Mobile Reminder for Flexible and Safe Medication Schedule for Home Users

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Abstract. iMAT is a system of automatic medication dispenser and software tools. It is for people who take medications on long term basis at home to stay well and independent. The system helps its users to improve rigor in compliance by preventing misunderstanding of medication directions and making medication schedules more tolerant to tardiness and negligence. Medication schedule manager in iMAT can be deployed either on standalone automatic, intelligent medication dispensers, or on computers and smart phones accompanied with traditional pillboxes. In this paper, we present the design and implementation of PROMUS and the results of a user experience study. PROMUS is a medication scheduler manager and reminder for modern smart phone devices. Similar to the scheduler for the iMAT dispenser, PROMUS scheduler takes into account both user preferences and medication directions in generation of flexible medication schedules and compliance enforcement. In particular, we focus on the interactions between the user and medication schedule manager to avoid medication errors. PROMUS schedules medication events to be more flexible and friendly by grouping the medication doses to reduce the number of times medications are to be taken and allow the user longer response time. PROMUS also provides intuitive, visually appealing user interface, clear organization, and familiar terminology that can be acted upon in conformity with the original behavior of medication record keeping.

Keywords: Medication Scheduler, Smart Devices, and Medication Compliance.

1 Introduction

This paper describes a system of smart medication dispensers, medication schedule managers, and its implementation on smart phones. The system, called iMAT (intelligent medication administration tools), targets as users the growing population of elderly individuals and people with chronic conditions who are well enough to maintain active, independent lifestyles. Such a person may take many prescriptions and over the counter (OTC) medications and health supplements at home and work without close professional supervision. In subsequent discussions, by a user, we mean such a person.

J.A. Jacko (Ed.): Human-Computer Interaction, Part III, HCII 2011, LNCS 6763, pp. 107–116, 2011.

Nowadays, modern drugs can help people conquer previously fatal diseases, control debilitating conditions, and maintain wellness and independence well into old age, provided that the drugs are taken as directed. Unfortunately, even critically important drugs such as those for treatments of hypertension, diabetes, and heart conditions are often not taken as directed [1]. The fact is that statistics on health care quality continue to show alarmingly rates and serious consequences of preventable medication errors [2–5]. Administration errors due to non-compliance to medication directions are known to contribute 25-40% of all preventable medication errors and are the cause of approximately 10% of hospital admissions and 23% of nursing home admissions. The primary goal of iMAT is to prevent administration errors as much as possible and when errors occur despite prevention efforts, reduce the adverse effects caused by them. iMAT can also help to make sure that interactions among all medications of each user and their interactions with food and drink have been properly accounted for by the directions for the user.

A look at causes of non-compliance points out that information technology can help eliminate many common ones, including misunderstanding of medication directions, inability to adhere to complex medication regimens, and inconvenience of rigid schedules. iMAT is designed specifically to eliminate these causes. A user of iMAT medication dispenser and schedule manager has no need to understand the directions of her/his medications. iMAT enables the pharmacist of each user to extract a machine readable medication schedule specification (MSS) from the users prescriptions and OTC directions. Once loaded into an iMAT dispenser or schedule manager, the tool automatically generates a medication schedule that meets all the constraints specified by the users MSS. Based on the schedule, the tool reminds the user at the times when some doses should be taken and provides instructions on how the doses should be taken (e.g., with 8 oz of water, no food within 30 minutes, etc.) In this way, iMAT helps to make complex regimens easy to follow.

PROMUS is a variant of iMAT: It is designed as a medication scheduler manager and reminder for modern smart phone devices. Similar to the scheduler for iMAT medication dispenser [6], PROMUS scheduler takes into account both user preferences and medication directions in the generation of flexible medication schedules and enforcement of compliance. In particular, we focus on the interactions between the user and medication schedule manager to avoid non-compliance errors. PROMUS schedules medication events to be more flexible and user friendly by grouping the medication doses to reduce the number of times medications are to be taken and to allow the user longer response times to reminders. PROMUS also provides an intuitive, visually appealing user interface, clear organization scheme, familiar terminology that can be acted upon in conformity with user's original behavior of medication record keeping. To evaluate the effectiveness of PROMUS, we conducted a field trial on users with different backgrounds: different jobs, ages, genders and lifestyles. We logged all the user activities on the smart phone to understand how the users used the devices.

The remainder of the paper is organized as follows. In Section 2, we present an overview of iMAT and related works. Section 3 presents the design and implementation of PROMUS. Section 4 presents our evaluation results. Section 5 concludes the paper.

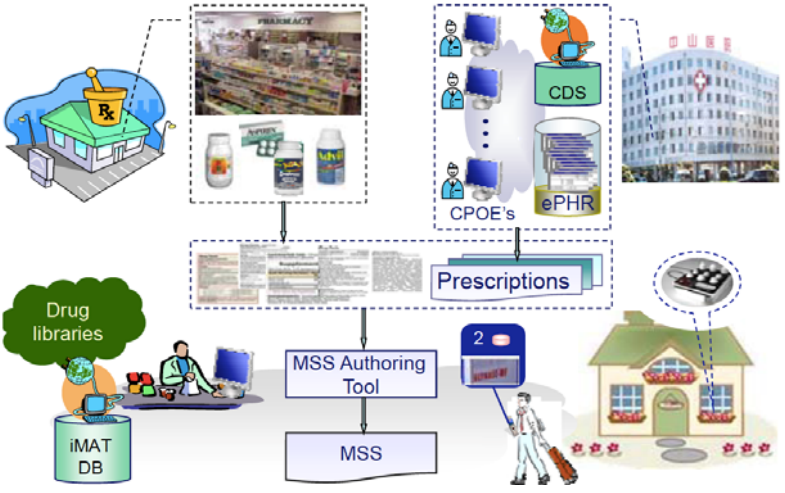

Fig. 1. iMAT in medication use tool chain

2 Overview of iMAT and Related Works

iMAT, as a distributed service, is designed specifically to eliminate the causes for medication non-compliance. A user of iMAT medication dispenser and schedule manager has no need to understand the directions of her/his medications so as to correctly take medications. Figure 1 shows how iMAT fits in a chain of information systems and tools for medication use process: It complements computerized physician order entry (CPOE) systems [7-12] at the top level by supporting the dispensing and administration stages of the process. By far, computerized physician order entry (CPOE) systems are the most well developed tools in the tool chain. Today, CPOE systems are used in a majority of hospitals and clinics in developed countries. Recent data on their effectiveness show that CPOE systems, together with clinical decision support (CDS) and electronic patient health and medication records (ePHR and eMAR) systems [13, 14], can help prevent up to 80% of prescription errors, i.e., 40% of all medication errors.

The MSS authoring tool and iMAT database, shown at the lower left half of Figure 1, are for pharmacists. An essential function of the authoring tool is to merge the directions of all medications of each user and generate from the merged direction a machine readable medication schedule specification (MSS) for the user. As stated earlier, the MSS is needed to guide the operations of user's medication dispenser and schedule manager. We describe the operations of a version of the tool in [15].

A user may have an iMAT medication dispenser for use at home, as shown in the bottom right corner of Figure 1. The medication scheduler that runs on the dispenser can serve as a schedule manager. It delivers reminders to a cell phone and other mobile devices, also shown in the figure. A user may choose to have only a schedule manager and have the tool run on a PC, laptop or a smart phone that can hold the MSS and has network access. These devices have the same purpose as numerous

pillboxes and programmable medicine dispensers (e.g., [16-18]) for home use and mobile medication administration tools (e.g., [19, 20]) for use in hospitals and long-term care facilities. Existing pillboxes and dispensers require the user to load the individual doses of medications into the device, understand their directions and program the device to send reminders accordingly. This error-prone manual process and rigid medication schedules are serious disadvantages for users targeted by iMAT.

Intelligent medication advisory tools and services such as MEDICATE Tele-assistance System, Magic Medicine Cabinet, and other medication advice services [21-24] can check directions for drug interactions for users at home. Like schedules used by our dispenser and schedule manager, medication schedules used by these automatic devices and scheduling tools can also be adjusted to compensate for user tardiness and condition changes. The advices and adjustments are provided by care takers who monitor and supervise the user via Internet, however. Those devices are better suited for users who need close professional supervision and fully integrated health care services. In contrast, our medication dispenser and schedule manager are capable of making schedule adjustments permitted by existing prescriptions without requiring their users to incur the costs in fees and privacy loss of close monitoring and care.

3 Design and Implementation for Mobile Phone Reminder Applications

An advantage of the iMAT dispenser is that it can help, as much as an IT device can, to make sure that user retrieves the right dose of each medication from the right container when the user responds to reminder and comes to retrieve the medication. When the user is away from home, a portable medication reminder is required to reminder to take medications. Figure 2 shows two configurations of the portable schedule manager. The dotted box below the devices encircles the software components. Here, the user interface manager plays the role of the dispenser controller. It manages the interface to facilitate the interactions with the user according to the user's preference. Like a dispenser, the manager also maintains locally the user's current medication schedule specification and medication record.

PROMUS is a variant of iMAT: It is designed as a portable medication schedule manager that is deployed on smart phones. The current version is implemented in Java and is compatible with Android 2.1 or greater.

As discussed in previous reports, most, if not all, of the medication schedules highly depend on patient's daily schedule, such as the time to start a day and to take meals. When not necessary, PROMUS does not ask the users to change his/her daily schedule for medication compliance: It allows the users to provide their daily schedules so that the PROMUS scheduler can adjust each user's medication schedule to fit his/her daily schedule. Figure 3 shows the screenshot for configuring user preferences on PROMUS. The users provide their schedules for wake-up, breakfast, lunch, dinner, and go-to-bed. These parameters will be used as input parameters for medication scheduler. The users can also choose the preferred mode(s) such as vibration, rings, or music for reminders.

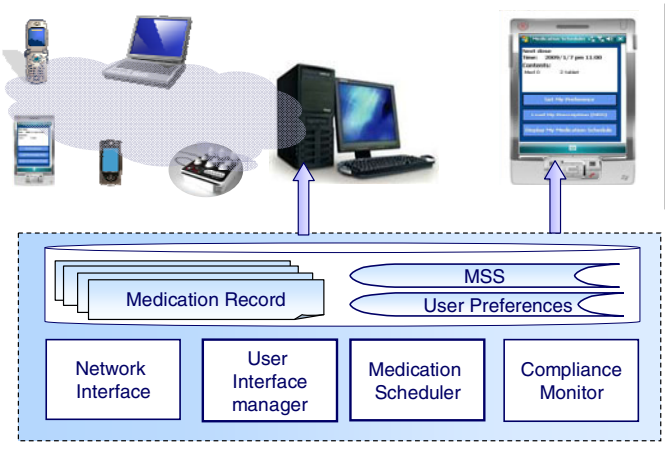

Fig. 2. Alternative Configuration of iMAT Medication Scheduler

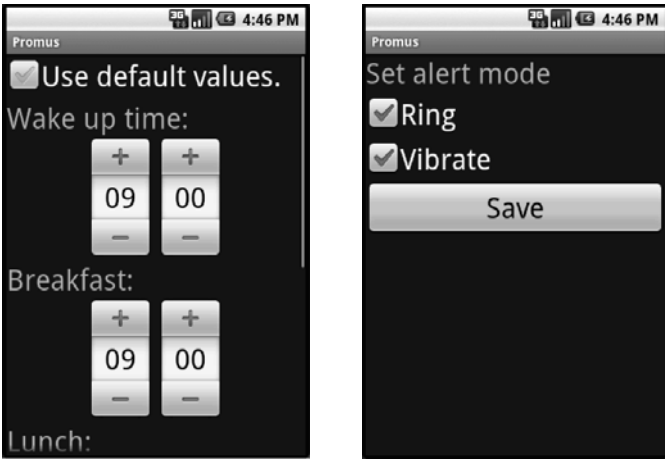

Fig. 3. User Preference Configuration

PROMUS periodically checks if there is any medication due to be taken. The period is now set to one hour and can be adjusted in the configuration file. One hour is most practical for the users not staying in health care institutes. When some medication is scheduled, PROMUS sends reminder(s) to the user. (PROMUS now provides three types of notifications: *pop-up notification window*, *vibration* and *rings*.) The user can select the preferred notification mode in preference configuration. In pop-up windows, there are three options to choose: "Take medications now", "Remind me later", and "Skip this dose". If the user chooses "Take medications now", PROMUS displays the directions including medication names, dosages, colored photos of the medications and special instructions for the medications. The information for the scheduled medications is displayed for one medication at a time by to avoid confusion. Figure 4 shows the screenshot for the medication information and medication

prescriptions. The medication directions stored in PROMUS, including names of medications (Chinese name, English name and scientific name), granularity of medications, total amounts of medications, usage, dosage, warning, therapy and side effects are from the Health Insurance Bureau of Taiwan government. One can use different databases to provide such information. For each scheduled medication, the user can choose to take or to skip it. PROMUS records the user's choices in the user's medication record. If the user decides to take medication later, PROMUS suspends notifications for a user-defined postpone interval. The default postpone interval is 5 minutes and can be changed in preference configuration. If the user decides to skip the dose, PROMUS stops sending notifications and waits until next schedule point.

The scheduled time for a medication is only a candidate time instance to take the medication. Often, there are numerous feasible schedules conforming to the medication schedule specification, [25]. PROMUS takes advantage of this fact to provide the user with the option to check whether he/she can take medications before scheduled times. In this mode, the user can take medications within a tolerable interval before the scheduled time. On PROMUS, the user can choose "Available medications now". PROMUS checks and displays the medications that can be taken at that time. (Again, the user can choose to take it or to skip it by pressing the button on the screen, and PROMUS would record all the user's actions automatically.)

We use four frequency tables to represent the feasible medication schedule times. They are the number of days for a prescription period, number of days to take medications per period, number of dose times in a day and intervals between each doses. Take as an example, the direction "Take every next day, three times a day, after meals". This direction indicates that the period for the prescription is two days, the elapsed interval for each prescription is one day, the number of dose in a day is three, and the intervals between two consecutive doses are four to six hours. Hence, when the user takes meals at 8AM, 12PM and 5PM, the doses will be scheduled at 9AM, 1PM and 6PM, respectively.

Fig. 4. Prescription and Medication Information Review

The PROMUS scheduling algorithm uses a data structure to represent the schedule and status for each medication: The structure contains "Schedule", "Allowable time slots", "Record", and "Status". "Schedule" is generated based on the dosages specified by the medication directions, frequency table and user preference. Usually, feasible time to take medications is not a single point of time. Instead, it is a time interval, which is represented by a number of time slots. In addition, most medication directions include instructions such as "If you miss the dose, please take it as soon as possible. If the time is close to next dose, please skip this one and go back to your regular schedule. Do not take it twice." Such instructions give PROMUS the flexibility in computing the time interval for user to take medications and the time intervals for not taking medications.

For the example described above, the allowable time slots for user to take medications would be 9:00 am to 12:00pm, 1:00pm to 4:00pm and 6:00pm to 2:00am. Figure 5 shows the data in PROMUS on this schedule.

Time (hour)	0	1							9				13				18						
Schedule	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Allowable time slots	1	1	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	1	1	1	1	1	1
Initial state																								
Record	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Status	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
After user takes medication																								
Record	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Status	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1

Fig. 5. An example of schedule tables

"Record" is used to record the time that the user takes the medication. "Status" is used to avoid overdoses and is set to false after user takes medications. Every time when the user responds that he/she takes the medication, PROMUS records the action and updates the status from available to unavailable of the medication by changing the element values of "Status" array to zero. The time granularity of the time tables are set to one hour, which is consistent with the period for the timer to check the prescriptions.

4 Field Trials and Evaluation Results

To evaluate the effectiveness of PROMUS and to build incrementally a record of use patterns, we select ten users with different education background, job types, and ages. Their ages range from 25 to 60 years and their occupations include students, engineers, housewives, retirees, and businessmen. The medications they took include those for diabetes, hypertension, heart disease, asthma, and other chronic diseases. In the experiment, both the prescriptions issued by physicians and extracted from OTC directions are stored in PROMUS. Each subject uses PROMUS for five to seven days.

Before the subject starts to use PROMUS, we logged their medication compliance using questionnaires on paper. According to the records, on average, they take 5 to 8 kinds of medications and take medications 3 to 5 times a day. The records also show that their average missing dose rate is approximately 1/3 for prescription medications and the average delay time in take medications is approximately 1 to 3 hours. Due to the space limit, we describe below three cases in the experiment.

Case 1: The subject is a 30-year-old male who is an office staff in a science and technology company and uses smart phones daily. He is a diabetic and takes 11 types of medications. He takes medications at least four times a day. Although his daily schedule is very regular, he often forgets to take medications in the morning. Sometimes, when he remembered to take medications later, he took the medications without paying attention to see whether the time is close to the next dose time. Consequently, he either missed the dose or took overdose in those occasions. To maintain the stability of blood sugar for a diabetic is very important. Overdose may lead to low blood sugar levels and cause the patient faint. According to the user's response, PROMUS reduces the chances of missing medications in the morning and helps him not to overdose. He found that the user interface is clean and the operation is simple without error-prone human input.

Case 2: The subject is a 24-year-old female and is a graduate student with Computer Science major. She is an asthma patient and never uses smart phones before. She has two medications to take and must take them every 12 hours for controlling her asthma. She also takes vitamins in an irregular schedule. However, her daily schedule is not as regular as the others. She sometimes stays up all night and sleeps for more than 12 hours in the next day. As a result, she misses medications from time to time. According to her logged activities, she missed some doses and later took medications when she did not feeling well or until she got the asthma attack. Asthma attack is very dangerous and acute asthma may cause death. Having a regular medication schedule is important for them to control the asthma and decrease the attack probability. PROMUS identified the medication for controlling asthma is critical and forced her to wake up take the medication even when she was sleeping. According to her feedback, PROMUS repeatedly sent reminder until the medications are take and helped her to take medication at right time. The chances for missing medication were significantly lowered.

Case 3: The subject is a 60-year-old businessman and has both hypertension and diabetes. He has eight types of medications for his diseases and usually takes medications three times a day. He never uses smart phones and is not interested in learning how to use new IT devices. Due to his tight schedule and frequent business meetings, even when he remembers to take medications, he still misses doses because it is inconvenient for him to take medications in front of his colleagues and visitors. Later he would either skip medications or take all the medications including missed medications and medications scheduled on the next dose time. His feedbacks show that the best part of PROMUS is that he does not need to spend much time to learn how to use it. After having PROMUS, he relies it to follow the medication directions. PROMUS reminds him and shows the medications he can take later without asking him to reschedule the dose time. In this way, PROMUS decreases the miss dose rate and helps him to take medications correctly. The operation flow requires the least user input, and the screen shows the concise and necessary information, which save his time to understand and then responds.

The experimental results show that PROMUS does improve medication compliance for those users who are busy and may forget to take medications, and users who are not sure when should take medications or what should be taken. However, for those users who do not want to take medications because of other mental and physical factors. For example, one may hate to swallow medications; the other one do not think he/she needs to take medications. These users may deliberately ignore the notifications for taking medications sent by smart phone or intentionally fraud by responding that they have taken medications. PROMUS cannot force them to take medications and is unaware of fraud. Modern smart phones often run out of battery, and the devices cannot perform any function when they are in the off state. In this situation, PROMUS cannot work and needs the user to provide his/her medication record when it can be turn on and working again. There is a higher risk that user may miss doses when PROMUS does not work since they already have the habit to rely on PROMUS to remind them to take medications. In addition, some medications are prescribed to take when necessary instead of being taken regularly. These medications usually require the user to measure some vital sign to determine whether to take or not the medication. PROMUS cannot provide any assistant on this matter.

5 Conclusions and Future Works

PROMUS is designed as a medication scheduler manager and reminder for modern smart phone devices. As a portable implementation of iMAT, both user preferences and the medication directions specified by prescriptions are taken into account to carry out compliant and flexible medication schedules. In particular, we focus on the interactions between the user and medication schedule manager to avoid medication errors. The experimental results show that PROMUS does help to improve medication compliance for certain types of users but not all. The major factor is whether the users are comfortable for using smart phones as a reminding device. Few of our test subjects prefer to have vocal feedback and reminder, rather than text or graphic base reminders. Last, providing the advice and assistant for taking PRN medication will be added to PROMUS.

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