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A Sensor-based app for self-monitoring of pill intake

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Abstract. Accurate adherence to prescribed medications is essential for the effectiveness of therapies, but several studies show that when patients are responsible for treatment administration, poor adherence is prevalent. Existing apps to support self-administration of drugs may interfere with the normal routine of patients by providing unnecessary reminders. More sophisticated solutions, including the use of smart packaging and ingestible sensors, are currently restricted to patients involved in a few clinical studies. In this paper, we introduce a novel app to support self-administration of drugs without interfering with the patient's routines. The system relies on cheap wireless sensors attached to medicine boxes to detect medicine intake. The app uses machine learning to detect intake events, and active learning to improve recognition based on the user's feedback. The app is available on Google Play Store.

Keywords. Pill reminder app, sensor-based activity recognition, human computer interaction

Introduction

Accurate adherence to medical prescriptions is a prerequisite for the effectiveness of therapies based on pharmaceutical drugs. Unfortunately, several patients experience difficulties in complying to the medical prescriptions. This problem is particularly relevant for patients with chronic illnesses, and can lead to increased use of healthcare services and detriment of life quality (Majumdar et al. 2006).

When non-adherence is unintentional, one of the main reported reasons is forgetfulness (Bartlett 2002). Consequently, different tools have been proposed to remind the patient about the medications to take. A simple solution is the use of "medication reminder packaging", where the medicine box incorporates the prescribed date and time of drug intake. However, those solutions showed a modest improvement of adherence on the long term (Mahtani 2011). RFID tags were used in (Riboni 2016) to let the patient manually register the medicine intake. Other tools actively remind the user, using pagers, custom devices, short message service and, more recently, smartphone apps (Dayer 2013).

Those tools proved to be quite effective on the short term; however, the effects on the long term are unclear (Vervloet 2012). Moreover, existing reminders are context-oblivious: the patient is notified with a reminder at each scheduled time of intake. Hence, such reminders may interfere with the normal routine of users, since they are issued even when patients have actually taken the prescribed drug at the prescribed time. Ideally, the patient should receive a reminder only when he/she actually forgets to take the prescribed medicine.

In this paper, we address the challenging issue of devising a system to support self-ad-

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ministration of drugs, which does not interfere with the normal routine of the patient. We introduce a novel system based on a combination of cheap wireless sensors, a smartphone app, and cloud infrastructure, to monitor medicine intake and provide reminders only when actually needed. Tiny accelerometers stuck to medicine boxes communicate motion data through a Bluetooth low energy interface to the patient's app. The app preprocesses accelerometer data to extract features of interest, and uses machine learning methods to detect intake actions. Detected intake actions are compared with the scheduled therapy. In case of missed intake, the app notifies the user with a reminder. The patient is asked to confirm of refute the detections of the app. The user's feedback is exploited by the app to fine-tune the prediction algorithm to the user's habits, using an active learning method.

1. System overview

The system includes a smartphone running the smart reminder app, tiny Bluetooth sensors (named tags) attached to medicine boxes, and communication with the cloud to acquire data about tags and to process the data at the server side. The app exploits user feedback to fine-tune medicine intake recognition to the patient's habits. A Web-based dashboard is available to clinicians for inspecting the history of medicine intakes of their patients.

As in normal pill reminder apps, the patient manually fills his/her therapies and the prescribed times of intake. However, through the smart reminder app, the patient also associates each therapy to a colored tag (Fig. 1), which is actually a tiny Bluetooth low energy (BLE) beacon with an integrated accelerometer.

The app queries the cloud to get tags information, including the color and the kind of image depicted on its surface, in order to facilitate tag identification. After the association, the patient sticks the tag to the medicine box.

When moved, the tag broadcasts packets containing its identification number and triaxial acceleration. Those packets are acquired by the app and analysed by a ML algorithm, which is in charge of classifying the movements of the medicine box in either "intake action" or "other action".

When the app detects a medicine intake action at the prescribed time, it discreetly displays a pop-up message asking the patient to either confirm or refute the intake, and to fill a mood and pain scale.

For the sake of this project, mood and pain values are important to understand why the patient is taking or not the prescribed medicines.

If the app does not detect the intake of a prescribed medicine within a time threshold, it vibrates, emits a sound and displays a reminder (Fig. 2). The patient can either confirm that he/she forgot to take the prescribed drug, or may report a misprediction of the app, indicating the actual time of intake.

The app has a calendar function showing the prescribed medicines to be taken in the current time of the day, as well as a "performance" function displaying the rates of correct intakes and average mood and pain values in the current day, week and month.

The app is part of the DomuSafe research project (http://sites.unica.it/domusafe/), and can be used both by patients participating to the project's experimental evaluation, and by other users.

The app data (therapies, motion data, medicine intakes, mood and pain values) are periodically communicated to a server in the cloud. The server provides a Web-based dashboard through which clinicians can evaluate the adherence to prescriptions of patients participating to the evaluation, and inspect the trends of pain and mood. Communication with the cloud is done through an encrypted channel. The data are stored on the server in an anonymous form. Each patient participating to the experiment is identified by a unique code; the association among codes and identities is known by the clinician only.

The app has been developed for the Android platform, using the Weka libraries for implementing the ML algorithms. In the current implementation, we adopt Estimote (https://estimote.com/) stickers as our tags. Stickers have an adhesive side that makes it easy to stuck them to medicine boxes. Their communication range is sufficient to cover most apartments. Stickers are disposable and have a life time of approximately one year. At the time of writing, their cost is ten US dollars each. The Web dashboard is implemented in PHP and HTML5.

Fig. 1
BLE sensor stuck to a medicine box

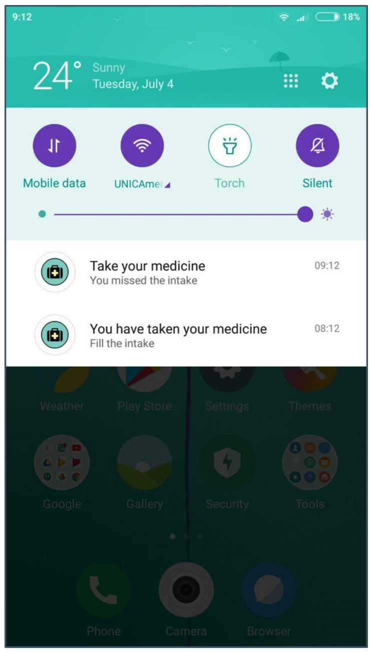

Fig. 2
Context-aware notification

2. Conclusion and future work

Our system for self-monitoring pill intake is based on a smartphone app and cheap wireless sensors to be attached to medicine boxes. We implemented the system and conducted a preliminary experimental evaluation.

Future work includes experimenting our system with real patientsbto evaluate both the utility and usability of our system. We also plan to investigate more advanced active learning methods, in order to fine-tune the prediction model to the patient's context and habits while reducing the effort of providing feedback to the app.

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