Adaptive Recommendations for Patients with Diabetes

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Abstract. Diabetes mellitus is a major epidemic with about 8.3% of the world population being affected. Proper treatment minimizes the risk of secondary diseases. The GlycoRec system aims to support patients in making decision that are related to the treatment by modeling their behavior and their physiology. Here we describe the aims and first steps towards the development of GlycoRec.

1 Diabetes Mellitus

Diabetes mellitus is a major epidemic and a threat to public health with about 8.3% of the world adult population being affected (Shi & Hu, 2014). The highest increase in diagnoses in recent years is observed in patients aged 60 and over. While there is no known cure for diabetes, it can be managed through a combination of diet, exercise and appropriate medication. However, when not managed in an appropriate way, patients are at high risk of developing secondary conditions comprising in particular as cardiovascular disease resulting in a significantly increased morbidity and mortality. Therefore, it is of high importance that patients are able to manage their diabetes treatment on their own aiming at near normal blood glucose levels (American Diabetes Association, 2014).

Most patients who treat their diabetes with insulin go through the same routine several times each day: they monitor their current blood glucose level using a glucometer; they estimate their carbohydrate intake; they calculate the required insulin doses and inject an appropriate amount. Different types of insulin that vary in onset and duration of action may be used.

One of the challenges in diabetes management is the patients' need to learn how their body reacts to food intake, activity and insulin application. Mobile

apps currently available for calculating insulin dose without reference to individual needs show systemic issues such as missing validity checks of input data affecting the safety of patients (Huckvale, Adomaviciute, Prieto, Leow, & Car, 2015).

2 Aims and Objectives

The GlycoRec system aims to support diabetes patients in managing their disease. It supports decisions and gives individualized recommendations based on the patient's behavior, physiology and treatment history. Individualized advise may include

- estimation of nutritional characteristics such as carbohydrate content and glycemic index of meals
- recommendations on insulin application based on glucose level, activity and food intake
- warnings if blood glucose levels are at risk of leaving the target range

3 Requirements Engineering

Complex adaptive interactive systems such as GlycoRec require systematic elicitation and documentation of requirements (Gena & Weibelzahl, 2007).

3.1 Requirements Elicitation

Based on an extensive review of the literature, we designed a survey for patients to explore both the patients' situation as well as the main barriers they encounter. Questions on the patients' current situation referred to their strategies for managing their disease as well as the technologies available to them. The exploration of barriers encountered will help to tailor functionality to patients and prioritize features. Moreover, semi-structured interviews with diabetes nurses will be conducted in order to validate the survey results and to elicit expert knowledge on diabetes management strategies (Dix, Finlay, Abowd, & Beale, 1998; Weibelzahl, Jedlitschka, & Ayari, 2006).

3.2 Preliminary Personas

In order to support the modeling process, we developed a set of personas (Cooper, 1999) that represent the main target groups of the system in regard to their needs and preferences. Figure 1 shows a condensed version of two of the personas developed based on the survey data.

Andreas

- male, age 59
- accountant
- type 2 diabetes
- diagnosed 12 months ago
- owns smart phone
- likes to prepare his own meals
- has lunch in company's cafeteria
- feels insecure when taking treatment decisions

Beate

- female, age 30
- shop assistant
- type 1 diabetes
- diagnosed at age 6
- uses smart phone and tablet PC on regular basis
- long-standing experience with diabetes management
- focus on healthy life-style, exercises three times a week
- wants flexibility, e.g., eat out, clubbing

Fig. 1. Condensed version of two of the GlycoRec personas

4 System Architecture

The GlycoRec architecture follows the high level pattern of interactive adaptive systems in accordance with Jameson (2008) comprising inference, modeling and adaptation decision. Figure 2 depicts an outline of the high-level system architecture. A variety of sensor data are collected including actual glucose level as measured by a glucometer, level of activity and insulin application. Data are gathered through smart phone, smart watch and networked glucometer and insulin pen, stored in a central database and analyzed in order to model current glucose level.

Patients interact with the system via smart TV, tablet or smart watch. While the smart watch interface is designed for interaction during the day where both the patient and the system can initiate interaction, the smart TV interface supports review and reflection on historical data and facilitates identification of patterns over time. Patients can also share their records with their physician or their diabetes nurse for discussion of their diabetes management.

5 User Modeling and Adaptation

From a user modeling perspective, GlycoRec tackles a number of challenges, including but not limited to:

Firstly, physical reactions to insulin, food intake and activity in diabetes are idiosyncratic. While the general patterns are known, individual patients seem to respond differently in similar situations, depending on factors such as age,

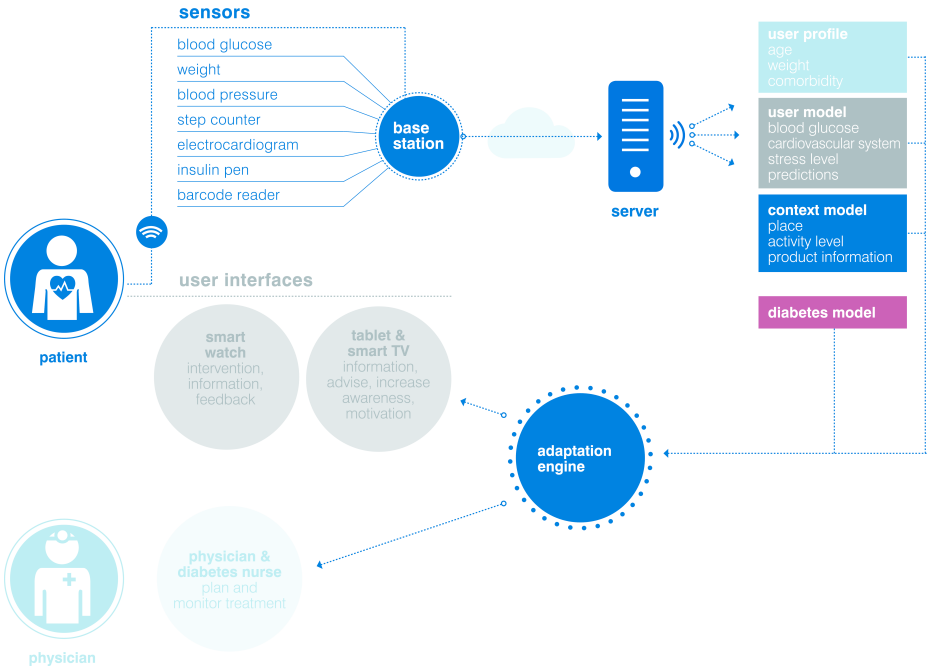

Fig. 2. Overview of the architecture of the GlycoRec system

weight, general heath, medication, comorbidities, to name but a few. Individual response patterns need to be observed and learned.

Secondly, this will involve combining a variety of sensor data. We have selected a number of candidates, but it will be necessary to narrow down the list for both modeling and practical reasons.

Thirdly, the available data vary greatly in granularity and quality. While for instance activity level can be assessed on a continuous basis, most patients measure their glucose level three to seven times a day, with some patients measuring only once a day. So while validation and readjustment of glucose level measures are sparse, the (predicted) glucose level need to be assessed at any time in order to be able to issue warnings. Accordingly, models will differ in certainty at different points in time.

Fourthly, the development process is subject to a number of regulations, as any device involved in the treatment of patients is considered a medical device that needs to be compliant with ISO 13485 (International Standards Organization, 2003). User testing and iterative development is less flexible under these conditions.

Lastly, designing the adaptive user experience for patients is challenging as the disease has huge impact on the patients' lives anyway. Any additional effort and new processes in managing their disease will only be accepted if the benefits are obvious and the required input is minimal, i.e., data collection and modeling need to happen with minimal or no user interaction in the background, but if and only if intervention is required the system needs to take initiative and make reliable recommendations.

6 Future Perspectives

This three-year project commenced in January 2015 and is in its early stages. Requirements have been gathered. Significant involvement of patients in the development process and the application of further user centered design methods (Norman, 1988) is planned for the next phase. A user evaluation including validation against physiological parameters of treatment quality such as the HbA1c value (Larsen, Hørder, & Mogensen, 1990) will demonstrate the effects of the system.

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