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Medication Adherence using Non-intrusive Wearable Sensors

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Abstract

Activity recognition approaches have been applied in home ambient systems to monitor the status and well-being of occupant especially for home care systems. With the advancement of embedded wireless sensing devices, various applications have been proposed to monitor userâĂŹs activities and maintain a healthy lifestyle. In this paper, we propose and evaluate a Smart Medication Alert and Treatment Electronic Systems (SmartMATES) using a non-intrusive wearable activity recognition sensing system to monitor and alert an user for missing medication prescription. Two sensors are used to collect data from the accelerometer and radio transceiver. Based on the data collected, SmartMATES processes the data and generate a model for the various actions including taking medication. We have evaluated the SmartMATES on 9 participants. The results show that the SmartMATES can identify and prevent missing dosage in a less intrusive way than existing mobile application and traditional approaches.

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1. Introduction

Medication adherence is known to be a problem for patients especially elderly or patient with dementia who experience memory lost and suffers from a number of medical conditions that require different medications. Studies have shown that 26% of the hospitalization involving elderly patients above the age of 75 years are related to fall, postural hypotension, heart failure and delirium caused by non-adherence of medicine therapy [1]. According to the World Health Organization [2], medication adherence is defined as "the degree to which the person's behavior corresponds with the agreed recommendations from a healthcare provider". When the patient begins to deviate from the recommended prescription, it is known as non-adherence. There are two types of non-adherence namely primary and non-persistence [2]. Primary non-adherence occurs when healthcare providers prescribe the medicine but is never filled or started. Non-persistence occurs when the patients accidentally miss or stop taking medication after starting it without the advice from a doctor. Non-persistence is usually unintentional and occurs when there is a misunderstanding between the patients and healthcare providers. It may also happen for elderly who suffer from dementia or a decline in functional abilities, such as cognitive, vision and/or hearing impairment, that prevent them from executing their decisions to follow treatment [3]. Hence, there is a need for an wireless based wearable technology to detect and alert the patient to take miss dosage or realignment of medication adherence.

Advancement in electronic technologies and smart mobile applications have made way for the development of small embedded devices to be used in medicine. Electronic monitoring chip, such as the Medication Event Monitoring Systems (MEMS) [4], has been inserted into medication bottle cap to record the date and time the patient opens and closes the bottle. Although this system can detect single opening and closing for a single dose, it may result in inaccuracy for multiple doses [4]. The device also can only record the prescription intake and does not provide any reminder

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or alert for missing dosage. It is necessary to alert the patients to take the missing doses using device such as CompuMed [5] and mHealth [6].

CompuMed is a medication dispenser that emits an audible tone to remind the patients. It can be programmed at regular interval to alert the patient to take their medication, with an option to call the patient. Although experimental results from Winland and Valiente have shown fewer missed doses with CompuMed compared to MEMS pill box [5], constantly sending alert to the patient at regular interval can be very annoying and disturbing. There is also a probability that patients may miss their medication when they are outdoor as they cannot take the CompuMed with them. The price of CompuMed is also significantly higher than MEMS pill box. Hence, it is more feasible to incorporate a mobile application such as mHealth [7]. mHealth consists of tools for sending text messages, Bluetooth-enabled electronic pill boxes, online messaging platforms, and interactive voice calls. Patients and healthcare providers generally prefer mHealth compare to other interventions.

In this paper, we develop a non-intrusive wearable Smart Medication Alert and Treatment Electronic Systems (SmartMATES) and test SmartMATES on 15 participants. SmartMATES uses two 3-axis accelerometer to track the left and right hand gestures and identify the motion of taking a medicine from its packaging and consuming it. Based on the measurement of accelerometers and radio signal between the left and right wrists, SmartMATES can detect and sent alert the user only if he or she did not take or follow the medicine prescription. In existing smart phone applications, they use predefined interval to remind the user but can be intruding when the users have already taken the medication. The main contributions of the paper are:

- A real time smart medicine adherence systems system that only alerts the users if they have not taken the medicine within the prescription time.
- An non-intrusive wearable sensor system that can identify and differentiate between the action of taking medication from other Activities of Daily Life (ADL). The sensor systems can be embedded into cardigan or clothings.
- A case study to evaluate the performance of SmartMATES.

The remaining of this paper is structured as follows. In Section 2, we present the architecture of the system and the components of SmartMATES follow by a description of the experimental scenario for analysis in Section 3. The results from the experiment are evaluated and discussed in Section 4. The paper concludes by highlighting the limitation and future works in Section 5.

2. System Design

Figure 1 shows the overall architecture of SmartMATES consisting of three units namely: M-App (A mobile Application), Left MATES Sense (LMS) and Right MATES Sense (RMS).

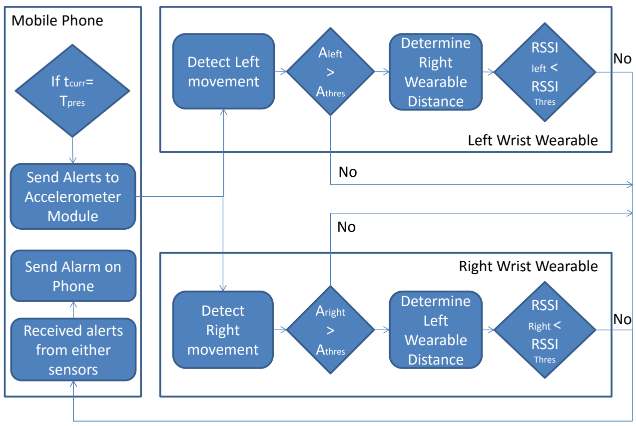

Figure 1. SmartMATES System Architecture

SmartMATES operates on the assumption that *medication intakes generally occur within the same time of day or at a recommended interval*. This assumption is usually true for most medications such as hypertension medication or antibiotics. In SmartMATES, an accelerometer sensor is attached to patient's wrist to monitor the ADL and identify the action of consuming a medication when it is time for a patient medication. Accelerometer is commonly used for gait analysis to detect walking pattern [8] and fall detection [9] using Wireless Sensor Networks [10]. Using the same approach, SmartMATES uses accelerometer to detect non-medication adherence by applying gait analysis on the accelerometer x, y, z to determine the specific pattern feature of consuming the medication as shown in Figure 2. The algorithm used to detect the pattern is an extension of our previous work in [11]. The system generates an alert on the user's mobile phone if the feature is not observed within the time frame.

The LMS and RMS track the hand movement using the FLORA Accelerometer/Compass Sensor (LSM303) and a bluetooth module. The M-App is a medication management and alerting application installed on the mobile phone. M-App manages and stores the patient medication history and schedule information. When an user first installs the SmartMATES, he or she needs to enter his or her personal and medications details including user name, age, weight, drug name, type, strength, frequency of doses per day, doses intake times, number of doses per intake, and before or after meals. Currently, M-App does not verify the prescription instructions and assumes that all the information entered by the users are accurate. M-App can be extended to check and verify the instructions against a drugs database available in the Internet to ensure that the correct doses are consumed. Once the M-App is configured, the SmartMATES is ready to communicate with LMS and RMS.

3. Experimental Setup

The evaluation of SmartMATES consists of two stages: (i) Identifying the groups of participants and (ii) Deploying in homes with real patients. Our main goal is to demonstrate the reliability of SmartMATES to detect and prevent medication non-adherence and the non-intrusive feature of SmartMATES amongst the users.

3.1. Preliminary Study

We conducted an online survey to identify users had problem in adhering medication schedule. From 155 online participants, 86 respondents have medication adherence problem. 87.2% of non-adherence were caused by forgetfulness while the remaining 13.8% had disability problems that hinder them to take the medicines on time.

3.2. SmartMATES Case Study

From the preliminary study, we randomly selected 9 participants from the 86 respondents. Each participant wore a wrist strap, attached with an accelerometer

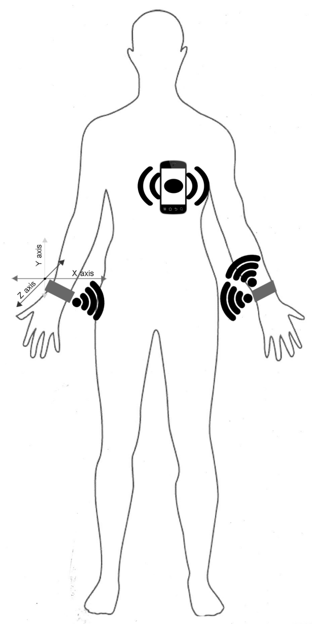

Figure 2. Attachment of Sensor nodes with accerometer x, y, z reading

sensor, on the left and right wrists to track the movement of the hands as illustrated in Figure 3. The LMS and RMS began to sample the accelerometers at a sampling rate of 100 Hz when the systems received a notification from the mobile phone M-App via the bluetooth. The M-App is configured to trigger the tracking systems on the LMS and RMS five minutes before the patient medication time.

Figure 3. A wearable accelerometer to track movements RMS

The participants were divided into 3 groups for three experiments. The first experiment was the control group where the participants did not use any tool and rely on oneself to take the medications. To check if the participants missed a medication, a carer was assigned to call and check on the participants remotely daily, five minutes after the prescription time for the patient. In the second experiment, the participants were asked to install the PillBox, a medication and pill reminder mobile application to help the patients to tracks and reminds their medications. The third and final group of participants wore and used the SmartMATES. The experiment ran for 3 days continuously. The participants were given the prescription to take the medication three times a day.

4. Results

As shown in Table 1, SmartMATES and PillBox have managed to prevent the patients from missing their medication and have achieved 100% adherence compared to manual intervention. In manual, one of the patients has forgotten to take his medication within the five minutes interval after the prescription time and was requiring reminder from the carer to take the medicine in day 3 (Table 1). Although the Mobile App and SmartMATES have achieved 100% adherence, SmartMATES had only triggered an alert to the patient

Table 1. Medicine Adherance for 3 days

Group	SmartMATES	My Pillbox	Manual
Day 1	100%	100%	100%
Day 2	100%	100%	100%
Day 3	100%	100%	50%

Table 2. Number of alerts

Group	SmartMATES	My Pillbox	Manual
Day 1	0	3	2
Day 2	0	3	3
Day 3	1	3	1

as he has forgotten to take the medication on time (Table 2). Users with SmartMATES have also reported they felt less intrusive as SmartMATES did not raise any alarm if the user have taken the medication compared to PillBox.

5. Conclusion

In this paper, we developed and tested a non-intrusive wearable medication adherence systems, SmartMATES. Although SmartMATES has only been tested for a small sample in short duration, SmartMATES had achieved the same reliability rate with a mobile application. In the future, we would like to test SmartMATES for long term clinical used.

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