual and unusual patterns in the states of each resident. For instance, if one day the caregiver observes that the resident is eating breakfast before someone read his vital signs, it would be an unusual pattern because it is mandatory for a caregiver to take the resident's vitals immediately after he gets out of bed. Another example is when a resident has the same succession of states, day after day, during a couple of months; then suddenly the resident changes something in his routine, the schedule should be capable of detecting this deviation.

5.2 Feasibility analysis

In this Section, we conducted a feasibility analysis of PRESENCE considering two perspectives: first, from activity data logs analysis, and the second from usage and ease of use of PRESENCE through a design session with the intended users.

5.2.1 Activity logs analysis

We explored the viability of the predictive schedule system by refining, organizing, analyzing and processing data from activities' logs gathered during the evaluation to find correlations and patterns among them. These data are mainly related with activities of the residents, from which we defined different states of them. Each state indicates the general condition of the resident at a given moment. Using these states we obtained regular transitions among their state and we built a general description of each resident.

We created an activity model to formalize the concepts and entities found among data. For this reason, we redefined the activities and characterized states of the residents to build the inference engine based on a finite state machine. The defined states were:

- *Sleeping*
  - Definition: the resident is in his bedroom or in the living room and presents a specific movement pattern. Usually, this state occurs at night but it may also occur in the morning or afternoon.
  - Measured by: the caregiver based on a physical inspection, motion sensors, pressure sensors and/or proximity sensors.
- *Eating*
  - Definition: the resident is eating by himself or with the caregiver's help. The residence can usually be in his bedroom or dining room. The residents must eat at least three meals per day.
  - Measured by: the caregiver or cooks, or by location, pressure or proximity sensors.
- *Socializing*
  - Definition: when a resident interacts or talks with another person.
  - Measured by: caregiver's visual observation, proximity sensors or voice activity detection.
- *Awake*
  - Definition: the resident just got out of bed.
  - Measured by: the caregiver based on resident's physical inspection, or motion sensors, pressure sensors (located under the bed) or proximity sensors.
- *Outside*
  - Definition: when the resident attends outdoor activities, outside the residence, he goes to a play in a theater, the movies, beauty parlor, etc.
  - Measured by: caregiver's visual observation, or proximity or location sensors.
- *Cleaned*
  - Definition: when the resident is taking a shower or is in the bathroom for changing the diaper, washing hands and brushing teeth.
  - Measured by: the caregiver can inspect the resident, location sensors.
- *Medicated*

  - Definition: when the caregivers or a nurse gives a medicine to the resident.
  - Measured by: caregivers' records.
- *Entertained*
  - Definition: the resident participates in a group dynamic, a playful activity in the dining room, living room or in the garden, watches T.V. or plays dominoes. Usually there is a group of people together in the same place at the same time. These activities occur between meals.
  - Measured by: caregiver's direct visual inspection or by proximity or location sensors.

We can observe that either caregivers or different types of sensors can gather information that can be used to infer the states of a resident. However, there exist great challenges in sensing accurate measures. For example, detecting a gathering of people interacting with each other can be very tricky for sensors; when they are located in common areas the information gathered comes from several sources. Furthermore, the resident can be at any place of the residence, have a lot of local mobility while resting, or low mobility when reading or performing a quiet activity. It is worth noticing that after inspection of the data collection we went with the most reliable reading, either a sensor or a human assessment. The above assignment should be done by the data fusion manager and the inference engine.

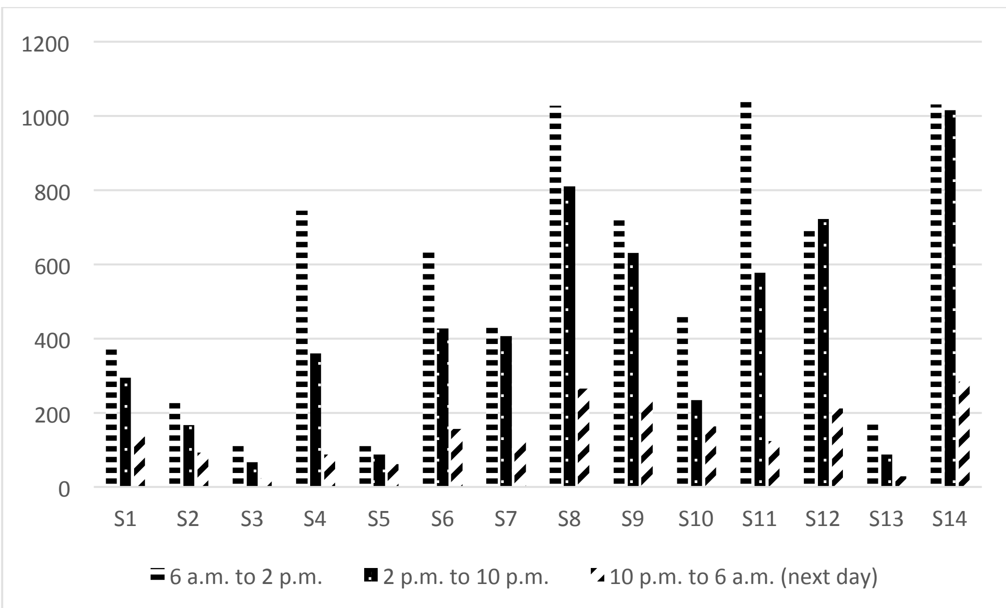


Fig. 13. Number of states transitions (frequency) of each subject (resident) at morning, afternoon and night (with medication).

Most events of the resident's routine were logged using the prototypes described. We have grouped the events by semantic similarity and obtained a transition matrix. This arrangement, although simplistic, is quite informative. The activity logs of 14 subjects (residents marked as S1 to S14) were processed to obtain the transitions between states, and we counted the number of times one state follows another. In this process data were split into 8 hours chunks depending on the timestamp. The first chunk includes activities between 6 a.m. and 2 p.m., the second between 2 p.m.

and 10 p.m. and the third from 10 p.m. to 6 a.m. of the next day. In general, changes of state occurred often from 6 a.m. to 2 p.m. because residents and caregivers performed more activities (*e.g.* taking showers, changing clothes, taking breakfast, and having medication) at the beginning of the day. Then a decrease in transitions was observed during the following two time slices (afternoon and night) (Fig. 13).

The residents had different medical conditions and hence the needs of each one are variable. One finding of this study is that the number of transitions is a very consistent indicator of independence. In other words, residents who can still do things by themselves have a smaller number of transitions than residents who need more assistance.

In Fig. 14 we can see the aggregate number of transitions by time slice. For example, resident 14 (S14) has the largest number of transitions at any given time slice. He is also the one with the most needs of care, because he has advanced Parkinson's disease. Subject S14 cannot perform almost any activity without assistance since he cannot move, walk or even talk. In the case of subject S12, the transitions in the afternoon were more than in the morning and night; in this case the resident had dementia and he usually woke up later than the rest, and his activities started late, which implies a shift in the activity period, coinciding with everybody else in the afternoon. When residents went to sleep the number of transitions was significantly reduced. The transitions plot might be used to predict the level of care needed by each resident, which is highly valuable information for planning purposes. Another application for the transitions plot is to separate residents into groups; another usage is to assign a more skilled caregiver for the more demanding group.

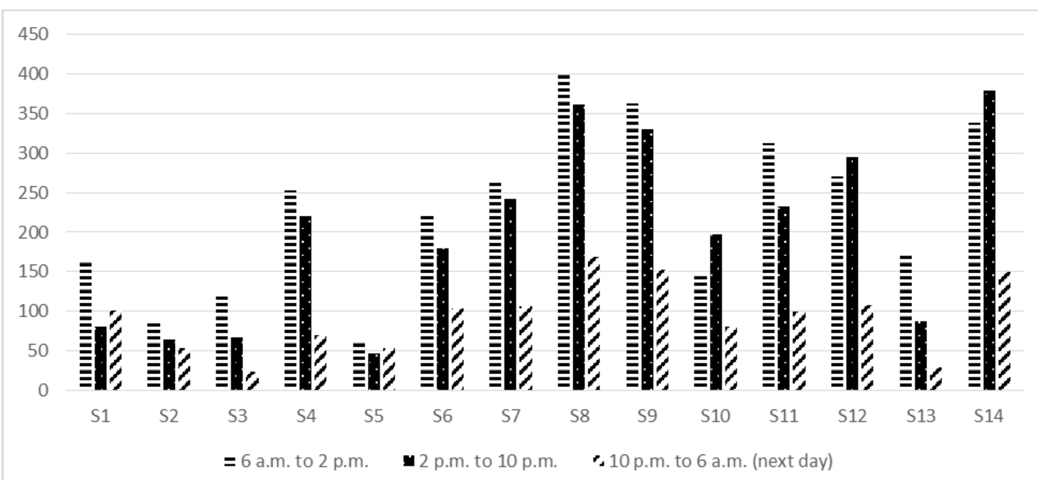


Fig. 14. Number of states transitions (frequency) of each subject (resident) at morning, afternoon and night (without medication).

We also analyzed the activities performed for each resident on weekdays versus weekends. We could observe a difference in the transitions between states. During weekdays the level of activities is higher than during weekends: This happens because in some cases the family visits and takes their relative out or when they spend a weekend outside.

The naïve transition matrix (see Fig. 15) has other applications. We can infer usual and unusual days or periods of time for a given resident. Another application is to use it as the basis to construct a useful narrative to describe the day of a resident and to use it to inform the relatives, for instance:

> *During the last 4 months, mornings have been* ***usual*** *for Juanita. She begins the day* ***asleep*** *and wakes up around* ***7 a.m.*** *She receives* ***her medicine*** *and* ***after she changes her clothes****, she goes to* ***the dining room to have breakfast****. Later,* ***the caregiver gives her medicine*** *and, afterwards,* ***assists in Juanita's shower****. When Juanita* ***is clean*** *she* ***takes a walk*** *and then* ***she eats again*** *because she* ***has very good appetite all day****.*

6 a.m. to 2 p.m.	Sleeping	Eating	Cleaned	Awake	Medicated	Entertained	Outside	Socializing
Sleeping	0	0	0	2	1	0	0	0
Eating	2	5	19	4	54	1	0	0
Cleaned	0	12	16	0	7	0	1	0
Awake	0	47	12	2	2	0	0	0
Medicated	1	19	32	18	235	0	0	0
Entertained	0	0	0	0	0	0	0	0
Outside	0	1	0	0	0	0	0	0
Socializing	0	0	0	0	0	0	0	0

Fig. 15. State transition matrix of a subject (resident) telling the story of her usual mornings.

The boldface sections on the above narrative, comes from the most likely transition in the matrix, after some polishing for readability. For each resident and each transition, a phrase is added. Please notice that the transition matrix was elaborated by hand using the available data of five months usage of two prototypes. More sophisticated analysis can be done after data cleaning and training. The proposed inference module generalizes the probabilistic finite automata represented by the transition matrix.

There are many machine learning tools to make predictions based on generalizations of finite state machines. The most well-known examples are Markov models and Partially Observable Markov Decision Processes (POMDPs). The former assume the next state in a transition matrix only depends on the current state, while the later assume no knowledge about the current state of the system and instead maintains a distribution of the possible current states of the system.

The automata we constructed from the data (Fig. 16) is just a simple example for illustration. The most important part is to define the states, once this is done the learning process is standard.

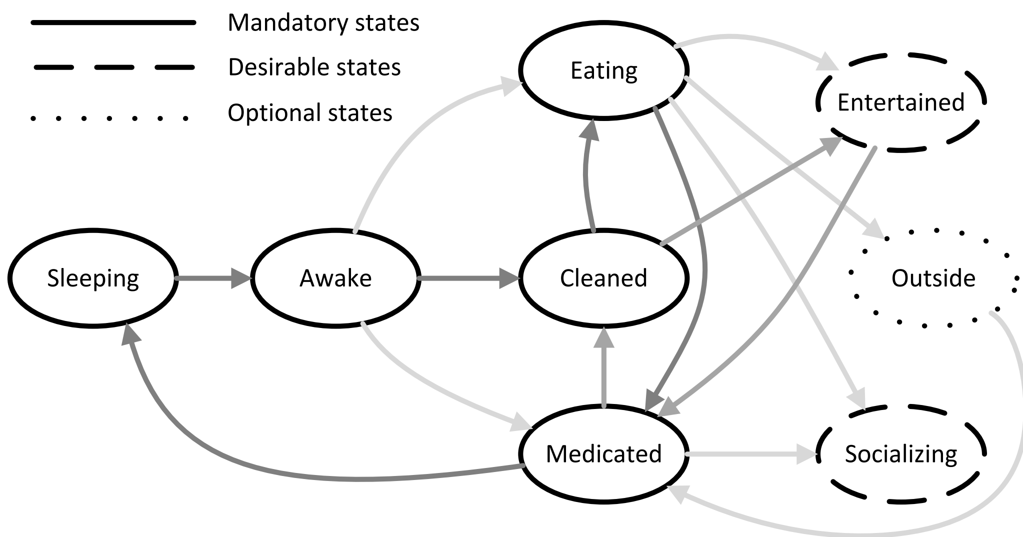


Fig. 16. Example of a sequence of states following the most probable path.

In our vision, predicting the next state of the resident with the highest probability is just one aspect of the problem. The schedule for a given resident may or may not consider the predicted activity and, if predicted, will have a degree of compulsoriness. The external information to the model needs to be considered for the design. It is necessary to establish the compulsoriness of an activity. Another parameter would be to assign a dynamic threshold for each resident. Passing the threshold will trigger a notification; for example.

The predictive schedule has to conciliate three aspects in the model: the transition probability, if the event is scheduled to happen, and the degree of compulsoriness. We have identified two cases where action is needed (*e.g.* sending a reminder/warning to the caregiver). For the analysis, we assume state *E1* is bound to happen for a certain resident with high probability and state *E2* is scheduled. We have two cases either *E1* and *E2* are different, or they are the same. If they are the same, then nothing is done. If they are different and the compulsoriness threshold for either the scheduled event or the event bound to happen is surpassed, then an alert is sent to the caregiver, because in either case the scheduled event is important, and is not bound to happen; or the predicted event is important and will collide with another event in the schedule.

There will be, of course, events neither scheduled nor predicted. Think for example in the resident entering the infirmary or the kitchen. For these events there are techniques already published (Bamis et al. 2010) to prevent risky situations for the residents, they will not be considered in our design as a challenge.

The transition matrix is a way to obtain valuable information. It has the advantage of being in a very readable form and it happens to be a nice metaphor for visualizing the activity of a resident as illustrated in Fig. 17. The sequences of states indicate a daily leading path of the states of the residents. One day of activity is a sequence of states describing the day of a resident. It is far from just guessing what the most likely next state (with high probability) is.

6 a.m. to 2 p.m.	Sleeping	Eating	Cleaned	Awake	Medicated	Entertained	Outside	Socializing
Sleeping	0	0	0	2	1	0	0	0
Eating	2	5	19	4	54	1	0	0
Cleaned	0	12	16	0	7	0	1	0
Awake	0	47	12	2	2	0	0	0
Medicated	1	19	32	18	235	0	0	0
Entertained	0	0	0	0	0	0	0	0
Outside	0	1	0	0	0	0	0	0
Socializing	0	0	0	0	0	0	0	0

Fig. 17. Individual path following the transitions of the states.

The inference module is the central part of the predictive schedule design. Sensors and caring personnel are very rich sources of data. Non-invasive activity recognition algorithms from heterogeneous data sources will be a good source of context. Modeling each resident individually is also a challenge and might provide better predictions.

5.2.2 Design session

We conducted an evaluation of the design of the predictive schedule system, PRESENCE, and its functionalities with caregivers. Using scenarios and low level prototypes, we presented the proposed system design to a group of 4 caregivers and 2 nurses (Table 1).

Table 1. Respondents profile (N = 6).

	Age	Occupation	Title
Nurse 1	32	Nurse	Nurse coordinator
Caregiver 1	31	Nursing assistant	Caregiver
Caregiver 2		-	Caregiver
Caregiver 3	42	-	Caregiver
Caregiver 4	47	Teacher	Caregiver
Nurse 2	22	Nurse	Nurse

PRESENCE was presented to the participants and at the end of the focus group session a 7-point-scale Technology Acceptance Model (TAM) (Fred 1989) questionnaire was applied (see results in Table 2). In general, the caregivers considered PRESENCE as a useful application meanwhile it demands little attention and time to register. For residents the use of these type of application was perceived less useful (compared with caregivers) due to the reluctance elders may express to technology and the advance stages of theirs medical conditions.

Table 2. Results of the TAM data analysis.

		Question Number	Mean	Std. Dev.	Average mean	Average std. dev.
Caregivers	Perceived usefulness (PU)	Q2	5.83	1.47	5.60	1.36
		Q3	6.33	0.82		
		Q4	6.33	0.82		
		Q5	4.67	1.97		
		Q6	4.83	1.72		
	Perceived ease of use (PEOU)	Q7	6.17	0.75	5.44	1.41
		Q8	5.67	1.03		
		Q9	4.83	1.72		
		Q10	5.50	1.64		
		Q11	5.00	1.67		
		Q12	5.50	1.64		
Older Adults	Perceived usefulness (PU)	Q13	3.83	1.72	4.39	2.19
		Q14	4.33	2.16		
		Q15	4.50	2.26		
		Q16	4.50	2.51		
		Q17	4.33	2.34		
		Q18	4.83	2.14		
	Perceived ease of use (PEOU)	Q19	4.67	2.07	4.40	1.88
		Q20	4.50	2.07		
		Q21	4.83	1.47		
		Q22	4.00	1.67		
		Q23	4.00	2.10		

* Scale items were based on seven-point Likert-type scales (1 = "Strongly disagree", 7 = "Strongly agree")

Then the comments of the sessions and questionnaires were analyzed and we obtained evidence of how the system would be perceived by caregivers when using it in their work.

The caregivers judged PRESENCE and they agreed that the anticipated information management system would be useful. They mentioned that including crying spells is very important to detect periods of depression. Also, some of them were worried about the way depression would be identified, *"it is a little hard to know when somebody is depressed, unless she/he has a button or something, but it is difficult because in a moment residents are well, and the next moment they are not, it is because of the disease"* [Caregiver 2]. We hypothesized that analyzing the activities' log could identify these sudden variations and the caregivers' annotations. Then the system could provide a good approximation when the periods of depression will occur.

All the caregivers and nurses emphasized that the time is at essence. They do not have enough time to register the activities; therefore they will not use a system that distracts them. When the appearance of PRESENCE was presented, they commented about the facility to register activities because all the activities would be there and only caregivers would check them. Caregivers argued that is very complicated to follow a strict sequence of activities due to the number of residents and the different tasks with each of them, so PRESENCE will help them to minimize the time for activity registration.

The calendar form appearance was attractive for caregivers because they want to be able to consult previous accidents or major incidents about the residents. With the system currently in use they do not perceive the utility of registering step by step all the activities because they cannot query previously stored information.

PRESENCE was perceived as a *"rapid diagnostic of each resident"* because of the individual view of each resident and the flexibility to change the schedule with the activities of each elder. It was perceived as useful because they were presented in the same screen and the navigation was simple. We agree that the right path is to combine different sources of contextual information (*e.g.* location, mobility, social interaction, medical data, vital signs and activities performed) to create individualized profiles enabling caregivers to know the care needs of each resident. The knowledge generated will be digested and used by PRESENCE, which will "learn" from the caregivers' annotations, and will manage and organize information so that caregivers will have advanced and specific information on each resident, their habits and traditions.

The caregivers highlighted the notifications of medications, special procedures or vital signs, as the most important features related to older adult care. Most of the caregivers and nurses preferred an alarm or voice mode of notification as a reminder when they forget to do some important activities, *"when by omission I forgot doing some procedure at a specific time, the system will remind me timely"* [Caregiver 1].

In the system currently in use the device size for the system was detected as an issue. Sometimes the size of the smartphone makes it impossible to register the activities due to the sleep deprivation of the caregiver, the time of the night and the workload during the day. As a consequence, the time consumed for registration increases and the caregivers spend extra time after the shift has concluded *"the reality is that there is not enough time"* [Caregiver 3]. The use of tablets with a bigger screen and keyboard, or computers was proposed; therefore PRESENCE should offer multiplatform support.

Nurses were more focused on the incorporation of more medical information into the system, in this way diagnostics, decisions and actions could be more patient-centered, *"it [the system] could incorporate some extra medical activities"* [Nurse 1]. The nurse assessments are based on patterns they observed in the residents. Therefore, PRESENCE would consider incorporating these nursing patterns, *"we base our diagnostics on patterns. When a diagnostic is obtained we propose a prioritized caring program"* [Nurse 1]. Other medical information could be included to make the system more useful for nurses, medical staff and managers in the residence, *"I believe it would be good help for nursing functions. Instead of only* *registering the activities, it would also implement the nursing process to support the company legally"* [Nurse 2].

PRESENCE was also perceived as a training tool for new caregivers, "*We [caregivers] try to teach them [new caregivers] but sometimes we are very selfish and do not teach as well as we should do*" [Caregiver 4]. New caregivers just need to check and study the information in the application to know what to do with each resident and then as time goes by the new caregiver will learn, *"all data must be registered in the system, and the new caregiver should study and review what she must do in her job. In practice it will be different but she would have a prior notion"* [Caregiver 4]. Our system, PRESENCE, would not replace the personal and direct training of a caregiver but it would be a good first approach to the general knowledge of each resident and the whole elders' care process.

6. DISCUSSION

We studied methods and processes followed during the care of older adults in nursing homes. We conducted a longitudinal field study to learn the main variables describing the quality of care and the wellbeing of residents, and we identified opportunities to lower the workload of caregivers and to improve in general the caring process.

The field study gave us a number of insights, and based on those findings we designed and implemented two prototypes of technological aids to support residents' care, namely SSAMI and SMAMI. Those prototypes aimed at increasing the awareness of the caregivers on the whereabouts of residents, and helped caregivers to record activities, vital signs, routine tasks and eventualities. The prototypes were evaluated *in-situ*, giving more insights and knowledge about the care process with those tools.

With SSAMI, we focus on reducing caregivers' burden through supporting the completion of their daily activities (Czarnuch & Mihailidis 2011). Our findings complement other statements in the literature, namely that activity monitoring is an important variable to reduce subjective burden (Lexis et al. 2013). Caregivers need information of the activities and whereabouts of the elderly; this requirement is often opposed to the reluctance of elderly people to be monitored, particularly when obtrusive wearable technology is used (Rashidi & Mihailidis 2013).

One identified source of subjective burden, even with assistive technology, was the need to record routine tasks. The predictive schedule PRESENCE, emerged from the *in-situ* evaluation, was a compromise between the information needs of caregivers and medical staff, the monitoring of the elderly and their reluctance to wear obtrusive technology, and the repetitive nature of the majority of caring tasks. All the modules and requirements in the design of PRESENCE (such as inference tools, wearable sensors, wireless infrastructure, etc.) are readily available in the literature or can be acquired in the case of hardware. Our main focus was the design, the perceived usefulness, and the perceived ease-of-use from the viewpoint of caregivers and medical staff. We conducted a participative design session with the users, caregivers and medical staff, to evaluate the design of PRESENCE and obtained valuable feedback to improve it (Mortenson et al. 2013).

The goal of any assistive technology for elders is to improve the elders' health. However, the challenge is to develop a technology that works for every single elder with different needs and conditions. PRESENCE is offered as a personalized solution to support the elderly and adapt the system to their personal needs (Czaja et al. 2013). PRESENCE was designed following a user-center methodology and all the design insights emerged from a field study which enables to collect real contextual information related with elders' care process in geriatric centers.

In the evaluation, the nurses and caregivers considered the inclusion of more medical information, such as nursing process; these this observations suggest the need of continuous training for caregivers to provide more professional and specialized care, and encourage the confidence in the task they performed (Bourbonniere & Evans 2002). The final design helps caregivers to register events faster, to be aware of the residents' needs and in general to increase the quality of the care process with a small cognitive load. The integration of caregivers' annotations and sensor data is informative, it satisfies the required predictive features and is simple enough to be integrated seamlessly in the caring workflow.

7. CONCLUSIONS

Research in assistive technology have focused on shifting the need of human caregivers and substituting them with technological aids to leverage independent living of older adults. This is certainly a plausible path in the future, in a healthier society with a small prevalence of chronic, incapacitating diseases. Geriatric centers, on the other hand, will be here for a couple of generations. They have an urgent need to lower the burn out of caregivers and to improve care quality for current and future residents.

Our proposal is sensitive to current problems of geriatric centers, and takes into account the needs of the caring and medical staff; instead of planning for their dismissal with upcoming technology we proposed mechanisms to increase the care quality, lower the burden and contribute to the wellbeing of the residents.

The proposed system, is perceived as useful by the caring personnel, medical staff, and management. The potential users are eager to try a system with the functions described to incorporate them in their daily workload. The use of PRESENCE could free caregivers from routine tasks, so they can concentrate on other activities such as leisure and socialization time with residents, and in general to give a more personalized attention.

Future work includes implementing the system and conducting a long term field study to evaluate the impact of this technology in the care facilities.

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