Demonstration of a Sensor-based App for Self-Monitoring of Medicine 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 demonstrate 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. In the demonstration, we show a working prototype of the system, which includes a Web dashboard for physicians to monitor the rate of intakes.

Author Keywords

Medicine intake monitoring; e-health; activity recognition.

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

System overview

The system is depicted in Figure 1, and includes a smartphone running the smart reminder app, tiny Bluetooth sensors, named *tags*, attached to medicine boxes (Figure 2), 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.

The app is part of the DomuSafe research project[1], 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

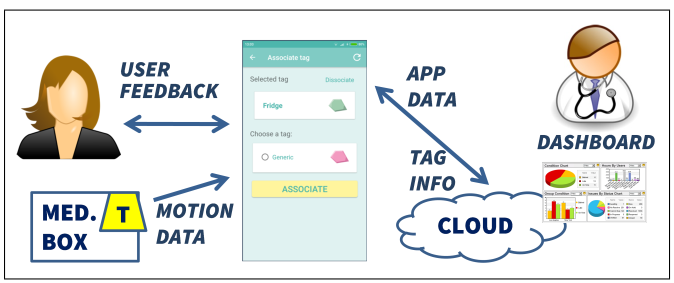


Figure 1: System overview.

[1]http://sites.unica.it/domusafe/

Figure 2: A tag stuck to a medicine box.

to the experiment is identified by a unique code; the association among codes and identities is known by the clinician only.

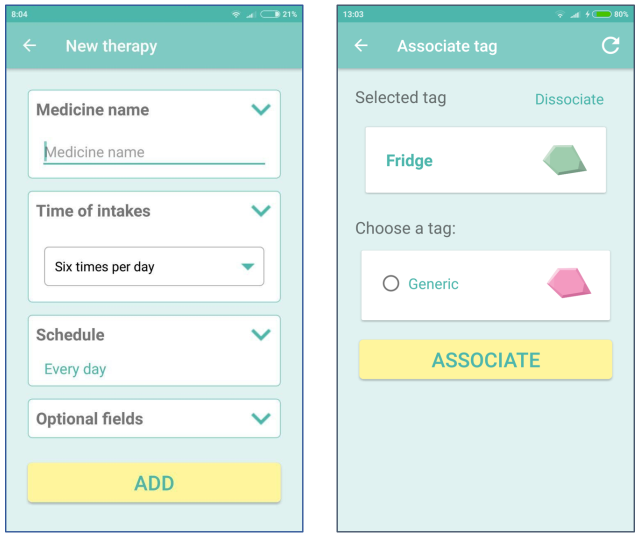
The app has been developed for the Android platform, using the Weka [2] libraries for implementing the ML algorithms. In the current implementation, we adopt Estimote[2] stickers as our tags. Stickers, as the one shown in Figure 2, have an adhesive side that makes it easy to stuck them to medicine boxes. 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.

A detailed description of our system, including machine learning methods to detect intake actions based on sensor data, can be found in [1].

App interface

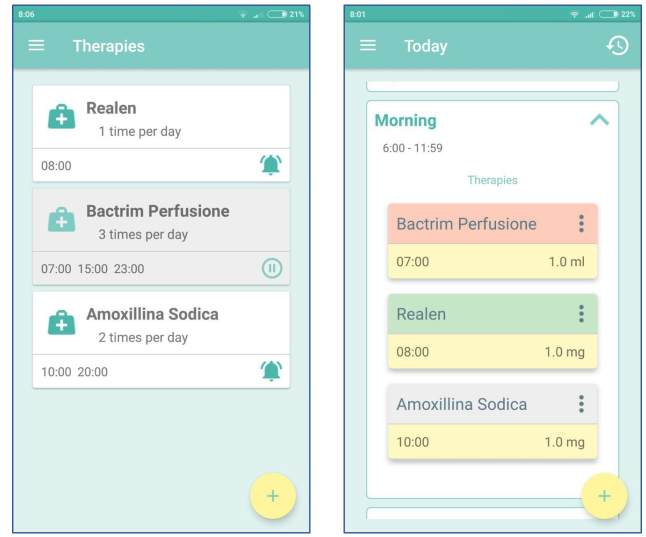
The app's name is DomuPharm; the app can be downloaded for free from Google Play. As in normal pill reminder

[2]https://estimote.com/



(a) Adding a new therapy (b) Associating a tag to a therapy

Figure 3: New therapy and tag association



(a) List of therapies (b) Current medicines to take

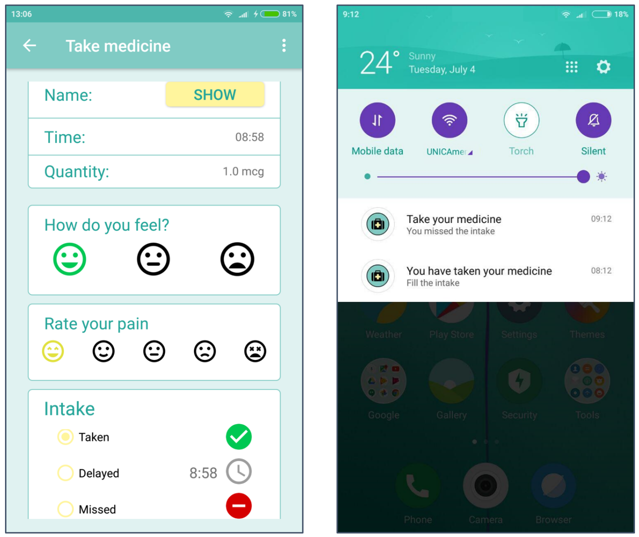
Figure 4: Therapies and current schedule

apps, the patient manually fills his/her therapies and the prescribed times of intake (Fig. 3(a)). However, as shown in Figure 3(b), through the smart reminder app, the patient also associates each therapy to a colored tag, which is actually a tiny Bluetooth low energy (BLE) beacon with an integrated accelerometer, and sticks it to the medicine box.

The user can inspect the list of therapies (Figure 4(a)). Therapies can be modified, removed, and paused. While a therapy is paused, the app does not monitor its intake. Of course, a paused therapy can subsequently be re-activated. The "Today" activity shows the therapies to be taken in the current time of the day (Figure 4(b)). The relative item is green if the medicine has been taken at the right time (i.e., within a one hour interval from the prescribed time). It is red if the intake is missed. It is grey if the medicine is yet to be taken.

When moved, the tag broadcasts packets containing its identification number and tri-axial acceleration. Those packets are acquired by the app and analysed by a machine learning 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, the patient receives an unobtrusive screen notification (the lowest notification shown in Figure 5(b)) that



(a) Intake data (b) Context-aware reminders

Figure 5: Intake data and reminders

produces a vibration of the smartphone but no sound. That notification reminds the patient to confirm or refute the detection, and to fill the scales of pain and mood (Figure 5(a)).

The mood section contains three icons that represent the emotional states: happy, neutral, and sad. The pain section includes five icons to rate the pain experienced by the patient, from no pain to unbearable pain. The icons of mood and pain change color when selected. Hence, the user has an immediate feedback about his/her action. The values of mood and pain scales can be inspected by clinicians on their Web dashboard for further analyses. On the contrary, when the app detects that the intake was skipped, the patient is alerted with both a vibration and a ring, in order to immediately draw his/her attention, and the upper notification shown in Figure 5(b) is issued. Therefore, when the patient takes the drug at the right time, the notification is much less invasive than when he/she misses the intake. Anyway, the patient can modify the behavior of notifications by accessing the settings entry. 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 also has a “performance” function displaying the rates of correct intakes and average mood and pain values in the current day, week and month.

Conclusion and future work

In this demonstration, we show a novel system to support self-administration of medicines through context-aware reminders that do not interfere with the normal routine of the patient. The system is based on a smartphone app and cheap wireless sensors to be attached to medicine boxes. Future work includes experimenting our system with real patients, and improving the interface and recognition accuracy based on the experimental findings.

Acknowledgments

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