Coping with Prospective Memory Failures: A Study of FCM Based Reminder System

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Abstract

Forgetting is common in daily life, especially for older adults. Most of the forgetting is due to prospective memory (ProM) failures. People tend to use various techniques to improve their prospective memory performance. Setting up a reminder is one of the most important techniques. However, people are not satisfied with existing reminders because of their limitations in different aspects including reliability, optimization, and adaption. Based on the prospective memory processes, we propose a reminding model based on Fuzzy Cognitive Maps (FCM) to computationally incorporate various factors that influence prospective memory. An application, ProM Agent, was developed and incorporated with the reminding model. A user study was conducted to evaluate the effectiveness of ProM Agent. The results support that ProM Agent remind more effectively than commonly used time-based reminding system.

Keyword: Prospective Memory, Fuzzy Cognitive Maps, Reminder System.

I. Introduction

Forgetting is common in daily life, and 50-80% every day's forgetting is due to prospective memory (ProM) failures, which have significant impacts on our life [1, 2]. More seriously, some of these memory lapses can bring fatal consequences such as forgetting a sleeping infant in the back seat of a car. ProM problems are common with older people [3]. Old adults tend to use ProM reminders to cope with their ProM decline [4, 5]. Without reminders, the challenge for performing a ProM task is that the intention needs to be initiated while people are simultaneously engaging in the ongoing tasks [6]. Reminders provide a solution to initiate the prospective task at an intended time, and they range from paper notes to advanced technological time-based reminders. Originally, most of technology-based reminders (e.g., MEMOS, Memojog) were designed for users with cognitive impairment to promote their independence and assist them in health and wellbeing of individual [7, 8]. Currently, time-based reminders are popularly used by individuals, such as Google calendar.

In some cases, people are not satisfied with their reminder system because of its failure in reminding, issuing burdensome reminders (annoyance), or disagreeable signal (e.g., some persons prefer sound reminder to visual reminder). This study is motivated to investigate the improvements to the generic reminder system that will be more reliable, optimal and adaptive. Therefore, the tradeoff between the reliability and the annoyance as how many reminders should be issued to users for a specific ProM task is one of the main objectives.

To address above challenge, we propose a reminding model which draws its theoretical basis from existing ProM research and employs Fuzzy cognitive Map (FCM) to incorporate the theoretical basis computationally [9]. This structural model is developed by reasoning various factors which potentially influence the ProM performance. The reminding model can determine an appropriate number of reminders for a ProM task based on the predicted performance of the task. Guided by a reminder schedule function, the ProM Agent is proposed. Mathematical functions are embedded into the ProM Agent to calculate the optimal number of reminders and the reminding schedule.

To evaluate the effectiveness of our proposed ProM Agent, a study with 24 senior participants was conducted. The participants were divided into two groups to complete the same ProM tasks. ProM Agent and a time-based reminder were used in the two groups, respectively. The results show that the performance of participants in ProM Agent group is significantly better than the participants in time-based reminder group.

This paper is organized as follow: Short review of ProM and current ProM aid is presented in Section II. Our proposed reminding model and ProM Agent are introduced in Section III. In Section IV, we described the study to evaluate our proposed ProM Agent. In the end, we summarized this paper in Section V.

II. Related Works

As mentioned before, ProM is vital for our health and social life. ProM failures produce great challenges to people and directly influence their life quality. According to Kliegel and Martin (2003), a significant number of 50-80% memory failures related to ProM problems [1]. To avoid the consequences of ProM failures, people are likely to use memory assists to help their memory, especially for old people [10]. Most studies demonstrated that both young and old people benefit from using memory assists (e.g., [11, 12]). Memory assists help users to store information or remind the user an event they might forget [13]. In this research, we investigate the reminder function of memory assists relative to ProM, rather than the storing function relative to retrospective memory. According to Harris (1978), reminders are generally categorized as active or passive reminders [14]. Examples of diaries, lists, and calendars are passive reminders which require the user to actively check them, whereas google calendar and mobile phone are examples of active reminders which attract users' attention and instruct them when and how to perform an intention. ProM reminders vary from the traditional way of pen and paper to technology-based way of electronic devices. The purpose of designing a ProM reminder also varies from specific to generic use. The current study targets on a technology-based reminder of generic use, since our ultimate aim is to produce a reminder system with more flexible and adaptable features.

Earliest technology-based ProM aids were mainly targeting brain injured or cognitively impaired people, e.g. MEMOS [15] and Memojog [16]. There are also general purpose ProM aid systems, such as Google Calendar and AutoMinder. McDonald et al. evaluated the effectiveness of Google Calendar. When compared with standard diary use, the participants found Google Calendar was much more effective. However, they also mentioned that sometimes they failed to perform ProM tasks even if they noticed reminders from Google Calendar [17]. AutoMinder is a ProM aid system that targets to help older adults in their home environment [18]. By monitoring users' execution of ProM tasks through feeds from sensors at home, AutoMinder decides whether and when to issue reminders. According to Caprani et al., observable information from sensors were not always reliable, which may result in assumption failures [19]. Similar to Google Calendar, most existing ProM aid systems are time-based and only support manual creation of reminders. Users of these systems manually decide the number, schedule and reminding methods of the reminders. AutoMinder attempted to determine the number and schedule of reminders automatically based on sensory information. However, assumptions based on sensory data decrease the reliability of its reminders [19].

III. FCM Based Reminding Model

To cope with the challenges related to ProM, we feel that it is necessary to refer to relevant theories and studies in ProM. From a vast amount of ProM literature, we identified six performance influencing factors and four contextual elements which can help determining the appropriate number of reminders and the reminding method [9]. The six influencing factors are: *Delay of ProM task*, *Complexity of ongoing tasks*, *Relatedness of tasks*, *Importance of ProM tasks*, *Motivation* and *Age*. The six factors are not completely independent from each other. For example, study showed that the perceived task *importance* was higher when there was a social *motivation* [20]. *Age* is associated with *Complexity of ongoing tasks* [21], *Relatedness of tasks* [22], and *Motivation* [23]. Four contextual elements are identified to characterize the task-related and environmental context to help determining how salient a reminding method needs to be in that particular context, which are *Complexity of ongoing task*, *Importance of ProM tasks*, *Tolerance for disturbance*, and *Noise level*.

Fuzzy Cognitive Map (FCM), first developed by Kosko [24], is well suited for modeling dynamic systems [25]. FCM is widely used to represent the cause-effect relationships among concepts in real-world systems [26-28]. More specifically, FCMs have been used for brain tumor grading [29] and differential diagnosis of language impairment [30]. The proposed reminding model employ FCM to determine an appropriate number of reminders (τ) for a ProM task based on the predicted task performance. To arrange an effective reminder schedule (*r_schedule*), the model follows a reminder schedule function to determine the issuing time of each reminder. The reminding model selects an appropriate reminding method (*r_method*) for each reminder based on the salience level required. The mathematical algorithm of proposed FCM methodology can be found in [9].

To evaluate the proposed reminding model through human subject experiments, this study developed a simple application using JAVA, the ProM Agent, which incorporates the model. The architecture of ProM Agent is illustrated in Figure 1. It has three components: the Reminder Planner, the ProM Process and the Personalized User Model. The Reminder Planner realizes the reminding model proposed. For every ProM task created, it produces a reminding plan which consists of an appropriate number of carefully arranged reminders, each with a selected reminding method. The ProM Process is designed in the light of the process model [31]. It includes encoding of a ProM task, maintaining the task, issuing reminders based on the schedule produced by the Reminder Planner. The Personalized User Model customizes the reminding plan according to user profile and user's interactions with the application.

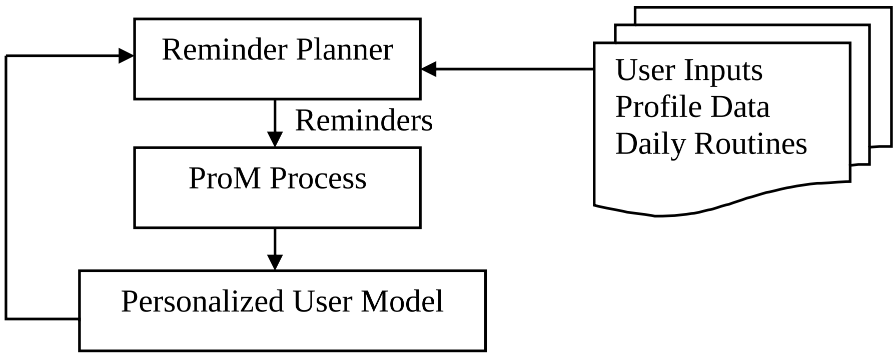

Figure 1 The Architecture of ProM Agent

IV. Case Study

To investigate the effect of our proposed ProM Agent, we conducted a case study with two purposes: 1) evaluating elderly's performance of ProM task by using the proposed reminder system; 2) evaluating elderly's performance of ProM task in groups. 24 participants aged between 60 to 80 (M = 71.7,SD = 7.88) were invited to attend the experiment. IRB approval was obtained ahead of the experiment.

4.1 Method

All participants first completed the consent forms before the experiment. We used an adaptation computerized game called *Pumpkin Garden* to conduct the experiment. There are two tasks in this game. The first task *Weeding* requires participants to move both index fingers simultaneously to remove the grasses appeared on the screen, which has been used as ongoing task. The second task *Watering* requires participants to move in circles with their fingers on the screen to water the pumpkins, which has been used as the prospective task. The interfaces of the game and the tasks are shown in Figure 2. Participants are required to familiarize the game before the actual experiment.

Figure 2 Interfaces of the Game and Tasks

During the experiment, participants played *Weeding* task 3 rounds (a numerical timer displayed on the screen), and they need to remember to water the pumpkins when they play *Weeding* for 100 seconds (time-based ProM task). 12 participants in control group were given one reminder by using a simple time-based reminder (e.g. Google reminder) before they started the game. Another 12 participants in experimental group had ProM Agent reminders during the time they were playing *Weeding* game. As the proposed reminder system, when the time approaches to the ProM task, reminders were given to participants more frequently.

ProM Task (Individual)		
	Experimental Group	Control Group
No.	12	12
ProM Task (Group Reminding)		
	Experimental Group	Control Group
No.	6 (2 groups)	6

Table 1 Participants in Case Study

To evaluate the effect of group reminding on the ProM task, 6 participants from the experimental group have been set into 2 groups, and each group included 3 participants. The summarized participants numbers in each task are shown in Table 1. The difference between individuals and groups is time of reminder. Individual participants has 3 reminders and groups only have 1 reminder. The participants accomplished survey questionnaires through individual interviews after they finished playing games.

4.2 Results

Table 2 and Table 3 show the participants' performance in ProM task with the proposed reminder system and time-based reminder. In Table 2 we can find that 10 out of 12 participants performed the ProM task successfully with the proposed reminder system, and 7 out of 12 participants failed in performing the ProM task with a simple reminder. We conducted a Chi-squares test. The result for the data is (χ^2 (1) = 4.44, p = 0.035), which significantly shows that the participants' performance in the ProM task with the proposed reminder system is better than the simple reminder. The result shows the effectiveness of our proposed reminder system on improving elderly's performance in ProM task.

	Remember the ProM task	Forget the ProM task	Total
Experimental Group	10	2	12
Control Group	5	7	12

Table 2 Numbers of participants remembering the ProM task in two reminder system

	ProM Agent	Time-based reminder
Performance of ProM task	p = 83%	p = 41%

Table 3 Summary performances in ProM task

In the experimental group, 6 participants were evenly divided into two groups. The participants who worked in groups got reminders not only from the simulated system, but also from their group members. In the control group, 6 participants worked individually. They only got reminders from the simulated reminding system. Table 4 and Table 5 show the results of group reminding experiment. From the tables, it could see that all participants performed the ProM task successfully in groups even with less reminders, and 2 out of 6 participants failed the ProM task in the individual group (Table 4), which shows that the performance of ProM in group is much better than individual (Table 5).

	Remember the ProM task	Forget the ProM task	Total
Group	6	0	6
Individual	4	2	6

Table 4 Numbers of participants remembering the ProM task in group and by individual

	Group	Individual
Reminder time	1	3
Performance of ProM task	p = 100%	p = 67%

Table 5 Summary performance in ProM task with ProM Agent

In the proposed ProM Agent for group tasks, it has built a computational model for determining the number of reminders for each individual. This study identifies it is necessary for a reminder system to consider the interactions between group members and the number of reminders could be decreased when interactions among group members increase.

4.3 Qualitative Study and Results

After participants finished the ProM task, a couple questions were asked through interviews: 1) Would you want reminders in your life? 2) Do you feel annoy if there are many reminders to remind you to do something (ProM task)?

Only one participant said reminders are not necessary for him since he could remember to do the planned tasks very well. All other participants want reminders. Some of them complained a lot of forgetting in their daily life, especially taking medicine at a regular time. They said if there are reminders in their life, it would be very helpful to cope with forgetting. This study also confirmed that reminders are important for elderly in their daily life.

There are interesting findings in this study. Referring to the number of reminders, participants appreciated multiple reminders. The reminding model can determine an appropriate number of reminders for a ProM task based on the predicted performance of the task. If the predicted performance is poor, more reminders will be generated for the ProM task. If the predicted performance is good, fewer reminders will be generated to minimize disturbance. In this case study, the participants had high motivation of completing the ProM task, not only they were interested the game, also they could get a voucher after they finish the ProM task. However, 22 out of 24 participants wanted a large number of reminders even though their motivation to perform the ProM task was high. This interesting finding helps us to address the future work. First of all, it seems like that when mapping the performance of ProM task to the number of reminders, for specific users especially elderly, it is not a simple reciprocal proportion. Some factors such as importance and motivation of the ProM task directly and positively influence the number of reminders. Secondly, although this optimal model can generate the number of reminders, it might not be accurate since we couldn't take all factors and aspects which influence the performance of ProM task in real life. Furthermore, people live in a dynamical environment. It is more reasonable to use some adaptive strategies so that the reminding plan can change over time based on users' feedbacks and preferences.

V. Summary

Based on the theoretic background of ProM, we propose the factors that will affect the ProM task performance and an FCM-based computational approach for determining the appropriate number of reminders and reminding method. The ProM Agent was developed based on this reminding model. To evaluate the effectiveness of ProM Agent, a user study was conducted. The results show that participants felt ProM Agent is appropriate and this approach provides a better overall experience and reminds more effectively than its control version. In addition, we found reminders from group improve participants' performance of ProM task. In the future, we will consider improving customization of the proposed reminding model. The model will be able to cater to individual differences, since individual ProM task performance may respond to the six performance influencing factors differently.

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