Chung Shan Medical Journal 2015; 26:15-22

Original Article

Intelligent reminder system for taking of medicine and potential interactions

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Purpose: Many studies have pointed out that chronic diseases are among the top ten causes of death. Chronic diseases require long-term medication and care. We propose an intelligent reminder system for taking of medicine and food-medicine and medicine-medicine interactions developed on the Android platform.
Methods: A smartphone camera captures the image of the patient's medicine bag. Next, the image quality is enhanced with contrast and saturation enhancement method. Finally, the important characters are extracted and recognized. All of the information about the prescribed medicines is stored in the medicine database within the smartphone. The system provides reminders to take medicine and of possible food-medicine and medicine-medicine interactions. Finally, medical ontology is applied to make users aware of the relationships of foods and medicines.
Results: We used survey questionnaire to test the efficiency of the system. The results showed 94% user satisfaction. When people are busy they can forget to take their medicine or may eat foods that interact with the medicine, leading to reduced efficacy of the medicine or potentially dangerous reactions. With this system, efficacy increased from 72% to 92%. From the experimental results, our system is beneficial for people requiring long-term medication.
Conclusion: The proposed scheme was especially developed for the Android platform. It consists of the extraction of medicine bag information, reminder to take medicine and confirmation that the medicine has been taken, as well as information regarding potential interactions. It was evaluated and verified by a large number of users, doctors and nurses.

Key words: Intelligent reminder system, Smartphone, FDA, Medical ontology

Introduction

With rapid advances in medicine and economic development, the human lifespan has increased and the world's population has aged[1]. As the elderly population increases globally, more attention must be paid to elderly care and chronic care. As modern life is fast paced and busy, people tend to eat and drink too much and sleep too little, which are factors for the development of various diseases[2]. Chronic diseases are among the top ten causes of death[3]. Hence, health care for chronic disease

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patients is an important issue.

Previous studies have noted that people who take long-term medication must pay attention to the contents of their prescriptions such as dosage frequency[4-5], pharmaceutical uses and side effects[6]. People may forget this information or to take their medicine on time, which can lead to deterioration of their condition[7-13]. The food and beverages that people consume may cause food-medicine interactions[14]. These interactions can reduce the efficacy of the medicine, making improvement less likely, or result, in the worst case scenario, in adverse reactions or death. Thus, it is important to help patients develop good medicine taking habits and increase their knowledge of the medicines that they are prescribed. Through psychology[15] and decision analysis[16] confirming medicine taking habits is also crucial. The purpose of this study was to propose an intelligent reminder system for the taking of medication and for preventing food-medicine and medicine-medicine interactions. This system is comprised of two major parts: medication reminder and medicine and food interaction queries. We will introduce these parts in detail.

The remainder of this paper is organized as follows: In section 2, the use of image recognition technology with Optical Character Recognition (OCR) is described for obtaining medicine bag information. From the information on the medicine bag, the system reminds the user of dosage frequencies and food-medicine and medicine-medicine interactions. Finally, psychology and decision analysis are applied to allow the system to judge whether users have taken their medicine on time. In section 3, the data received from survey questionnaires is analyzed to understand the specific benefits of our system. Finally, section 4 is the conclusion with analysis and comparison of the results.

Materials and Methods

This system is composed of three main functions: security alert function, medication record function and medication taking confirmation function. Fig.1 shows the structural diagram. The

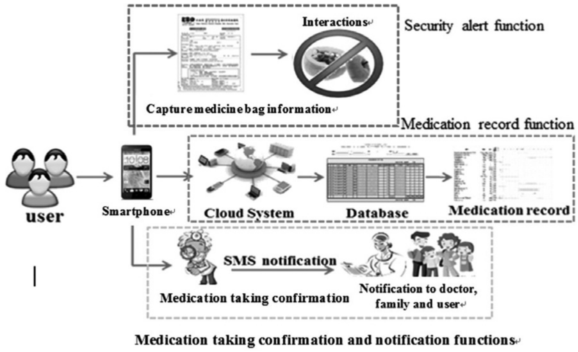

Fig. 1. Structural diagram of our proposed system

process flowchart is shown in Fig. 2.

First, users login to the system using their password and ID. With the camera in their smartphone and our proposed OCR procedure they obtain the information from their medicine bag. The system automatically inputs the information, such as medicine type and dosage frequency.

When it is time to take medicine, the system sets off an alarm or sends an alert to remind the user. Next, the system checks whether the user turns off the alarm or alert immediately, which may indicate that the user has not taken the medicine and the system continues to send out reminders. If the user turns off the alarm or alert after a few minutes, the system asks the user "Do you want to take the medicine now?" If the user clicks on "No", the system reminds the user again after a few minutes. If the user clicks on "OK", the

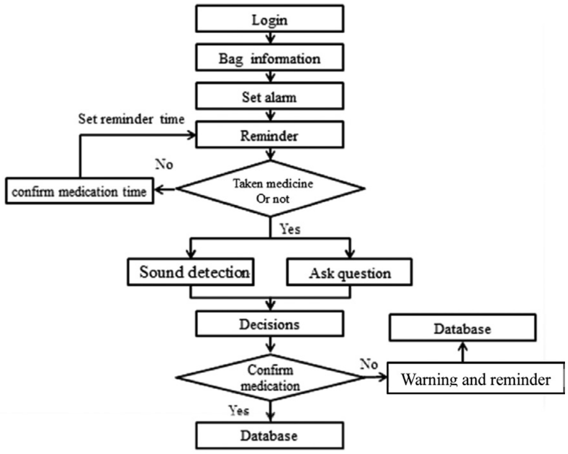

Fig. 2. The process flowchart of our proposed system

system moves onto the next step to confirm that the user has taken the medicine by asking a series of questions and detecting the sound of the medicine bag. If taking of medicine is not detected via these methods, the system sends the user a warning and records this warning in the database within the smartphone. After the warning, the system reminds the user to take his/her medicine again. If by the third warning, the user has not taken the medicine, the system sends an SMS message to the user, as well as the user's family member or doctor.

Security alert function

There are two main parts to this function. One is the medicine bag information extraction. The other is reminders of possible food-medicine and medicine-medicine interactions. Fig.3 shows the process flowchart of this function. After obtaining the information from the medicine bag, the system inputs the dosage frequency to remind users to take their medicine on time. Meanwhile, the system provides a message regarding food-medicine and medicine-medicine interactions to avoid adverse reactions.

A. Medicine bag information extraction

OCR is a recognition technology for text within an image. Fig.4 shows a medicine bag image. Information to be input into the system is highlighted within the dotted line frame. As shown in Fig.5, we proposed a two-step extraction method for medicine bag information. The first step involves image pre-processing and the second step involves recognition of characters.

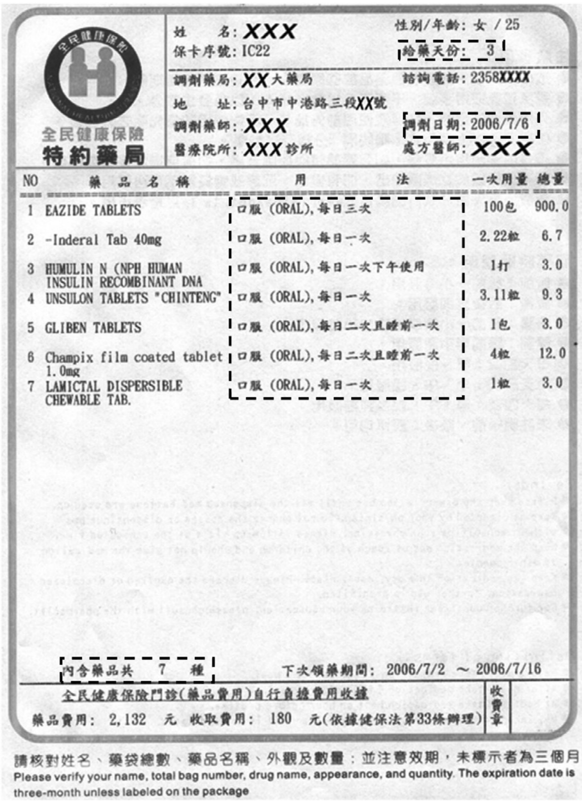

Fig. 4. Medicine bag image

Pre-processing involves binarization, denoising, skew correction, layout analysis, and character cut. For the binarization step, the system performed color space conversion to obtain the gray image and via the Otsu method obtained the threshold value for binary image. Next, median filter was used to remove the noise. Captured document images were obtained informally and the image produced skew, which required character recognition software for correction. We used Affine Transform to perform skew correction. Picture layout analysis process was implemented to segment the paragraphs of text. When the distribution of lighting is non-uniform, characters often appear connected. Thus, we used image projection method to separate the

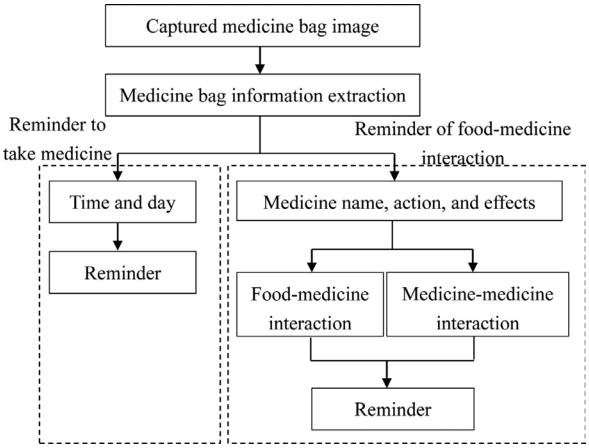

Fig. 3. The process flowchart of security alert function

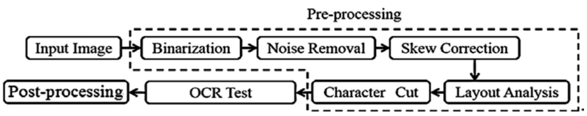

Fig. 5. The flowchart of medicine bag recognition with OCR

characters.

The second step involved recognition engine. We used the open source Tesseract OCR engine to recognize characters[17].

B. Reminder of possible interactions

In our proposed system, two types of interactions, food-medicine and medicine-medicine interactions, are addressed. We built a database based on the food-medicine interactions calendar provided to patients at the Liouying Chi Mei Medical Center, which is shown in Fig. 6.

Finally, we used ontology technology to combine food database with medicine database to provide information regarding potential interactions.

Medicine-medicine interaction information is especially important for patients taking different types of medications such as antibiotic, analgesic anti-inflammatory and anxiolytic. For example, if a patient takes an antibiotic before consuming alcohol, disulfiram-like symptoms may develop. These can include flushing of the face, nausea, vomiting, headache and occasionally breathing difficulty. To avoid these problems, the system automatically reminds patients of potential interactions after they input the medicine bag information and before they take any of the medicine.

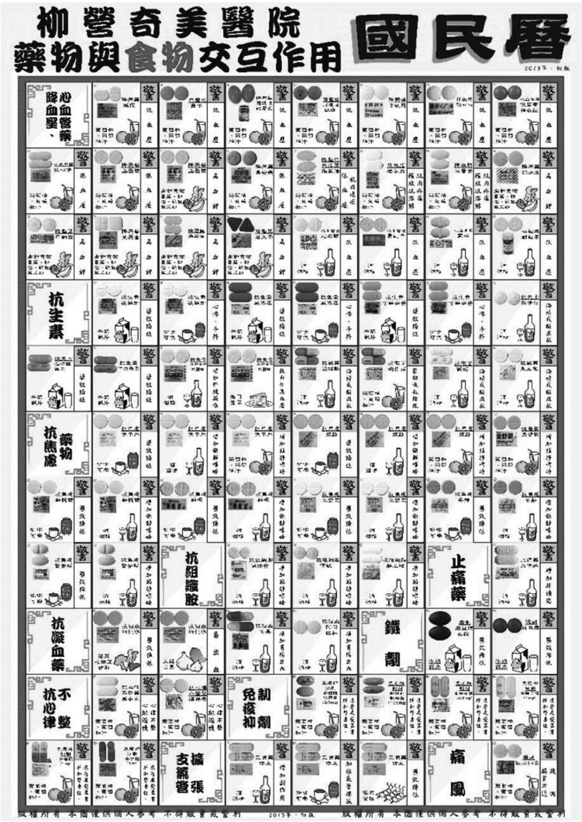

Fig. 6. Calendar of food-medicine interactions

Medication record function

Fig.7 is the flowchart of the medication record function. Once the user inputs the medicine bag information, the system, through medical ontology, searches the relationships of foods and medicines, and shows the interaction information, such as which foods to avoid before or after taking the medicine to prevent an adverse reaction. Each time the user takes medicine, the system confirms this. If the system determines that the user has not taken the medicine, it asks the user to recheck. In addition, the system records this status in the database and notifies the relevant people. If the system determines that the user has taken the medicine, it moves onto the next function.

Confirmation of the taking of medicine and notification functions

To help the user to take his/her medicine on time, confirmation and notification functions are very important. Fig. 8 shows the process flowchart of these functions.

To confirm that the user has taken his/her

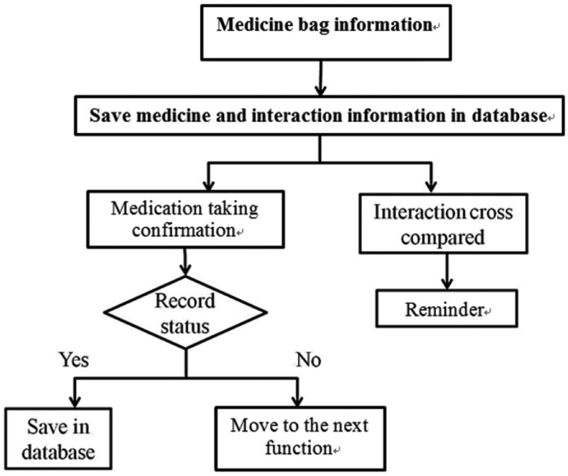

Fig. 7. Flowchart of medication record function

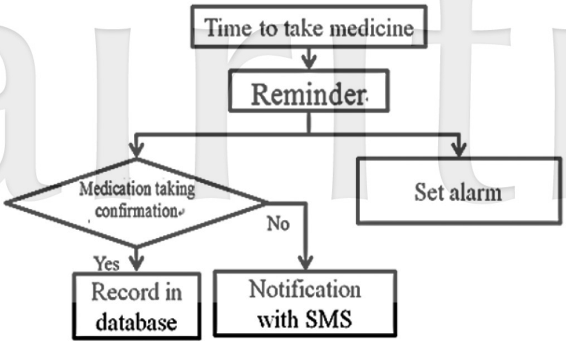

Fig. 8. Process flowchart of confirmation and notification functions

medicine, the system asks a series of questions such as the shape, taste or texture of the pill. These questions were designed based on psychological research and to appear in random order. If the user does not answer at least half of the questions correctly, the system determines that the user has not taken the medicine. After reminding the user, the system sends notification to the doctor or family member that the user has not taken his/her medicine on time and inputs this notification into the database for later tracking. Algorithm 1 is as follows:

Algorithm 1. Pseudo-code of medicine taking confirmation

Input: time of user to press the alarm clock, user's facial image

Output: start alarm, or recording of data into database

```
Begin
  If(user turns off the alarm within 5s) {
        .The user has not taken the medicine and the alarm stays on
  }
  else
  {
        . camera start and facial recognition
        {
            if(system detects face) {
                  Repeat {
                        . random production of new question and response
                        if(the response time is less than 5s) {
                              . system records data in database including question number,
                                response time, user's location and medicine characteristics.
                              . alarm stays on
                              . facial recognition
                              if (system does not detect face and time elapsed is more than
                                60s)
                                {
                                  system sends message to user's family and relevant
                                  people
                                }
                        }
                        else
                              change to the next question
                  }Until all of the questions are completed
            }
        }
  }
End
```

Results

Performance evaluation

To test the reliability of the system, we designed a questionnaire which was given to 50 participants taking medicine regularly, including 29 men and 21 women, ranging in age from 21 to 30 years. Recovery rate of questionnaires reached 80%.

Before using the system, participants filled out a pre-test questionnaire. After using this system for two months, participants were administered a post-test questionnaire. We then analyzed the differences before and after using the system. The purpose of this paper was to test whether participants experienced substantial improvement in medicine taking habits with this system.

The experimental results pointed to the effectiveness of our proposed system, as shown in Table.1 The percentage of those taking medicine on time before using the system was 72%. This rose to 90% after using the system for two months. Satisfaction reached 94%. This implies that our system is beneficial to patients suffering from a cold or chronic illness who need to take medicine for a long time. We also uploaded this system to Google Play, to allow access to a broader spectrum of patients. The result has been high utilization rate with over 500 downloads and an average of 4.7 stars out of five stars on user reviews.

Android-based smartphone operation

Our proposed system automatically extracts information from the medicine bag, making use of image processing and OCR technology. This information includes the name of the medicine, efficacy of the medicine, side effects, number of days and dosage frequency. People

Table 1. The effectiveness of our proposed system.

	Number of participants	Testing time	Number reporting improvement	Number reporting no improvement
Men	22	2 months	19	3
Women	18	2 months	17	1

do not need to manually input this information. For unique prescriptions, the system has some flexibility. For example, Google voice recognition technology allows the user to input the medicine bag information orally. This information can be updated at any time.

Figure 9 shows the various functions and available information as they appear on the user's smartphone screen.

After the system automatically inputs the medicine bag information into the database, it is displayed on the screen as shown in Fig. 9(a). Hence, users can take advantage of their smartphones to quickly look up information. After obtaining the information, the system allows users to confirm that the information is correct, as shown in Fig. 9(b).

The system triggers the reminder function for taking medicine and potential interactions. For the taking medicine reminder function, an alarm can be set. Our system sets the time according to the dosage frequency on the medicine bag, as shown in Fig. 9(c). This reminder function allows the user to take medicine according to the doctor's instructions.

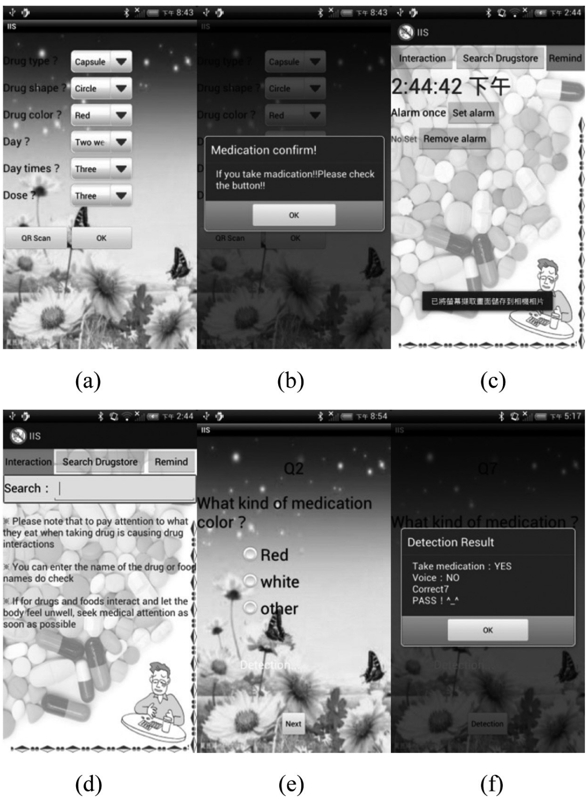

Fig. 9. (a) UI of medicine information, (b) UI of medication taking confirmation message, (c)User set alarm for taking medicine, (d) search function for interaction information, (e) medication taking confirmation question, and (f) medication taking confirmation.

We have established a large information network with access to interaction information. This has been built into the database within the smartphone, so that users can query this information, as shown in Fig. 9(d). The information on the medicine bag and the medicine which users have to take are cross compared. After cross-comparison, users are instructed on what not to eat and which medicines not to take to avoid harmful interactions.

After the user takes the medicine, the system starts the function of sound detection. The system can detect the sound of the medicine bag opening, tearing of pharmaceutical packages and drinking of water. The system carries out further confirmation by asking questions of the user, such as the number of days of medicine consumption or the shape and color of the pills, as shown in Fig. 9(e). According to the sounds produced and user responses, the system determines whether the user has taken the medicine or not, as shown in Fig. 9(f).

This app allows for more efficient health care by improving patient monitoring, as well as reducing dangerous interactions.

Conclusions

Many studies have pointed out that chronic diseases are among the top ten causes of death. Patients with chronic diseases require long term medication and care. Better compliance in terms of the taking of medicine can be achieved with the use of our proposed system. The proposed scheme was especially developed for the Android platform. It consists of the extraction of medicine bag information, confirmation of and reminders for taking medicine, and the provision of medicine and food interaction information. It was evaluated and verified by a large number of users, doctors and nurses.

Experimental results showed that our proposed system not only eliminates the need to manually enter the medicine bag information, but also the problem of forgetting to take medicine. The biggest advantage is the reduction in the risk of adverse interactions. Finally, the system can be easily used on any Android smartphone at any time.

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