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An Ontological Representation Model to Tailor Ambient Assisted Interventions for Wandering

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Abstract

Wandering is a problematic behavior that is common among people with dementia (PwD), and is highly influenced by the elders' background and by contextual factors specific to the situation. We have developed the Ambient Augmented Memory System (AAMS) to support the caregiver to implement interventions based on providing external memory aids to the PwD. To provide a successful intervention, it is required to use an individualized approach that considers the context of the PwD situation. To reach this end, we extended the AAMS system to include an ontological model to support the context-aware tailoring of interventions for wandering. In this paper, we illustrate the ontology flexibility to personalize the AAMS system to support direct and indirect interventions for wandering through mobile devices.

Introduction

Wandering is a common behavior among people with dementia (PwD), which is also one of the main concerns of caregivers since it can cause the person to get lost and injured. The frequency and manner in which a person wanders is highly influenced by the person's background and contextual factors specific to the situation (Algase, Beel-Bates, and Beattie 2003). In this sense, studies demonstrate favorable results when the tailoring of the intervention matches the elders' skill levels and cognitive physical abilities as well as their style of interest, resulting on a less disruptive wandering behavior (Hermans, Htay, and McShane 2007). Therefore, a successful intervention for PwD requires an individualized approach that takes into account both the evolving needs of the person and the perspective of the caregiver. From the literature review and an in situ intervention with persons suffering with Alzheimer's disease and their primary caregiver, we informed the design of an ontological model that facilitates the adaptation of an intervention provided by an Ambient Augmented Memory System (AAMS) (Navarro, Favela, and García-Peña 2010). The ontology is a representational model for Behavioral and Psychological Symptoms of Dementia (BPSD) (such as depression or anxiety), which was extended to represent the particular properties of wandering behavior. Thus, the ontology provides the contextual information to be used by the AAMS system to estimate the risk faced by the PwD, and then, to select the appropriate action to take, such as prompting the PwD or calling the caregiver. The contextual information represented through the ontology, includes proximal factors related to personal and physical needs as well as physical and social aspects of the environment (Algase, Beel-Bates, and Beattie 2003). For example, deficits in visual perception (background factor) reduce cues that aid in interpreting and navigating an environment with deficient lighting (proximal factor). Additionally, it represents the information that characterizes the particular wandering behavior of the elder (e.g. known locations), which is used by the system's decision model to recognize the user's wandering based on the current contextual information gathered from a mobile phone sensing application (such as current location, noise, and proximity to the caregiver). Thus, this paper presents the integration of this ontology to the AAMS system to support the personalization of the planning and execution of interventions to address elder wandering behavior. To reach this end, we illustrate the flexibility of the ontology to personalize the AAMS to support wandering assistance through mobile devices on an Android platform.

Characterizing Wandering Behaviors

Wandering is defined by the North American Nursing Diagnosis Association (NANDA) as: ”meandering, aimless, or repetitive locomotion that exposes a person to harm and frequently is incongruent with boundaries, limits, or obstacles” (Douglas 2004). It is estimated that more than 60% of dementia sufferers wander, yet its causes and manifestations are varied.

We use scenarios to illustrate some of the factors influencing wandering behavior and the different type of support required by a PwD who experiences wandering. These differences highlight the need to incorporate background information about the individual and contextual information of the situation in order to detect wandering behavior and provide appropriate assistance:

Scenario 1. Frida, is a 82-year old women who was diagnosed with Alzheimer's five years ago (MMSE=10). After taking a nap in the afternoon, she is watching TV on her living room with Rosa, a retired nurse who cares for her during the day. Suddenly, Frida walks to her room and starts taking cloth out of her closet. Rosa comes in, realizes that she is putting her cloth on a suitcase, and asks Frida why she is doing this. Frida replies that it is getting late and she needs to get back home. Rosa tells her that she is currently at her house, but Frida insists that her home is in another city, where she used to live 30 years ago. After several minutes discussing the issue, Rosa convinces Frida to stop trying to leave home by showing her some family photographs.

Scenario 2. Marie is a 70-year-old woman who lives in a small village in France near the beach. She was recently diagnosed with Alzheimer’s disease, and has increasing trouble remembering where she placed things and what her schedule is. She lives with her husband Roger, who is also 70 years old but does not have memory problems. One of Marie’s greatest pleasures is to take her dog for a walk, which helps her deal with the increased anxiety and depression that affects her as her disease progresses. She normally walks with her dog along the beach, but sometimes goes inland. At times she gets disoriented due to lack of attention and poor visual and spatial ability. When she is aware that she is lost, she asks for help and has been brought back home a few times by other villagers. She feels increasingly inhibited to go out on walks because of the social stigma attached to this dependence, and her husband feels increasingly anxious when she leaves. She has a number of friends in the village, and frequents a few of the shops regularly that are not on the beach. She finds it relatively easy to navigate to these shops and then find her way home again.

These scenarios, based on actual cases, illustrate some of the factors that lead to wandering behavior and the different ways in which it is manifested. The fist scenario was identified from a case study that we are conducting to evaluate the usability and effectiveness of interventions based on External Memory Aids (EMA) (Douglas 2004). Participants are patient-caregiver dyads living in the same home. Patients are persons over 65 years, diagnosed with Alzheimer Disease (AD), and have shown manifestations of at least two BPSD (screening via Neuropsychiatric Inventory Questionnaire and the Revised Memory and Behavior Problems Checklist). To personalize the intervention we collected information from the caregiver through the Personal Wants, Needs and Safety Assessment Form, and the Memory Aid Information Form. During four weeks, caregivers are required to implement this intervention using traditional external memory aids (e.g. whiteboards, calendars, index cards), and to keep a diary of BPSD using a mobile phone logging application. The second scenario was inspired from other cases of PwD who are not participating in this study. However, we considered relevant to analyze them, since they show how differences on the profiles of the PwD and on the factors that may lead to wandering, have to be considered to tailor an intervention. For instance, in scenario 2, providing Marie with anchors to reality, such as reminding her that she was heading home or showing her that a known location, i.e. the local bakery is nearby, can lessen her anxiety caused by feeling lost. And scenario 1 illustrates how Frida needs a direct intervention from her caregiver to prevent wandering behavior, which was manifested as a consequence of the sundowning syndrome that Frida experienced. Sundowning is a dementia-related symptom that consists of increased agitation, confusion, and hyperactivity that often occurs in the late afternoon and becomes especially severe at night (Ott, Reynolds, and Noonand 2006).

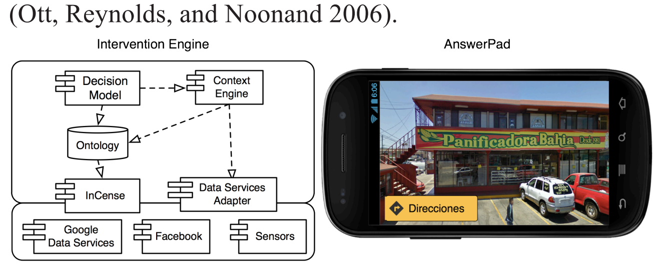

Figure 1 . *AAMS Architecture and the AnswerPad application*

The Ambient Augmented Memory System

We developed the Ambient Augmented Memory System (AAMS) to leverage on the pervasiveness of technologies for augmenting awareness about people, activities, places and things with additional information, to assist elders with early AD (Navarro, Favela, and García-Peña 2010). Our hypothesis is that providing situation awareness in an accessible manner can decrease stress in patients with AD and their caregivers. Figure 1 shows the architecture of the

AAMS, which enables to implement applications such as AnswerPad and AnswerBoard.

The AnswerBoard is a public ambient display implemented with a touch screen LCD computer. It provides information of the person's activities for the current day and reminder messages, which can be created by the caregiver from scratch or by selecting and filling out one of the predefined templates. Through the AnswerBoard the caregiver adds activities and appointments to the patient's agenda. The AnswerPad is an application running on an Android mobile phone. It includes different widgets aiming to offer the PwD time and place awareness, reminder notes, cues on his/her current activity, and to maintain the connection with his/her social network.

AnswerPad recollects data from the mobile phone's sensors to feed the Context Engine using the InCense application (Pérez, Castro, and Favela 2011). Additionally, caregivers may use AnswerPad to manage elder's daily activities, keep track of his/her whereabouts, create reminder notes, and keep a diary of patient's behavior. The diary application uses RFID tags to record incidents of BPSD via the NFC reader in the mobile phone, which launches a survey presented in figure 2, to document a) the degree of burden imposed by this behavior, b) the perceived degree of affectation, on the PwD and c) the specific signs shown by the patient. At the end of the survey, the caregiver may leave an audio-message to explain the incident.

The Intervention Engine container is a logical representation of the main components that support the functionalities of the AnswerPad and AnswerBoard. For instance, the InCense application and components that collaborate to tailor and suggest interventions for the PwD. These components are explained in the following sections.

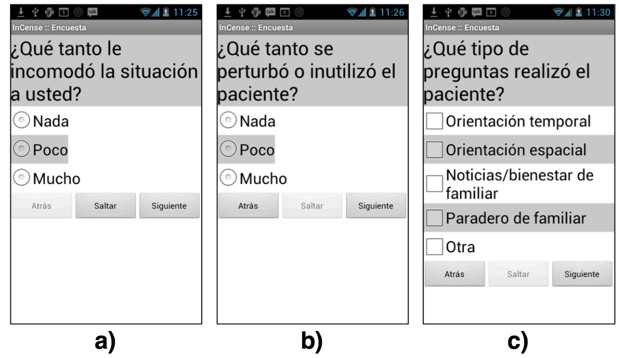

Figure 2. *InCense survey collecting information of a BSPD (repetitive questioning) from a caregiver, including: a) To what extent was the situation unconfortable? b) To what extent the situation perturbed the patient; and c) What type of question asked the PwD?*

Ontology Design

An ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used to define a domain and reason about its properties (Grubber 1993). We designed an ontology to represent the knowledge within the domain of non-pharmacological interventions for problematic behaviors. It was extended to represent the properties of wandering patterns, which according to Algase et al. (2003), it is relevant to monitor these properties on a regular basis to enable caregivers to improve an intervention.

Representation Model for BSPD

Figure 3 presents the ontology developed to represent problematic behaviors (*BSPD*) and corresponding non-pharmacological interventions. It represents the types of BSPD that a cognitive impaired elder may face, such as *Depression, Aggression, Agitation* and *Wandering*. Wandering behaviors have been classified according to the following patterns (Algase, Beel-Bates, and Beattie 2003; Martino-Saltzman et al. 1991), represented in the ontology: *Random* walking (ambulation having frequent direction changes), *Lapping* (moving in circuitous or looping fashion), *Pacing* (moving back and forth repetitively between two points), and *Direct* ambulation. BSPD can be identified through different Manifestations observed by the Caregiver. For instance, in Scenario 1, Rosa observed when Frida suddenly walked to her room and started taking cloth out of her closet, which was a *Manifestation* of the *Wandering* behavior observed by Rosa. Additionally, some BSPD can be *Manifestations* of other BSPD. Thus, *Repetitive Questioning* and *Lapping* may be *Manifestations* of *Anxiety*. According to the ontology, when a BSPD manifestation is identified by the *Caregiver*, she should use an *Intervention,* which can be based on *Cognitive Oriented, Emotion Oriented, Sensory Oriented,* or *Activities* that the elder likes to do or is able to do with the help of the *Caregiver*. For instance, the interventions recommended to use for the sundowning syndrome, include exposing the

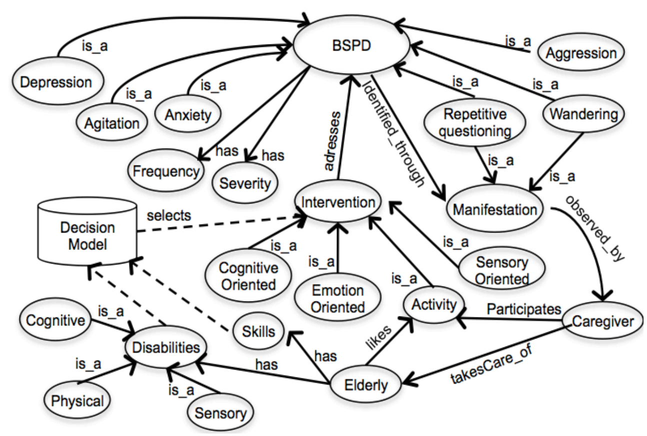

Figure 3. *Non-Pharmacological Interventions Ontology*

PwD to bright lights in the early evening in order to reduce the effects of sundowning, and using name-tags and clear labels around the living quarters to help her to reduce memory demands (Sitzer, Twamley, and Jeste 2006). An *Intervention* has properties such as: "type", which describes if the assistance will be provided through the caregiver, i.e indirect intervention, or directly through a system; and a property to depict if it was successful or unsuccessful intervention. The ontology registers other relevant properties to represent how dangerous was the elder's behavior, such as the frequency of the BSPD, its severity, and the burden for the *Caregiver*, that is, how often it has occurred, how much it disturbed the *Older adult*, and how much it emotionally distressed the *Caregiver*, respectively. The abovementioned properties and the information regarding the elder's *Disabilities* and lost *Skills* can be used by a Decision Model to select a type of Intervention to use. For example, based on the fact that showing family photos to Frida, successfully prevented her from going out; it may be suggested to Rosa to prevent a problematic wandering when Frida exhibits the sundowning syndrome.

Representation Model for Wandering Properties

Figure 4, presents the representational model of the observable and measurable properties of wandering (Martino-Saltzman et al. 1991). The *Rhythmic* parameters of wandering are limited to *Cycle period, Frequency* and *Phase*s. A *Cycle period* encompass the time elapsed from the onset of one episode to the onset of the next. The *Frequency* represents how many times the wandering episode occurred during a day. A *Cycle period* is composed of *Phases*, which may consist of: *Locomoting* phases, during which a person navigates through a space, and *Non-locomoting* phases, during which a persons sits, lies, or stands without forward propulsion. During any of these phases several locations are associated with any of them; i.e. while the PwD is moving she is traversing *Frontier* locations, and when she stops she is in a *Visited* location. Both of these types of locations have properties to identify its position (such as, altitude, longitude for outdoors locations, or X,Y coordinates for indoors locations), and a property to represent if it is a location known by the older adult. For instance, in scenario 2, while Marie was walking with her dog, she may stop in some locations to talk with some of her friends, and also to traverse several known locations, even though she did not recognize some of them when she felt lost.

Ontology Decision Model

The Decision Model depicted in figure 3, consists of a rule base with conditions to be met in order to support the tailoring of the intervention. These rules provide a

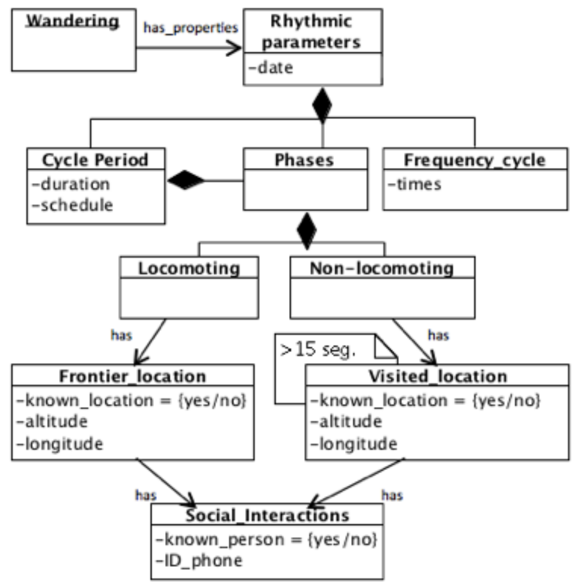

Figure 4. *Ontological representation for wandering*

representation of how the AAMS system should support the tailoring of the system, either by suggesting the caregiver to enhance the intervention due the elder's behavior pattern has changed according to the ontology, or by selecting the intervention to use according to the elder's current context.

Tailoring the AAMS System

The ontology supports the tailoring of the AAMS services in two phases to realize their deployment: i) customizing the AAMS services for a PwD before deployment, and ii) providing a timely and adequate intervention while the system is being used by the caregiver and PwD dyad.

Tailoring the AAMS System for the Patient

For explaining this type of tailoring we revisit Scenario 2 to illustrate the tailoring of the AAMS services for assisting Marie. The following are the steps that system developers, supported by the caregivers need, need to complete:

1) Create an ontology instance with the information gathered from her caregiver through the preliminary survey and assessment instruments. For instance, the ontology initially describes the presence of Marie's amnesic behavior (BPSD), and that sometimes (frequency) she gets disoriented while she walks her dog. This is an Activity that she enjoys to do since it enables her to cope with depression and anxiety (BSPD). However, this situation severely distresses (burden) her husband.
2) Decide what intervention should be initially provided by the system, and then register it on the ontology by using a descriptor that identifies it. In this case, we

decide to use the AnswerPad for displaying external memory aids consisting on messages with photograph of Marie's nearest known-location.

3) To enable the AAMS to support the abovementioned intervention, an instance of the wandering ontology (figure 2) should be created to represent the locations that the PwD used to visit when taking a walk, the frequency and schedule that she used to walk, and information related to the social interactions she might have with known people.
4) Afterwards, configure the set of messages that will be displayed to reorient the PwD when she feels lost. To reach this end, we used the widgets provided by the Data Services Adapter to create a set of notifications consisting on messages and images of the places known by Marie.

An information baseline of the elders' wandering behavior is created in step 1-3, which can be updated through the context information collected by the InCense mobile application; i.e. from a study we carried out to identify mobility patterns of 15 older adults who used inCense during approximately 20 days, we were able to identify the locations they used to visit and the routes they followed (see figure 5) (Hoey et al. 2012). Thus, the AAMS system is able to construct and update the ontology by using the InCense application. As we will explain next, the Decision Model will consult the ontology to look for changes in order to decide to adapt a non-pharmacological intervention to the baseline information changes.

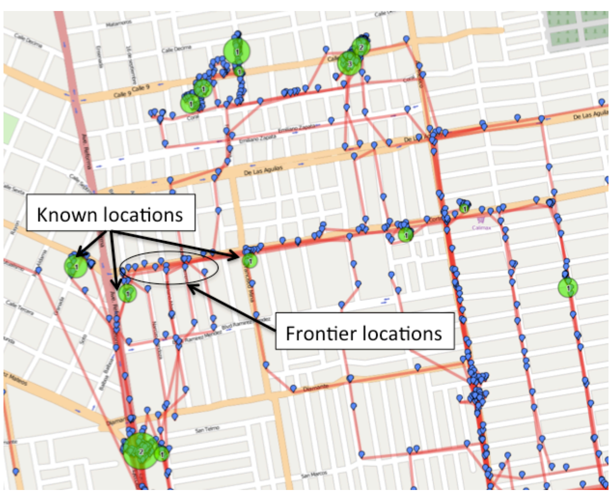

Figure 5. *Data gathered with InCense application from an elder*

Conxtext-based Tailoring of the Intervention

During the deployment, instances of the ontology are populated by integrating data from different sources (e.g. context captured through the InCense application, incidents logged by the caregiver using AnswerPad). These ontology instances create an information baseline about the pattern and amounts of wandering, and the applied interventions. When a wandering incident is faced by the elderly, the Intervention Engine components gather the current context, contrast this with the baseline information to decide if an intervention tailoring is needed, and support the caregiver to tailor the intervention. Thus, the Intervention Engine recommends an intervention to apply based on information of previous manifestations of wandering, current manifestations, and related context information, such as PwD location.

Application Scenario

Considering Scenario 2, when Marie decides to take a walk she passes an RFID through the NFC reader of her mobile phone, which will activate the sensors for capturing her context. When Marie feels lost, she presses a button on the mobile phone to register this incident on the ontology. The InCense application triggers an event to launch the AnswerPad application and to generate a new instance of the ontology. The event contains information of Marie's current location estimated with the GPS, which is used by the Decision Model to determine the nearest location to her. This is used by the AnswerPad (as presented in figure 1) to display a note with the photograph of the bakery that Marie likes to visit and where she can find her friend, Dominique, who can give her instructions for getting back home. Then, Marie locates the Bakery and approaches it to receive help and get back home. Finally, the trajectory (i.e. visited and frontier locations) followed by Marie and her social interactions are registered on the ontology to be used to tailor future interventions. For instance, when new instances of this incident happens, a map showing this trajectory may be presented to Marie, from which she can access photographs of the places she visited.

Related Work

Several middlewares use ontologies for representing context information and reasoning about it to enable the flexible addition and replacement of hardware that captures context information (e.g., sensors, actuators) (Soldatos et al. 2007). Some of these middleware propose two-layered ontologies to support for acquiring, discovering, interpreting and accessing various contexts (Gu, Keng-Punga, and Da-Qing 2005; Bochini, Curino, and Quintarelli 2007). To use such context models, a developer must create instances of it stipulating the type of context he is modeling and the rules associated with it. In this direction, several ontology-based architectures for specific domains have been proposed, which are of particular interest for our project. For instance, with the aim of enhancing the effectiveness of therapeutic treatments for persons with cognitive problems, the SOAD ontology was designed to capture the agitation experienced by PwD and the contextual conditions that have to be met to provide different intervention options, such as music therapy (Foo Siang Fook 2006). Similarly, the Mout Framework provides an ontology for modeling the treatment of persons with mental disorders (e.g. depression). A rule-based reasoning uses this ontology to identify the services that patients/professionals need to establish an online session for Cognitive behaviour therapy (CBT) (Bin Hu et al. 2010). On the other side, Biswas et al (2010) proposes an ontology to support providing assistance services to PwD through different devices; i.e. an instance of the ontology is needed to interface a device (e.g. IPTV, and mobile devices) with the assistance service. These works emphasize the utility of using ontologies to enable the adaptation of assistance systems according to contextual conditions, such as the type of device to be used, the context of a therapy session, or the quantification of a particular patient behavior to decide the intervention to use. Thus, these works motivated us to design an ontology to enable the two levels of adaptation that we identified as relevant for facilitating the deployment of ambient assisted intervention systems.

Conclusions and Future Work

In this paper we presented an ontology-based ambient augmented memory system (AAMS) to provide PwD with non-pharmacological interventions for wandering behavior. We argue that the ontology is flexible enough for enabling the tailoring of the system, since it enables developers to configure it with baseline information, i.e. the initial contextual information relevant to provide an intervention. Additionally, this baseline information evolves when instances of the ontology are populated to represent manifestations of wandering and the applied intervention. This facilitates to maintain a history of PwD problematic behaviors, representing the patterns and amounts of wandering, which can be used to reason about the evolution of wandering. In this sense, we plan to explore reasoning algorithms to determine if the PwD present an inefficient wandering, such as goal-directed wandering, which may require that the AAMS system provides caregivers with timely notifications. We also plan to validate the ontology flexibility for representing the rhythms that characterized the different types of wandering (such as, lapping, goal-directed, pace).

Acknowledgements

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