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glUCModel: A monitoring and modeling system for chronic diseases applied to diabetes

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ABSTRACT

Chronic patients must carry out a rigorous control of diverse factors in their lives. Diet, sport activity, medical analysis or blood glucose levels are some of them. This is a hard task, because some of these controls are performed very often, for instance some diabetics measure their glucose levels several times every day, or patients with chronic renal disease, a progressive loss in renal function, should strictly control their blood pressure and diet. In order to facilitate this task to both the patient and the physician, we have developed a web application for chronic diseases control which we have particularized to diabetes. This system, called *glUCModel*, improves the communication and interaction between patients and doctors, and eventually the quality of life of the former. Through a web application, patients can upload their personal and medical data, which are stored in a centralized database. In this way, doctors can consult this information and have a better control over patient records. *glUCModel* also presents three novelties in the disease management: a recommender system, an e-learning course and a module for automatic generation of glucose levels model. The recommender system uses *Case Based Reasoning*. It provides automatic recommendations to the patient, based on the recorded data and physician preferences, to improve their habits and knowledge about the disease. The e-learning course provides patients a space to consult information about the illness, and also to assess their own knowledge about the disease. Blood glucose levels are modeled by means of evolutionary computation, allowing to predict glucose levels using particular features of each patient. glUCModel was developed as a system where a web layer allows the access of the users from any device connected to the Internet, like desktop computers, tablets or mobile phones.

1. Introduction

Chronic patients must carry out a rigorous control of diverse factors in their lives. Diet, sport activity, medical analysis or blood glucose levels are some of them. This is a hard task because some of these controls are performed very often, for instance some diabetics measure their glucose levels several times every day, or patients with chronic renal disease, a progressive loss in renal function, should strictly control their blood pressure and diet.

In addition, currently there is great pressure from various scopes to reduce the costs of health care systems, both public and private. The general reduction of benefits, the fear of job loss, or difficulties in commuting make people with chronic diseases to reduce the number of physical visits to the specialist and sometimes this implies a worse control of these diseases and a consequent acceleration of physical deterioration caused by the disease. But all are not bad news, the expansion of new technologies, the generalization of the use of the Internet and the development of telemedicine applications for both PCs and smartphones, open an avenue for redress this situation and improve the control of chronic diseases without increasing costs. Moreover, telemedicine reduces the number of visits to the specialist and facilitates the health care irrespective of location.

The definition of telemedicine (also called e-health) is different depending on the context and the field of medicine. There is some agreement on a definition as technological systems to facilitate health care. A good definition is made by Van der Heijden et al. in [1]: "Facilitating health care irrespective of location by means of technology". Oh et al. found up to 51 unique definitions in 2005, with a wide range of themes, but no clear consensus about the meaning of the term eHealth [2]. They identified health and technology as universal themes. Perhaps the best definition is "e-health is a field in the intersection of medical informatics,

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public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies" made by Eysenbach in [3] and also adopted by Pagliari et al. [4].

Undoubtedly the reader should agree that the most important is not the definition but the resources that should be included on an e-health system. We defend the idea of including not only database systems but also more complex and automatic tools to facilitate the independence of the patient in non-critical situations, allowing a reduction in the number of visits to the hospital and, hence, reducing the costs for the health companies or public health systems.

Nowadays an e-health system should include e-learning systems, recommender systems and modeling tools based on a centralized database. In this way, the work described in this paper covers all those features. We present a telemedicine system consisting on: (1) a database, (2) an environment for e-learning, (3) an automatic recommendation system (both medical and didactical to improve control of the disease) and (4) a system for modeling and predicting parameters. The latter system provides important aspects in controlling the chronic disease using techniques from the field of evolutionary computing. The system takes full accessibility and computational capabilities of current computer systems. Any patient with a chronic disease can benefit from systems like ours. Despite that we adapted the system for diabetes, not only the idea but also the web architecture can be useful for any other chronic disease.

Following other recently published works, we intend to have a tool that allows the patient and the practitioner to establish the degree of interaction and dependency between them. Our tool allows the physician to delegate certain tasks, passing their control to nursing. Our work tries that the electronic device does not limit access to the system capabilities. Therefore, no specific platform device has been developed. In fact, it seems more comfortable to access the education module through a tablet, laptop or desktop computer and, on the other side, data uploading, queries to models, and short tasks are much more practical if they are made from a smartphone. For all these reasons we have implemented the user interface of the system as a web service, which is platform independent.

The on-line architecture allows collecting all the necessary data from patients, which improves the direct communication between the physician and the patient. It also incorporates a case-based recommender, which feeds back an e-learning system. This technology allows updating data in a more simple and friendly way, through the use of smartphones and other similar platforms. In this way the patient will no longer need to keep track of his data (diet, measured glucose, exercise, etc.) during the day, and then write it down when getting home, updating the information immediately after each event. Some of these features are already available, albeit partially, on other systems. However, there are three new elements in our work: the recommender system is connected with an e-learning module; the physician can upgrade the recommender system; and models are automatically customized for each individual patient.

The rest of the paper is structured as follows. Section 2 introduces the Diabetes Mellitus disease. Section 3 shows an overview of glUCModel. Section 4 analyses the structure of the application, and explains the main features of each part. Section 5 introduces a novel method to obtain patient models, which are used to predict the health status of a patient. Section 6 explain different functionalities of the application with an example of use. Finally, Section 7 concludes the paper and explain the ongoing and future work.

2. Diabetes Mellitus disease

Diabetes Mellitus is an illness that affects around 336 million people in the world, causing 4.6 million deaths each year. Therefore, much effort is devoted in improving the diabetics quality of life. Diabetes is a chronic disease characterized by a decrease in insulin production by the pancreas, or by a resistance to the insulin action, increasing the levels of sugar in blood. The cause of this disease is a decrease in insulin production by the pancreas, or the inability of the cells to react to the insulin. Insulin is necessary for glucose to enter in the cells. Thus, this hormone plays an important role in the regulation of the glucose level in the blood (glycemia). Depending of this level, a patient can have normal values or *Normoglycemia* (values between 70 and 120 mg/dl), high glucose level or *Hyperglycemia* (more than 120 mg/dl) or low glucose level or *Hypoglycemia* (under 70 mg/dl).

There are two main different diabetes types:

- **Diabetes Mellitus type 1 (DM1):** Cells do not produce insulin because of an autoimmune process. Currently, requires the person to inject insulin or wear an insulin pump.
- **Diabetes Mellitus type 2 (DM2):** Results from insulin resistance, where cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency.

Our system is specially useful for insulin dependent patients both DM1 and DM2, however patients with oral antidiabetic drugs for the prevention of type 2 diabetes can also benefit from glUCModel. It might be useful the education module (except insulin adjustment lessons), the recommender system (with selected information, i.e. hypoglycaemia management, diet, symptoms, etc.) and the use of glUCModel for medical monitoring of their diabetes (analytical, ocular fundus test, notices, etc.).

It is very important for diabetic patients to have a good control of the illness to prevent chronic complications like nephropathy, retinopathy or microangiopathy; in the worst scenario patients can even reach an acute complication such hyperglycemic and hypoglycemic comatose state or die. Thereby, it is fundamental to have a tracing of the parameters affecting diabetes, both by the patient and by the doctor. This tracking affects those principal factors that have great influence in the disease like sport activity, insulin injections, glucose levels or diet.

There have been different approaches to facilitate the diabetes control. However, most of them have been designed only for specific glucometers. For example, many pharmaceutical companies have developed their own application for managing diabetes. *Bayern* created *Glucofacts Deluxe* [5], which exports data from Contour or Breeze glucometers, also owned by *Bayern*. *Abbot* developed *CoPilot Health Management System* [6], which works with Abbot's meters, like *FreeStyile InsuLinx* [7]. This meter allows us to record glucose levels and insulin doses, and to compute the amount of insulin that must be injected. *MenaDiab* [8] was developed by *Menarini Industrie Farmaceutiche Reunite*, but, as occurs with other companies, it only offers service with its glucometers (in this case, GlucoMen). Instead, *MyCareTeam* [9] offers support with for many glucometers, but it is not a free application.

Nowadays there are different mobile applications that carry out a control of the patients lifestyle. *OnTrackDiabetes* [10], *Glucose Meter* [11], *Diabetes Pharma* [12] or *Diabetes Hypoglycemia* [13] are only a few of all the available applications. However, most of these applications are only dedicated to the patient, and the physician does not have access to the data. In some of them, patients have the possibility of sending back information by e-mail. Applications like *HealthJibe* [14], *CVS Caremark* [15], *Heart360 Cardiovascular Wellness Center* [16] or *Live Healthier* [17] are built over a cloud infrastructure like Microsoft Health Value or the extinct Google Health. Using a cloud storage system, data have less privacy than if applications use their own database.

We can find also some academic and research papers on this topic. Fonda [18] proposes a similar web application using Microsoft