A Life-logging Architecture for Monitoring Patients' Quality of Life

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Abstract. Life-logs, which are automatically acquired by wearable trackers and smartphones, can be leveraged to show quality of life indicators to patients. This can help patients better assess the effects of treatments and therefore improve the long-term adherence to medications. In this paper, we present a system dedicated to the acquisition, fusion, and storage of life-log data generated by commercial wearable trackers and smartphone sensors. We also outline how, in particular, the fatigue indicator can be inferred from life-logs.

Introduction

E-health and m-health interventions promoting patients' mental and/or physical health promise to enhance patients' long-term adherence to prescribed medications (Anglada-Martinez, 2015). The acquisition of patients' life-log data by commercial wearable trackers and smartphones can become a low-cost way to acquire valuable information on which effective interventions can be based.

In this article, we illustrate how low-level data acquired from commercial wearable trackers and smartphone sensors can be acquired and leveraged to infer higher-level knowledge of patient's health status. In particular, we focus on four indicators of the Quality of Life (QoL): *activities* performed by the patient; *sleep* quality; level of *fatigue*; and *mood*. With an accurate description of how these indicators vary over time, patients can better self-reflect on the effectiveness of their therapies and therefore can improve the long-term adherence to medications, or even adopt healthier behaviors. For example, allergic patients are often requested to fill questionnaires on the impact of the disease symptoms on their QoL, so that an evaluation of the long-term effectiveness of the treatments can be done. Hence, the automatic provision of QoL indicators at the time of questionnaire filling can help them assess the impact of their disease and find the motivation to stick to the planned therapy.

In this paper, we describe a system aimed at building patients' life-logs by integrating data continuously collated from wearable trackers and data gathered from smartphone sensors. Other generic architectures for the acquisition of life-logs from smartphones have been proposed, e.g., (Rawassizadeh, 2013) (Froehlich, 2007), but none of them constructs integrated time series of data from smartphones and wearable trackers.

Life-logging architecture

The implemented system (see Figure 1, left) automatically acquires data related to the patients' state during the day. Data streams are collected from Fitbit[1] wearable trackers and Android smartphones. While the tracker provides step count, burned calories, covered distance, heart rate, and sleep quality, the smartphone collects data about performed calls, sent SMSs, position, and temperature. All the collected data are useful for the computation of QoL indicators. For example: phone calls to/from colleagues/work partners are indicators that the user is probably working; small variation of heart rate during the day can be used to infer physical fatigue; mood can be associated with physical activities (Peluso, 2005).

The collected life-log data are aggregated and stored on a dedicated server by two software components: a LIFELOG APP and a server side LIFELOG AGGREGATOR. The LIFELOG APP is developed for Android SDK 4.0+ and runs on the user's Android smartphone. It runs in the background, gathers life-log data from the phone, and periodically uploads them to the server. This is done by two always-active services (see Figure 1, center): (1) the SENSORDATA COLLECTOR listens to sensors and stores their values in an internal database; (2) the LIFELOG UPLOADER starts at regular intervals (typically every hour) and uploads all data from the internal database to the LIFELOG AGGREGATOR. In order to avoid

[1] http://www.fitbit.com.

draining the smartphone battery, the SENSORDATA COLLECTOR does not poll sensors for their status, but only reacts and asks for data when a sensor status change occurs.

The LIFELOG AGGREGATOR is composed by two services (see Figure 1, right). The FITTRACKER is responsible for accessing the Fitbit server and fetching data from there. It is based on a Java client library provided by Fitbit, which facilitates Fitbit authorization and resource access. When the user uploads new data to the Fitbit server, a notification is sent to the LIFELOG AGGREGATOR, which starts the FITTRACKER service. The FITTRACKER then download the new data using the Fitbit API. The second component of the LIFELOG AGGREGATOR provides REST web services with JSON responses. Some web services extract basic life-log data from the LIFELOG DATABASE, others give access to higher-level derived information on patient's QoL.

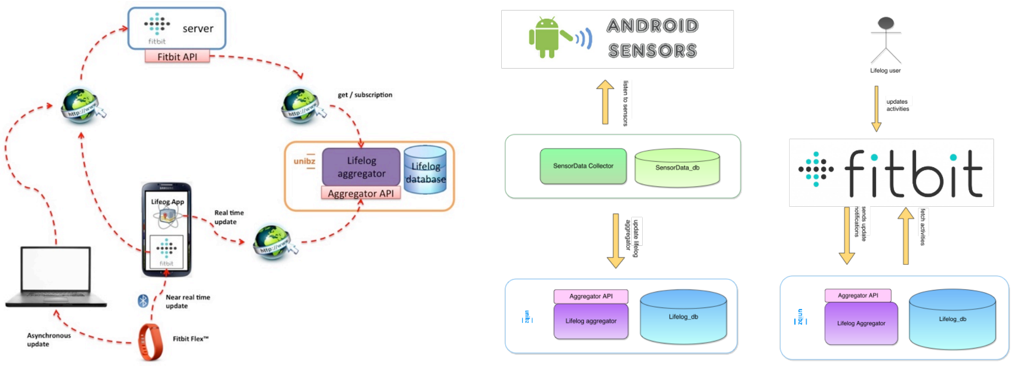

Figure 1. Life-logging architecture.

Inference of fatigue

Studies (Schmitt, 2013) report a relation between physical fatigue and Heart Rate Variability (HRV): people who are more fatigued show a lower HRV. In order to have a proxy of the patient's fatigue in a day, we decided to use the log of the patient's heart rate and to calculate the HRV as the standard deviation of NN intervals over a 24-hour period. A NN interval is the time between two consecutive heartbeats. Since the mapping between HRV and the level of fatigue varies from person to person, we need to tune it. This can be done by assessing a patient's level of fatigue for a period of time using the Chalder Fatigue Scale (Cella, 2010) and, over the same period, calculating the value of HRV using the heart rate log. The Chalder Fatigue Scale is easy to administrate (there are only 11 questions) and it has been validated for the general population.

Conclusions

In this paper, we have presented a system dedicated to the acquisition, fusion, and storage of life-logs data from wearable trackers and smartphones. We are now selecting the most effective techniques for activity recognition based on wearable sensors (Lara, 2013). In the future, we will develop a mobile app that allows the patient to easily visualize the trend of the QoL indicators (Zini, 2015), and we will use the proposed life-logging system to improve an advisory system for allergic patients that we have developed (Nguyen, 2014). The target patients for this advisor system are teenagers under immunotherapy treatment at the Bolzano hospital. By means of a live experiment and by involving also their allergologist, we will be able to gain very useful feedback on the usefulness of our solution.

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