Improving the Effectiveness of Medical Treatment with Pervasive Computing Technologies

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1 Vision

Hippocrates, the father of medicine, already realized that "the physician must not only be prepared to do what is right himself, but also make the patient ... cooperate" [1]. Medical compliance – commonly defined as the extent to which a patient conforms to medical advice about lifestyle and dietary changes as well as taking medication as prescribed – remains a challenge more than twenty centuries after Hippocrates. When Sullivan et al. [4] studied the cost of noncompliance with medication regimens in the American health care system, they found that 5.5% of all hospitalizations they investigated in their study were due to patients not taking their medications as prescribed.

Our vision is that the application of pervasive computing technologies can significantly help patients manage their diseases and hence improve patient adherence to medical treatments.

The scenario that we envision is one in which smart medication – e.g. a medication package augmented with pervasive computing technologies – informs the patient about the effectiveness and side effects of the treatment, sends reminders to take the medication, informs relatives of elderly patients about their adherence to the treatment, detects dangerous combinations between different types of medication and alerts users about recalls or expired medication.

From a technological perspective, we propose that the combination of smart objects and the patient's mobile phone has a lot of potential in the healthcare domain because the smart objects will benefit from the ubiquitous communication infrastructure, the storage functionality and the familiar user interface the mobile phone provides.

2 Current work

We currently work on the design of smart medication packages that monitor consumption and provide additional services to the patient. In the past we developed a prototype of a smart blister pack that monitors the medication consumption

Fig. 1. Smart Blister Pack: A conventional blister pack is equipped with sensors to detect the removal of pills. The blister pack is attached to a communication module, which observes the "pill" sensors and transfers the compliance data to the patient's mobile phone.

unobtrusively, transmits the sensed data continuously to facilitate analysis by medical staff during the treatment and reminds patients when they missed a dose on their mobile phone (see Fig. 1 and 2). By invisibly monitoring the patient adherence and reminding the patient only when she missed a dose, the smart blister pack constitutes another example of Mark Weiser's vision, where embedded technology will calm our lives by removing the annoyances [6].

To realize the above features we equipped a conventional blister card with sensors to detect the removal of a pill by the patient (see Fig. 3 for details). Fig. 1 shows how this modified blister pack is attached to a small electronics board, which is equipped with a communication module and which transmits the "pill removal" events via Bluetooth to a mobile phone. This mobile phone acts as a mobile access point and transfers the data via the GSM network to a backend infrastructure (see Fig. 2).

The patient removes pills from the blister pack just like she would do under normal circumstances. Whenever a pill is removed, the sensors in the blister pack detect the removal and the pill removal event is transmitted without any involvement of the user. The patient will however receive a friendly reminder on her mobile phone, if the data from the compliance monitor indicate that the patient is not taking her medication as prescribed.

The use of the electronic compliance monitor is envisioned in various scenarios. In clinical trials the smart blister pack is intended to help trial investigators to measure a patient's compliance and to allow them to better assess outcomes [2, 3]. The system allows clinical trial staff for example to determine whether adverse reactions or inadequate therapeutic responses are a result of the drug or a result of the patient not taking the medication. The compliance data gathered can be used to actually improve patient adherence during the trial, e.g. by

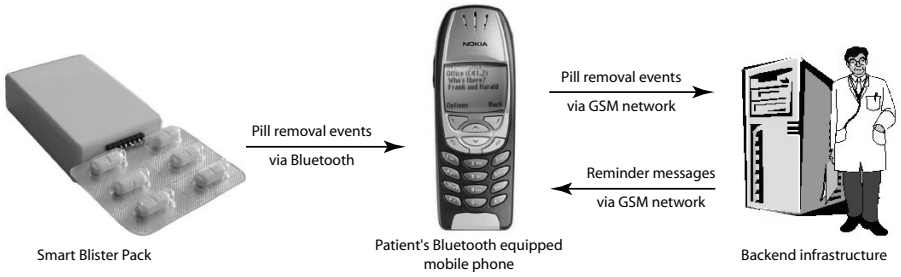

Fig. 2. Overview over the entire electronic compliance monitoring solution with smart blister pack, mobile phone of the patient and backend infrastructure. The mobile phone acts as the mobile infrastructure access point as well as the user interface.

selectively reminding patients with text messages or by targeting patients with additional education by doctors.

The use of the smart blister pack can also be beneficial in the general medical practise. Potential usage scenarios are medications that are especially unforgiving, where forgiveness is defined as the latitude that patients have in dose timing without the loss in therapeutic action [5]. Other application areas include patients that have a high risk of being non-compliant such as elderly patients. The application could then inform family members that the medication was not taken as prescribed.

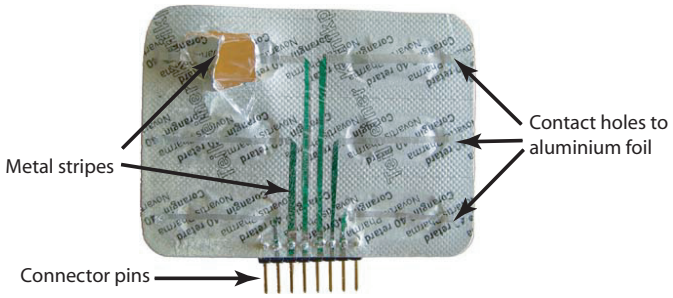

Fig. 3. Blister pack from the backside showing the ripped stripe of metal foil across the opened blister, the contact holes to the aluminium foil, and the pins to connect to the electronics board.The blister pack shown contains currently only 6 pills. Smart blister packs with a larger number of pills are currently under development.

We are currently enhancing the smart blister pack so that it indicates whether the medication it contains has been recalled or is out-of-date. The next version will also detect other "smart" medication items in the vicinity and warn of potential dangerous combinations.

3 Expectations towards the workshop

In our work on personal wireless medical devices we are currently facing several challenges that we believe to be common to pervasive healthcare applications. These include privacy and ethical issues related to monitoring patient behaviour in the healthcare domain and inferring patient behaviour from sensor observations. For our smart blister pack prototype we for example assume that a pill removal from the blister pack also means that a patient will take the pill. Innovative "healthcare" approaches to common technological challenges such as power management of battery powered devices and the intuitive, but reliable pairing of wireless devices are also of great interest to us. This includes the question how we can minimize "expensive" data communication, while still maintaining an adequate quality of service for a healthcare application.

We hope that the workshop allows us to gain insights into how other researchers in the pervasive healthcare domain address these challenges. We also anticipate that we will benefit from the discussions around the various methods proposed in this field.

4 Authors' biography

4.1 Christian Floerkemeier

Christian Floerkemeier's main research interest is the application of pervasive computing technologies to the healthcare domain to improve medical treatments. In co-operation with the pharmaceutical industry he is working on personal wireless medical devices that support patients to better manage their diseases.

Christian is currently a doctoral candidate at the Institute for Pervasive Computing at the computer science faculty of ETH Zurich in Switzerland. His research is funded by the Swiss pharmaceutical company Novartis, which is one of the sponsors of the M-Lab, a joint initiative of the University of St. Gallen and ETH Zurich to promote the application of pervasive computing in business environments.

He holds a Bachelor's Degree and Master's Degree in Electrical and Information Science from Cambridge University, UK. Before joining the M-Lab at ETH Zurich, he was heading the software development at Ubiworks, a start-up company based in Amsterdam providing mobile data solutions for the logistics and finance industry.

4.2 Frank Siegemund

Frank Siegemund's main area of interest is the augmentation of everyday objects and products (e.g., medicine) with active information technology and sensors. He is interested in the design of smart object applications that remove the annoyances of conventional computing applications by considering the situational context of users, and implicit human-computer interaction. Frank also works on

problems such as how to embed smart objects into a surrounding service infrastructure and how to facilitate context-based collaboration among computer-augmented everyday artifacts.

Frank holds a Master's Degree in Computer Science and is currently a doctoral candidate at the Institute for Pervasive Computing at ETH Zurich in Switzerland. His research is funded by the Swiss Federal Office for Education and Science under the umbrella of the Smart-Its project, which aims at augmenting everyday things with computing capabilities and sensors in order to provide novel context-based services to users in smart environments.

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