HYCARE: A Hybrid Context-Aware Reminding Framework for Elders with Mild Dementia

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Abstract. Dementia occurs much more frequently in the elders who exhibit impairments of memory, thought and reasoning. In this paper, we present a hybrid context-aware reminding framework intended to help elders with mild dementia improve their level of independence and quality of life. Based on the user study in three different pilot sites, the reminding services are identified and classified into four types according to the nature and urgency. The framework with a novel scheduling mechanism is designed which handles both synchronous time-based and asynchronous event-based reminding services. In order to facilitate the interaction between the caregivers and system, we also provide a simple software tool for caregivers to create and edit the reminding services. Finally, we present some initial implementation results.

Keywords: reminding, context-aware, hybrid scheduler, event-based.

1 Introduction

Dementia is a progressive, disabling, chronic disease affecting 5% of all persons above 65 years old and over 40% of people above 90 [4]. People with a diagnosis of dementia experience progressive cognitive impairments that typically start with memory problems but can encompass thought, speech, perception and reasoning difficulties, which lead to an inability to perform the most basic functional activities such as washing and cooking, and in extreme cases to damages and even loss of life. From social, economic and elder's perspectives, it is of paramount importance to enable the elders with mild dementia to remain in their own homes for longer periods, and to relieve the burden of formal and informal caregivers.

Pervasive computing technologies have been proposed to assist elders suffering from mild dementia to improve their level of independence and quality of life through

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cognitive reinforcement [9]. Much research has been done on the reminders which aim to prompt the elder for performing daily activities. For example, Autominder [10] adopts a plan-based approach to decide when and how to prompt subjects effectively, it handles the time-based activity plan by solving the disjunctive temporal problem. The approach is limited to time-based reminding plan. Location-based reminders are described in [13,5,1] which have all shown location is a key element for reminding services. However, there is more to context than location when designing various reminding services for elders with mild dementia, for example time and user activities are two important elements of context for reminding. Cybreminder [3] and ComMotion [8] are two examples of context-aware systems which support reminder applications. They attempt to build a context-aware infrastructure and make use of rich context information to support reminding services, but they focus more on when and how to prompt the subjects, without tackling the coordination and execution of different reminding services. Helping elders with mild dementia to perform activities of daily living (ADLs) is a hot research area, the basic idea is to monitor if the subject is stuck in a certain step and the system will inform the elder what and how to do in the next step if needed. So far the research is still limited to assisting certain specific activities such as brushing teeth and washing hands [2][7], systems that can assist a variety of ADLs have not appeared yet. Medication prompting is another hot topic associated with reminding services, a statistical reasoning system is presented in [12] for determining in what circumstance the subject should be prompted for medication, but it doesn't provide a general framework for coordinating different reminding services. The wearable computing research community have also explored various reminding approaches [6,11], their focuses are usually more on how to remind people rather than when to remind them.

If we look at all the previous work on context-aware reminders, they mainly focus on when and how to issue reminding signals to the subjects according to the context, they seldom consider the coordination of different reminders and the situation of the reminding activities interrupted by another event, which are common and crucial in assisting elders with mild dementia. For example, a phone call or going to toilet often interrupt the on-going daily routines but they cannot be predicted in advance. The context-aware reminding framework should handle both the synchronous and asynchronous events correctly.

In this paper, we intend to build a hybrid context-aware reminding framework for elders with mild dementia (HYCARE) which can handle both the synchronous and asynchronous events. In particular, we propose and develop a novel scheduling mechanism that can coordinate various reminding services and remedy the possible conflicts. As part of the European project called "CogKnow", this work starts with the user study at three different pilot sites, the reminding services are then classified into four categories and the context-aware reminding rule set is formulated. In order to facilitate the interaction between the caregivers and system, we provide a simple software tool for caregivers to plan the possible reminding services. In Section 3, the hybrid context-aware reminding framework is presented with details, including the reminder planner, the reminder scheduler and the reminder adaptor. In Section 4, some initial results of CogKnow are briefly described. And finally, the concluding remarks and future directions are given in Section 5.

2 Design of the Context-Aware Reminding Services

2.1 User Studies

In the CogKnow project, we adopted a user-centered design approach and performed user studies at three different sites: Amsterdam (Netherland), Belfast (UK) and Luleå (Sweden). Workshops and interviews with 17 elders were conducted together with their caregivers. Four main areas of cognitive reinforcement have been identified as follows:

- Remembering
- Maintaining social contacts
- Performing daily life activities
- Enhanced feeling of safety

While these four areas cover the different aspects of user needs for living independently, each area is somehow linked to reminding the elders of things like appointments, the name of caller, locating the mobile devices and keys, making phone calls, meal preparation, brushing teeth, recharging devices, closing refrigerators, taking medication, turning off stoves, locking doors when going outside. Therefore, the reminding services are considered as fundamental functions to assist elders with mild dementia for independent living.

To look at the needed reminding services, *watching the favorite TV program* should be time fixed, for example, the news program starts at 7:00pm everyday. The subject will miss part of the program if he/she is prompted later than 7:00pm. *Preparing and having meal* can be scheduled based on time, but the prompting can be delayed a bit if the elder is not "ready", for instance, if the elder wakes up late or is on the phone. In addition to the time relevant daily activities, there are also cases that depend on events. For example, an elder should be reminded of *bringing the keys* with him/her when *going outside* (if he/she forgets so), he/she should be reminded of *washing hands* after *toileting* (if he/she forgets so). In the former case, the *bringing the keys* service should be prompted and executed before *going outside;* in the latter case, the *washing hands* service can be prompted with a bit delay and even not fully executed if it is interrupted by another urgent event such as phone call.

2.2 Reminding Service Classification

Based on the observation of elder's daily activities mentioned above, we classify the reminding services into four kinds as follows:

1) Time-based Prompting
    - Time fixed prompting service: The prompting is issued strongly at defined time so that the subject understands the urgency of executing certain activity.
    - Time relevant prompting service: The prompting is relevant to a time, but can be delayed within an acceptable time window.

2) Event-based Prompting

- Event urgent prompting service: The prompting is issued strongly when an urgent predefined event is detected.
- Event relevant prompting service: The prompting is related to other events, but it can be delayed within an acceptable window.

2.3 Context-Aware Prompting Rules

We adopt Event-Condition-Action (ECA) rules to describe context-aware prompting rules. While the event refers to the context info such as time, location, user activity, etc; and the condition tells if certain situation happens, then the corresponding reminding service is activated as action. The ECA rules determine when and what to prompt. The following examples are corresponding to the four kinds of reminders:

- Example of time relevant reminding service: taking medication

Later(current time, anchor time) ∧ *Earlier*(current time, anchor time+delay window) ∧ *LocatedIn*(elder, home) ∧ *IsSleeping*(elder,no) =>prompt

- Example of time fixed reminding service: watching favorite TV program

Matches(current time, TV program) ∧ *LocatedIn*(elder, home) =>prompt

- Example of event urgent reminding service: bringing key

Detected(elder, leaving home) ∧*IsBringKey*(elder, nc)=>prompt

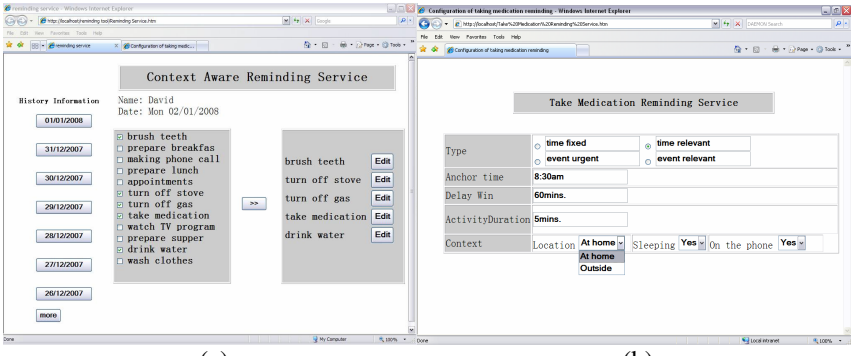
- Example of event relevant reminding service: washing hands

IsFinishToileting(elder, yes) ∧*IsWashhands*(elder,no)∧ *LocatedIn*(elder, home) ∧*IsOnThePhone*(elder,nc) =>prompt

2.4 Software Tool

To facilitate the interaction between the caregivers and system, a simple software tool as shown in Fig. 1 is built. Caregivers can use the tool to create and edit the prompting rules.

Fig. 1(a) shows a snapshot of reminding service creation and selection. In this example, brush teeth, turn off stove, turn off gas, take medication and drink water are selected as reminding services for the elder named David on Monday, 02/01/2008. History information buttons are provided for recalling previous records. The Edit button near each selected reminding service allows dynamic construction of an arbitrarily rich situation (context) comprising the associated events and conditions. Fig. 1(b) shows the snapshot of composing the events and conditions for the taking medication reminding service.



(a) (b)

Fig. 1. (a) Software tool for creating and selecting reminding services (b) Software tool for editing events and conditions for Taking Medication Reminding Service

3 The HYCARE Architecture

In this section, we introduce the hybrid context-aware reminding service framework for elders with mild dementia (HYCARE) that supports the processing of those reminding services (as shown in Fig. 2). The core of the HYCARE platform is the reminder processing engine which comprises three components: the reminder planer, the reminder scheduler and the reminder adapter. As the reminding services are context-aware, the acquisition and processing of the relevant context information should be properly managed. The Semantic Space context infrastructure [14] has been adopted to manage the dynamic query and subscription of all the context information related to reminding services.

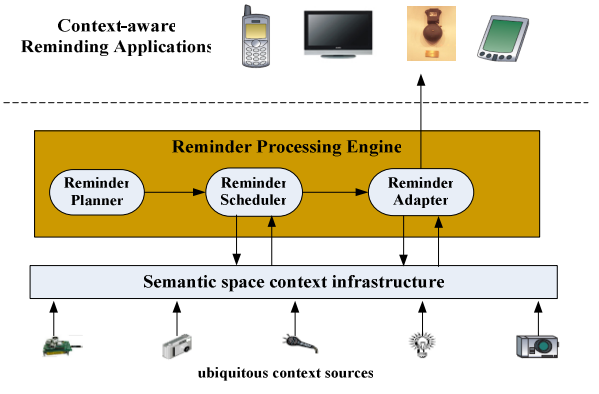


Fig. 2. Context-aware Reminding Service Platform Architecture

The Reminder Planer

Reminding services for elders with mild dementia are different from day to day due to the dynamic nature of people's activities, it is usually the caregiver who plans the

reminding services each day, by using the software tool as described in section 2.5. In order to make the planning clear and logic, the reminding services are advised to put into two groups: time-based reminder and event-based reminder. Through sorting the time-based reminding services by *AnchorTime* (the beginning time of a reminding service), the reminder inconsistency can be avoided in the planning stage. The reminder planner is responsible for transforming the caregiver inputs into ECA rules, and mapping the events and conditions in those ECA rules to the appropriate context query and subscriptions for Semantic Space context infrastructure.

The Reminder Scheduler

The role of the reminder scheduler is to schedule all the reminding services planned every day, handle the conflicts during the reminding process, and record if the reminding service finishes properly. In terms of reminding service execution sequence, there are three possibilities:

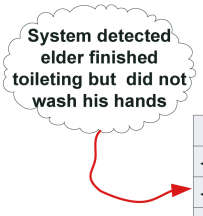
1. For all the time-based synchronous and event-based asynchronous reminding services, there is no conflict between any two reminders. This is the case when there is no event-based asynchronous reminding service requested, the scheduler just works out a logical sequence for time-based reminding services.
2. When a specific reminding service is triggered and executed, it is interrupted by a more urgent reminding service. For example, when the elder is preparing meal, the turning off gas reminder is triggered.
3. When a specific reminding service is triggered and executed, it is interrupted by an external event which the user chooses to respond. One example is that the elder is interrupted by an asynchronous event, such as a phone call, which causes the reminding service paused. Another example is that the elder totally ignores the reminding service and continues to perform certain activities that are not anticipated by the reminding service at all.

In order to handle the above three cases, a priority-based scheduling mechanism with consideration of reminder timing parameters is proposed as follows:

1. Event urgent reminding services have the highest priority. They should not be delayed nor interrupted by any reminding service with lower priority.
2. Time fixed reminding services have the second priority. They can only be delayed or interrupted by an event urgent reminding service.
3. Time relevant and event relevant reminding services are both in the lowest priority level. For these two kinds of reminding services with the same priority, we use a First Expired First Served (FEFS) algorithm to schedule them.

The basic idea of FEFS is to merge time relevant and event relevant reminding services into one waiting queue. The order in the waiting queue is determined by the *ExpireTime* (the time a service is supposed to expire) of each service. Here we present a simple example to illustrate the idea. In the scenario shown in Fig. 3., there are three time-based reminding services: brush teeth, prepare breakfast and take medication. When it is at 7:30am, the system detects that the elder is in toilet, so the prompting of preparing breakfast is delayed according to its DelayWin (the acceptable delay time window). After the elder finishes toileting at 7:35am, the system finds the elder didn't

wash his hands, then the washing hands reminding service is activated and inserted into the FEFS queue. As the *ExpireTime* of the washing hands reminding service is earlier than that of the preparing breakfast service, the washing hands reminding is activated first.



Reminding Service	AnchorTime	DelayWin	ExpireTime	Duration
<1> brush teeth	7:00am	15mins.	7:15am	10mins
<2> wash hands	7:35am	5mins.	7:40am	3mins
<3> prepare breakfast	7:30am	30mins.	8:00am	45mins
<4> take medication	9:00am	60mins.	10:00am	5mins
... ...				

Fig. 3. A snapshot of FEFS queue

When the more urgent reminding service or external event is complete, whether the system should resume to previous reminding service depends on if the current time exceeds the sum of *ExpireTime* and *Duration* (how long the reminding activity lasts). If it exceeds, the previous reminding service is aborted and recorded as incomplete. In the scheduling process, it is assumed that whether the reminded activity is performed by the subject is known.

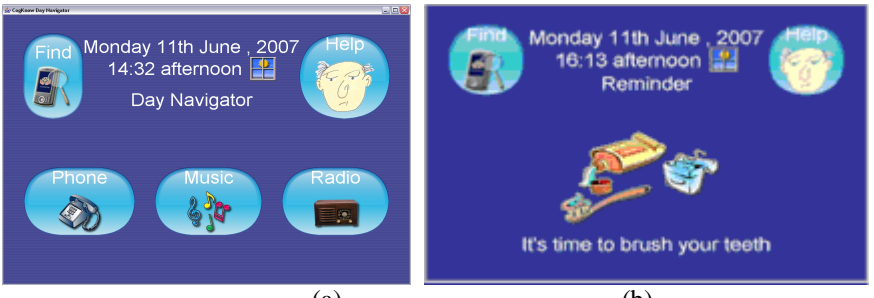
The Reminder Adapter

The reminder adaptor determines how to present the reminding message according to the user, device and environment context. Location is a very important context because it is more effective to prompt the elders using the devices nearby, otherwise they may fail to notice the reminding signal. Device constraint is another useful context, while an SMS text message is sent to the elder if he/she stays out of home with mobile phone, a video reminder may be preferable shown in the TV if he happens to watch the TV program at home. Environment context can be also crucial in choosing the right modality to alert the subject, for example, in noisy street vibration is more effective than voice for informing the elders of the reminding message. Due to the length limit of the paper, the detailed design of this module will not be discussed in this paper.

4 System Implementation and Trial

Till now the CogKnow project has already started for almost a year and a half. While the field trial #1 with time and location-based reminders was completed in all three pilot sites, the field trial #2 for context-aware reminding services is planed in April and May 2008. Fig. 4 (a) shows the screen shot for the main menu tested in trial #1, it contains functions such as picture dialing, listening to radio or music, locating the mobile device and making an emergency call. The elders can access those services

either on stationary displays mounted on the wall or on the CogKnow mobile device. Reminders are displayed either on stationary display or the CogKnow mobile, depending on the situation. Fig. 4(b) presents the reminder service for brushing teeth.



(a) (b)

Fig. 4. (a)Screen shot for main menu (b)Screen shot for brushing teeth prompting

5 Conclusion

In this paper, we have presented a hybrid context-aware reminding framework for elders with mild dementia called HYCARE, which can handle both synchronous time-based and asynchronous event-based reminding services. In particular, we develop a novel scheduling mechanism that can coordinate various reminding services and remedy the possible conflicts. In order to facilitate the interaction between the caregivers and system, we propose a reminding service description model and provide a simple software tool for caregivers to create and edit the reminding services with respect to the events and conditions.

In next few months, we plan to implement the proposed HYCARE framework with dozens of reminding services and test our prototype in the pilot sites. We believe that the real-world deployment and test are crucial to developing practical and robust solutions for elders with mild dementia. We hope that our novel context-aware reminding framework design and the future trial results will be of particular interest to pervasive healthcare community.

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