Providing Awareness of Elder’s Situations of Care through a Context-Aware Notification Environment

A Preliminary Evaluation

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Abstract—Taking care of an elder with cognitive decline is not an easy task. Given their condition, elders could be involved in situations that may affect their physical integrity or quality of life, and caregivers may be unaware of the situation or not be able to attend it on time. This paper proposes a context-aware notification environment to support the work of caregivers. The aim is to increase the caregiver’s awareness about the situations of care of older people in a nursing home, so that caregivers could act appropriately and timely to attend those situations. Firstly, we present the results of a study to understand the situations of care that occur at a nursing home. Later, we propose the design of a context-aware notification environment whose design was informed by this understanding. One of the main features of this environment is that it takes into consideration the contextual information both from the caregiver and from the elder in order to adapt the notification. Preliminary results of the evaluation of an implementation with an audio notification mechanism are promising. During the evaluation period caregivers perceived an increase in their awareness of the situations of care and a safer working environment regarding the provided quality of care.

Keywords: context-aware notifications; elders with cognitive decline in a nursing home; caregivers; user-centered design.

I. INTRODUCTION

According to the International Alzheimer's Disease Society there are 30 million people with dementia worldwide and it is estimated that this number will increase to over 100 million by 2050 [1]. In Mexico it is estimated that there are now between 500 thousand and 700 thousand elders with dementia [2]. This is significant not only by the number of people affected by the disease, but also by the number of people required to care for these patients. Given the complexity of the care task, a caregiver must pay special attention to everything that surrounds the elder. Situations that compromise the integrity of the elder may arise, without the caregiver being able to attend them, or even without being aware of them. This may affect the quality of life of the elder. Thus, technology may be used to improve the caregiver's awareness regarding the situation of care surrounding the elderly. Context-aware computing has enabled the creation of technologies in different areas of healthcare and wellness, including hospitals [3,4], support for activities of daily living (ADL's) [5,6], and the monitoring of elderly living at home to provide assistance [7,8]. Particularly in many of these works it is assumed that the elder lives independently. However, when the elder has limitations, either due to advanced age or an illness, an adaptation of the proposed solutions is required. Works such as [9,10,11] consider the detection of elder’s risks to alert caregivers. However, these works do not pay special attention to how notifications are presented to caregivers. Therefore, the combination of context-aware computing and notification systems calls for proposals that integrate the caregiver of an elder with cognitive impairment into this process, where the notification process includes contextual information from both the elder (what to notify), and from the caregiver (how to notify and whom to notify). We argue that a context aware notification system like this would increase the caregiver’s awareness regarding the situations of care surrounding the elder, and thus allow caregivers to act appropriately and timely to attend these situations.

The organization of the paper is as follows: Section 2 presents the motivation of this work, while Section 3 presents the results of a case study performed to understand the situations of care and the situations of the caregiver. Section 4 presents a set of design implications that emerge from this understanding and inform the design of a context-aware notification architecture. The results of an initial evaluation of an implementation of this notification environment, using an audio notification mechanism, are presented in Section 5. Finally, Section 6 discusses the main contributions of this work, and presents the conclusions; future work is presented in Section 7.

II. MOTIVATION

The quality of care is a factor that can be altered if an accident occurs during an elder’s care. It is required that caregivers be aware at all times of what is happening around the elder being cared to prevent, avoid or handle an event. Thus, the occurrence of an event of this type depends on: 1) the situation of care (contextual situation surrounding the elder), and 2) the situation of the caregiver (contextual situation surrounding the caregiver during the event). To illustrate some of the identified problems we present the following scenario.

In a nursing home, caregivers Suarez and Garcia take care of 8 patients who live there. Louise, a patient who suffers from...
Alzheimer's disease (mild stage), decides to stay in her room because she feels a little tired today. Caregiver Suarez brought her a glass of water before continuing preparing breakfast. At the other side of the residence, caregiver Garcia helped Gilberto, an 82-year patient suffering from mild cognitive decline, to walk into the courtyard. She usually leaves him sitting on the terrace for half an hour enjoying the morning's sun. Minutes later, while helping Rosita to dress herself, Suarez hears noises in the courtyard, but he does not pay much attention, as he does not know that Gilberto is there. Seconds later they hear a scream from the courtyard, Gilberto, while attempting to stand up and walk to reach a ball, had fallen.

From the above scenario we identify a set of caregivers’ needs regarding the care of the elderly, including having awareness of: i) the location of all older adults, ii) activity and current behavior of older adults, and iii) the activities of their fellow caregivers. To understand how technology could assist caregivers in their work, starting from problem scenarios as the one shown above, we identified a set of questions to guide our research, including: Which situations that may affect the quality of life of the elderly occur during their care?, How can caregivers be informed of these situations so that they could act in a timely and proper manner? What features should a technological solution consider in order to support caregivers in their efforts to provide care to the elderly? In this work we propose the use of a context-aware notification environment to increase the caregiver's awareness regarding the elders' situations of care. One of the main features of this environment is that it envisages that notifications to caregivers should take into consideration both the Elder's Situation of Care as well as the Situation of Caregivers.

III. UNDERSTANDING THE SITUATIONS OF CARE AND THE SITUATIONS OF CAREGIVERS

A Situation of Care is an event that may alter the quality of life of an elder; it is more than a situation of risk. To identify and understand the situations of care that arise in a nursing home, and to identify the situation of caregivers during those situations of care, we performed a case study in a local elder nursing home. This study was guided by the following research questions: i) Which situations occur during the care of elders with cognitive impairment that may affect their quality of care? ii) Which elements define the situation of a caregiver at the time she addresses a situation of care? iii) How do caregivers become aware of the occurrence of a situation of care? and iv) Which are the limitations that caregivers face during the elder’s care?. The study consisted of structured 40-minute interviews to 8 caregivers and direct observation to 4 of them while they performed their care activities. The observation lasted 40 hours and 29 minutes. The main findings, in response to the above questions are presented below.

A. Which situations occur during the care of elders with cognitive impairment that may affect their quality of care?

We identified 18 situations of care, 15 of which have occurred during the care of the elderly, while the remaining 3 were estimated by caregivers. The identified situations of care (see Table I) were grouped into the following categories:

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Ingestion</th>
<th>Health Status</th>
<th>Hygiene</th>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasion of personal physical space</td>
<td>Ingestion of incorrect medicine</td>
<td>Abnormal Arterial Pressure/sugar level (high/low)</td>
<td>Full Urine bag</td>
<td>Falls</td>
</tr>
<tr>
<td>Inversion of personal food</td>
<td>Ingestion of not recommended food</td>
<td>Same posture for prolonged periods of time</td>
<td>Dirty diaper</td>
<td>Escaping from the nursing home</td>
</tr>
<tr>
<td>Discussions and aggressive behavior between patients</td>
<td>Communication</td>
<td>Help to stand up or walk provided by another patient</td>
<td>Mobility</td>
<td>Need of assistance to stand up and walk</td>
</tr>
<tr>
<td>Aggressive behavior towards caregivers</td>
<td>Ingestion</td>
<td>Entering into sensitive areas (e.g. kitchen)</td>
<td>Communication</td>
<td>Not properly secured to bed/chair</td>
</tr>
<tr>
<td>Hygiene</td>
<td>Communication</td>
<td>Call to a caregiver from a patient</td>
<td>Communication</td>
<td>Call to a caregiver from another caregiver</td>
</tr>
</tbody>
</table>

Behavior (4) those arising or related to the behavior of the elderly, Health status (2) those that relate to health problems that the elderly could present, Hygiene (2) those related to the elderly hygiene, Mobility (6) those related to the elders’ coming and going inside the nursing home, Ingestion (2) those related to the ingestion of food, beverages and medicines, and finally Communication (2) those relating to communication between older adults and caregivers.

Each of the identified situations was analyzed to understand the context, including: i) Participant actors, ii) Place where the situation occurs, iii) Ongoing activity, and iv) Time at which the situation occurs. This context information could be used to set up a notification and to determine its priority.

B. Which elements define the situation of a caregiver at the time she addresses a situation of care?

Having identified the situations of care of interest to caregivers, we proceeded to identify the situations of the caregiver. We define the Situation of the Caregiver as the set of elements that establish the state of the caregiver during the occurrence of an elder’s situation of care. The elements considered include: i) the activity performed at that time, and ii) the location where that activity occurs. Each of these features is described next.

1) Activities of the caregivers.

As for the elder’s situation of care, the main activities of caregivers, and the time invested in them, were identified through observation and interviews. The identified activities include: Personal care, Mobility, Provision of food / medicaments, Vital signs taking, Treatments and therapies, Recreational activities, and House cleaning, among others.

Figure 1 shows the activities and the time (percentage) that is dedicated to them by caregivers of the morning shift. Note that the Personal hygiene of the elderly is the activity in which they invest the most time (18.2%), followed by Mobility of
patients (13.2%), Provision of food (12.3%), Communication among caregivers (11.1%) and House cleaning (10.8%). Similarly, Figure 1 shows that the Provision of medicaments and Vital signs taking are the activities in which morning shift caregivers spend the least time (both 0.3%).

A similar analysis was performed for the afternoon and night shifts. In the afternoon shift the activity in which the most time is invested is General assistance (18.1%), followed by House cleaning (13.7%), whereas for the night shift, the Personal hygiene (23.1%) activity is the one where the most time is spent, followed by General assistance (18.1%).

2) Location of the caregivers.

Regarding the location of the caregiver, Figure 2 shows the various locations and time spent (percentage) for caregivers in the morning shift. By a wide margin the Bedroom is where caregivers spend the most time (22%), followed by the Restroom (14.7%) and the Courtyard (14.1%). On the other hand, the Office and the Receiving room were identified as the least visited places (both 0.3%).

Similarly, an analysis was conducted for the afternoon and night shifts. In the afternoon shift the most visited location was the Bedroom (38.5%), followed by the Kitchen (15.2%), while in the night shift, the Bedroom was again the most visited location (51.9%), followed by the Living room (22.8%).

C. How do caregivers become aware of the occurrence of a situation of care?

According to the results of the study, caregivers are often unaware of a situation of care until it is happening or until it has happened. Less often, caregivers identify the possibility of occurrence of a situation of care based on their previous experience. We present next some examples provided by caregivers regarding how they become aware of a situation of care.

“In [I notice it] when I go to take a look on the elder… and then I see that something is wrong.” [Caregiver 4]

In the second case, caregivers become aware of the situation of care when it had already happened:

“The elder started yelling Ay!, Ay!, and we went to the bedroom and he was laying on the floor” [Caregiver 3]

Finally, the caregiver becomes aware of a situation before it happens, because she passes by and notices something unusual that draws her attention, allowing her to act appropriately.

“I entered the kitchen following him [an elder] and noticed that the scissors were on the table … I pick them up and asked the cook to pick them up every time she leaves the kitchen” [Caregiver 1]

D. Which are the limitations that caregivers face during the care of the elderly?

Based on the key findings of the study of understanding, and in order to answer the question: how technology could assist caregivers in these needs?, we identified some limitations that caregivers face while performing their work. These limitations include:

- Lack of support to assist the caregiver in the perception of care situations.
- Lack of awareness regarding the situation of the elder, in the sense of being able to prevent situations of care.
- Lack of awareness regarding the activities and location of other caregivers in the shift.

These limitations provide an opportunity to propose technology to support caregivers in the execution of their care activities, aiming at increasing the quality of care.

In conclusion, we can highlight the caregivers’ need to increase their knowledge about what happens to the elders they are in charge of at the nursing home. We define this as Awareness of the Elder’s Situation of Care. The understanding of this need leads us to propose a context-aware notification environment that considers the elders’ Situations of Care and the Situation of the Caregiver, which determine, among other things, What should be notified?, To Whom should be it notified, and How should it be notified?.

IV. DESIGNING A NOTIFICATION ENVIRONMENT

As an initial step for the design of the proposed environment, we established a set of design implications. After that, we propose a context-aware notification architecture based on our initial understanding and identified design implications.
A. Defining the Design Implications

Based on this understanding we proposed an initial set of design implications to be considered for the requirements specification and design of notification systems that seek to provide support for the caregivers of older adults in a nursing home, including: i) Setup the Notification according to the situation of care and context of the elder, ii) Provide notification criteria and priorities according to three phases of a situation of care, iii) Consider different devices to display the notification according to the situation of the caregiver. Further details about these implications are presented in [12].

B. A Context-Aware Notification Architecture

The proposed architecture consists of several modules that are arranged in 3 layers (see Figure 3): 1) Context Acquisition, 2) Notification Composition and 3) Notification Presentation.

A description of the functionality of each component follows:

- **Context Acquisition.** Aims to capture the Context of the Elder and the Context of the Caregiver. This contextual information includes: Identity (I), Location (L), Time (T), Activity (A) and the Situation of Care (SC). This context information comes from sources such as vision systems, RFID systems and various types of sensors [9].

- **Notification Composition.** In layer 2, contextual information is Filtered and forwarded for Message Composition, User Selection and Mechanism Selection. Later, the Notification is forwarded for Storage and Delivery. See Table II for more details.

- **Notification Presentation.** Finally, this module consists of the Notification Display, which submits the notification message to the caregivers through appropriate devices.

Finally, the presented architecture allows the creation and use of various notification mechanisms for caregivers of elders with cognitive impairment. The main feature of this notification architecture is that it is aware of the context, both of the elder, and of the caregiver. In the next section a first implementation for it is presented.

V. EVALUATING THE CONTEXT-AWARE NOTIFICATION ENVIRONMENT

To validate the previous design and architecture, and to obtain feedback from their possible application, we proposed to implement a notification system based on the architecture and to evaluate it at a nursing home.

A. Implementation of an audio notification mechanism

For this implementation we considered a basic functionality, including: Context acquisition, Context filtering, Message composition, Notification delivery and storage, and Notification presentation. User selection and Mechanism selection were not included, as in the first case we decided to notify to all caregivers at the same time; while on the second case, we decided to use a single mechanism and device (audio notifications through radio transmitters carried by the caregivers). Figure 4 illustrates the functionality of the audio mechanism. The elder’s context is continually evaluated, and whenever a Situation of Care is identified, a notification is created. This is performed by the context Filtering module. Later, a message is created, which is forwarded following two paths: i) firstly, it is transferred to the Notification Delivery component to be sent for presentation to the notification device, where it is displayed; ii) secondly, the notification is transferred to the Notification Storage module, so that it is recorded in a log for future analysis and statistics.

B. Context of the study

For context acquisition, we installed six video cameras in different locations of the nursing home: two in the hallway, two in the yard, one in the nursing central station and another

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**TABLE II. COMPONENTS OF THE CREATE NOTIFICATION MODULE**

<table>
<thead>
<tr>
<th>Component</th>
<th>Required context</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context Filtering</td>
<td>Elder (I,L,T,SC)</td>
<td>Creates the required context from the provided context, and forwards them to Message composition and User selection mechanisms.</td>
</tr>
<tr>
<td>Message Composition</td>
<td>Elder (I,L,T,SC)</td>
<td>Creates the notification message, based on the provided contextual information.</td>
</tr>
<tr>
<td>User Selection</td>
<td>Caregiver (L,T) + Elder (SC,L)</td>
<td>Determine to which caregiver(s) a notification will be sent, based on the caregiver’s location, and activity, and on the elder’s care situation and location.</td>
</tr>
<tr>
<td>Mechanism Selection</td>
<td>Caregiver (L,T) + Elder (SC)</td>
<td>Determine the most appropriate mechanism to notify, based on caregiver’s location and activity and on the elder’s situation of care.</td>
</tr>
<tr>
<td>Notification storage</td>
<td>---</td>
<td>It stores the notification in a log (Database).</td>
</tr>
<tr>
<td>Notification delivery</td>
<td>---</td>
<td>It sends notifications to selected caregivers (devices).</td>
</tr>
</tbody>
</table>
in the dining room. A researcher (Wizard of Oz) observed the captured scene to determine whether or not a situation of care happened. Based on this information she created and sent notifications. Participants were five caregivers of the nursing home, three women and two men, who worn a radio transmitter with headset for hands-free operation.

C. Procedure

We conducted a three-hour pilot session, so caregivers could familiarize themselves with the audio device. Subsequently, there were 9 sessions to observe the daily activities of patients and caregivers (an average of 3.89 hours per day) for a total duration of 35 hours and 10 minutes. At the end of each session, questionnaires were applied to caregivers regarding the notifications that occurred during that day. Finally, at the end of the study a structured interview was conducted to obtain information regarding the effectiveness and usefulness of the notification. The main results of the evaluation are presented next.

D. Results

a) Notified Situations of Care. During the 35 hours of the study a total of 97 notifications were sent. This notifications were classified into 9 types of notification messages, corresponding to 7 Situations of Care, including: Help to stand up or walk provided by another patient, Need of assistance to stand up and walk, Ingestion of not recommended food, The call to a caregiver from a patient, Entering into sensitive areas, Invasion of personal physical space, and Escaping from the nursing home.

The two last situations were notified using two variants (Time and Place). Table III shows the notified messages, the relevance of the situation of care and the frequency with which they were sent.

b) Status of the situations of care at the moment of the notification. The questionnaires applied to caregivers allowed us to know the caregivers’ perception of the situations of care when it was notified and attended. They considered that i) 79% of the notifications were occurring (e.g. patient is standing at the door of another patient’s room), ii) 6% of the notifications had already occurred (e.g. the patient had already taken the drink of another patient, and the caregiver took the glass and verified its contents to ensure that it would not hurt her), and finally, iii) 15% of the notifications prevented the occurrence of a situation of care (e.g. by notifying that a patient stood up to walk without assistance, a situation <fall> was prevented).

c) Evaluation of audio as a notification mechanism. To evaluate the effectiveness of the audio notification mechanism, we considered issues such as: clarity of the message (quality level of the audio to understand the message) and the interruption level (the degree at which caregivers had to suspend their activities to address and understand the message). Caregivers considered having received 90.63% of the notifications with a high level of clarity and 9.37% with medium level of clarity. On the other hand, they considered that 96.87% of the notifications had a medium (51.56%) or low (45.31%) level of interruption.

d) Qualitative results. Caregivers mentioned that by using the notification mechanism they considered themselves as being "more vigilant", "more careful", and "more alert". Also, they perceived that this enabled them to take more control in the nursing home regarding the situations of care. At the end of the study, caregivers perceived an increment in the quality of care they provided. When the system was removed and the researcher acknowledged the caregivers’ participation in the study, one of them said:

"We were saying yesterday that now [that you are leaving], who is going to notify us [regarding the situations of care]? We got used to it!"  
[Caregiver 2]

VI. DISCUSSION AND CONCLUSIONS

In a traditional nursing home, the situation of care (contextual elements that surround the patient in a situation that requires the intervention of a caregiver), and the situation of caregivers (contextual elements surrounding the caregiver during the situation of care) are key factors in determining i) How the situation should be addressed, ii) When to address it and iii) Who should or could address it. Furthermore, in an intelligent environment that reports these situations, these two concepts are fundamental to determine i) What to notify, ii) How to notify it, iii) When to notify it and iv) Who to notify it. The results of our work (referring to the initial understanding, a set of design implications, architecture design and implementation and evaluation of an initial prototype) not only confirm the feasibility of providing this information to caregivers through technologies that seek to increase the caregivers’ awareness about situations of care, but also provide evidence of the usefulness and ease of use of our proposal according to the perception of the caregivers, thus the importance of our work.

In the literature there are other context-aware systems that focus on patient care in healthcare environments, such as elder’s private homes [7,8] and hospitals [3,4]. Our work is developed in the context of a nursing home for the elderly.

A first contrasting point refers to the ratio between the number of caregivers and the number of patients they see directly in these environments. In the residence the number of elders receiving attention tends to be greater than the number of caregivers, which differs widely with respect to the case of a private home (usually 1 to 1) and is more similar to the case of a hospital (1 to many).
A second contrasting point refers to the kind of technology used for notification. For example, Paganelli et al. [11] proposes a reporting system for the caregiver, in which notifications are sent to a fixed computer or mobile device carried by the caregiver. This scheme provides that older adults and caregivers are in different places (e.g. each in their respective households) and the reported situations should be addressed on a deferred basis (e.g. until the next visit). In contrast, our proposal considers that both the elderly and their caregivers are in the same physical space (residence), so that notifications can be addressed immediately. Additionally, notifications may be sent to various devices available both at the personal level (e.g. mobile - phone or PDA or wearable - bracelet, necklace) or the environmental level (e.g. environmental or public screen display).

Finally, a third contrasting point relates to the time the notification is made. While in other work [9,10] the notification is sent to the caregivers after the occurrence of the situation of care, in our proposal, the notification can be sent before (alert or reminder), during (alarm) or after (alarm or report) the situation of care [13], according to the context of the elderly and the situation of the caregiver.

Additionally, it is also necessary to address some issues regarding privacy, work and information overload, and disruption that the notification could generate to the caregiver.

Privacy of the caregiver information. Regarding caregiver information, it is only used in the system to identify the mechanism that would be more appropriate to provide a notification and to establish the availability and location of caregivers and their notification devices. In addition, the information is only known to other caregivers in the same shift, who consider appropriate to provide this information to their partners, through a mutual reflexive agreement (I know about you and you know about me).

Information/Work overload. In this regard, it is considered that the reception of multiple notifications may be a possible cause of caregivers’ information overload. However, in this evaluation caregivers felt that there was not an overload, as they received an average of 10 notifications per session of 3.89 hours (i.e. about one notification every 20 minutes). Furthermore, regarding work overload, caregivers mentioned that the workload did not change. They even considered that maybe it had reduced because the number of times they voluntarily stopped their activities to go check on the health status of elders decreased.

Interruption. Unlike notification systems for office environments [14,15], where notifications arrive to interrupt the primary activity of the worker; in this case, the notification requires the caregiver to attend their primary activity: taking care of the elders. On several occasions it happened that on sending the notification, caregivers were carrying out secondary activities or caring for another elder, however, caregivers did not consider the notification as an interruption, but as a service that helped them to set priorities on their provision of care.

VII. FUTURE WORK

Finally, regarding future work, we consider two main directions: i) Extending the architecture to enable coordination among caregivers to collaboratively address the situations of care; and ii) Developing a prototype that considers the situation of the caregiver for the presentation of notifications.

REFERENCES