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MED-StyleR: METABO Diabetes-Lifestyle Recommender

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ABSTRACT

Lifestyle plays an essential role in controlling diabetes and in both the prevention and management of diabetes. Many reports from clinical research support the theory that healthy eating and regular exercise are much more effective at managing diabetes than traditional medication. In this paper we introduce an innovative approach to the multimodal recommender system conceived in the EU METABO project. The most important feature of the METABO Diabetes-Lifestyle Recommender (MED-StyleR) is to generate highly personalized recommendations that satisfy medical prescriptions for patients' long-term health alongside short-term preferences of patients in their daily lives.

Categories and Subject Descriptors

H.4.2 [**Information Systems Applications**]: Types of Systems—*Decision support (e.g., MIS)*

General Terms

Algorithms

Keywords

Clinical Decision Support System, Diabetes Management, Recommender System, Rule-based Recommendations

1. INTRODUCTION

Diabetes is a chronic metabolic disturbance characterized by increased blood glucose concentrations and decreased insulin secretion. The International Diabetes Federation (IDF) predicts that there will be 333 million people with diabetes worldwide in 2025, amounting to 6.3% of the world's population. Furthermore, it is estimated that up to 50% of people with diabetes are undiagnosed or are unaware of their condition.

The Diabetes Control and Complications Trial [8] including 1,441 subjects with Type 1 diabetes showed that effective management of blood glucose levels (BGL) can reduce the risk of late complications - such as visual disorders, heart disease, foot problems and kidney failure. Recently, many studies have reported that computer-assisted expert systems, such as clinical decision support systems (CDSS) and telemedicine, might help practitioners and diabetes patients to make reliable diagnoses and management decisions[1][2][7]. CDSS are active knowledge management systems that bundle basic clinical knowledge with specific information about cases and patients. This knowledge is then used to support health care professionals in making decisions about short- and long-term therapies. One major difficulty in constructing knowledge-based CDSS systems lies in the need for domain experts and training the system, which is time-consuming and therefore might cover only a narrow scope of applications.

On the other hand, lifestyle plays an essential role in controlling diabetes, in both the prevention and management of diabetes. Many reports in clinical research support the theory that healthy eating and regular exercise are much more effective at managing diabetes than traditional medication. In particular, for patients with Type 2 diabetes, lifestyle changes based on a heart-healthy diet with physical exercise may be sufficient for successful control of their BGL. However, changing a lifestyle requires a great deal of effort from patients and practitioners to initiate and sustain a targeted lifestyle program. Some patients report that traditional diet program and exercise prescriptions are often unrealistic and difficult to follow in the long term.

As part of the European METABO project[1], we are developing the METABO Diabetes-Lifestyle Recommender (MED-StyleR) to improve the quality of diabetes patients' self-management programs and support physicians in their decision-making by providing highly patient-specified supporting models. The architecture of the MED-StyleR is based on CDSS components and lifestyle recommendations related to food intake and workout, in order to satisfy medical prescriptions for diabetics' long-term healthy lifestyle alongside short-term preferences of patients in their daily lives. In detail the main part of the MED-StyleR consists of a knowledge-based rule engine supplemented by collaborative and case-based filters to validate the generated recommendations for the patients' food intake and exercises.

In this paper, we briefly introduce the METABO project and the architecture of MED-StyleR, part of the overall CDSS model defined in the project. Specifically, we will present a rule-generation engine that provides the possibili-

[1]EU FP7-ICT-2007-1-216270, www.metabo-eu.org

ties to simply manage multimodal knowledge and to realize collaborative data processing.

2. METABO

METABO (Controlling Chronic Diseases related to Metabolic Disorders) is a European collaborative project funded by the European Commission and started in January of 2008 by 22 partners from 9 EU member states.

The aim of METABO is to set up a comprehensive platform, running both in clinical settings and in everyday life environments, for continuous and multi-parametric monitoring of the metabolic status in patients with, or at risk of, diabetes and associated metabolic disorders. The type of parameters that will be monitored, in addition to "traditional" clinical and biomedical parameters, will also include subcutaneous glucose concentration, dietary habits, physical activity and energy expenditure, effects of ongoing treatments, and autonomic reactions. The data produced by METABO will be integrated with the clinical data and the history of the patient and will be used in two major interrelated contexts of care:

1. Setting up a dynamic model of the metabolic behavior of the individual to predict the influence and relative impact of specific treatments and of single parameters on glucose levels.

2. Building personalized care plans integrated into the current clinical processes linking the different key players in primary and secondary care and improving the active role of the patient.

3. The combined use of tools for predictive modeling and for the personalization of the individual process of care will close the loop between the patients, the professionals involved and the health organization. Mining the data produced by METABO will allow the identification of patterns and trends that will permit the fine-tuning of the model and the prompt adjustment of the care process.

METABO consists of a global platform that collects and processes data coming from the patient and the physicians' tools (a mobile device for the patients to acquire data from users and sensors and a web application for the physicians to present them with all the data collected and analyzed) and works as an information exchange bridge between physicians and patients. In addition, the system provides both groups of users with decision support systems to give them recommendations for a healthy lifestyle in a personalized short loop and for treatments in an integrated long loop (Figure 1).

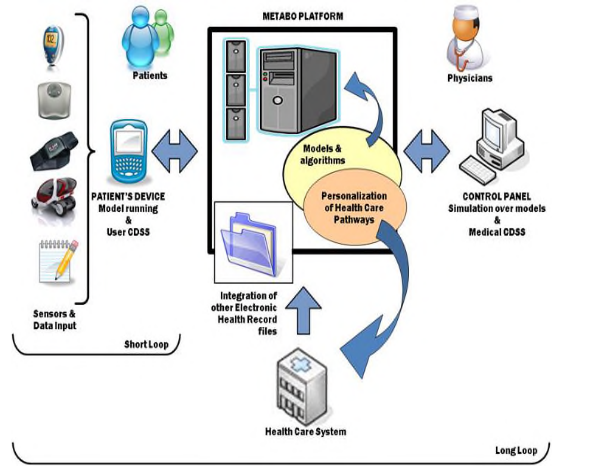

Figure 1: Diagram of METABO Platform (after METABO Annex I "Description of Work")

3. MED-STYLER

The MED-StyleR is one of different specific subsystems comprising the overall METABO CDSS model that takes into account the patient's metabolic changes and information about dietary, physical activities and other patterns of lifestyle. The MED-StyleR aims to support patients during everyday life by generating patient-specific recommendations and is intended to run on the patient's mobile device and to support the patients in adapting their lifestyle to their disease. It therefore delivers daily and highly personalized recommendations for meals and physical activities that should affect the patient's healthy life in the long term and his/her ambitions in the near future.
Regarding the food intake, we want to generate highly personalized recommendations with patient-specific and diabetes-friendly recipes. We therefore take into consideration general dietary guidelines for the intake of carbohydrates, fats and protein. The ultimate objective is to protect the heart and to control, for example, the levels of cholesterol and triglyceride and the blood pressure. This is very important because diabetics are at high risk of secondary disorders including heart and kidney disease. In addition, to the food intake, physical exercise plays a decisive role in energy and glucose consumption. Even light exercises can have benefits for diabetics and can increase sensitivity to insulin, for example. However, the system must be aware of the patient's glucose level and severity of disease, if providing recommendations for physical activities. For example, if the current glucose level is higher than 250mg/dl, which means that the patient is suffering from hypoglycemia, the system should recommend refraining from exercise. Insulin-dependent patients especially need to be given recommendations during their physical exercise. For example, they should reduce their insulin dose or should take in more carbohydrates before starting a high-impact workout. In addition, patients with already weakened blood vessels in the eyes or feet should avoid high-impact exercises.

3.1 Architecture

The MED-StyleR is designed to work as a knowledge-based hybrid architecture, as shown in Figure 2. The recommender includes several sub-modules. These modules are responsible for gathering (GUI-based input panel) and analyzing (Data Compiler, Profile Updater) daily instant data such as food intake, physical activity, the glucose level, demographic data such as age, gender and weight, and stereotypical data such as obese type or lean type with absolute insulin secretion deficit. In addition, the *lifestyle trend analyzer* analyzes the trends related to the patient's food habits and physical activities that affect the rule generation and ex-

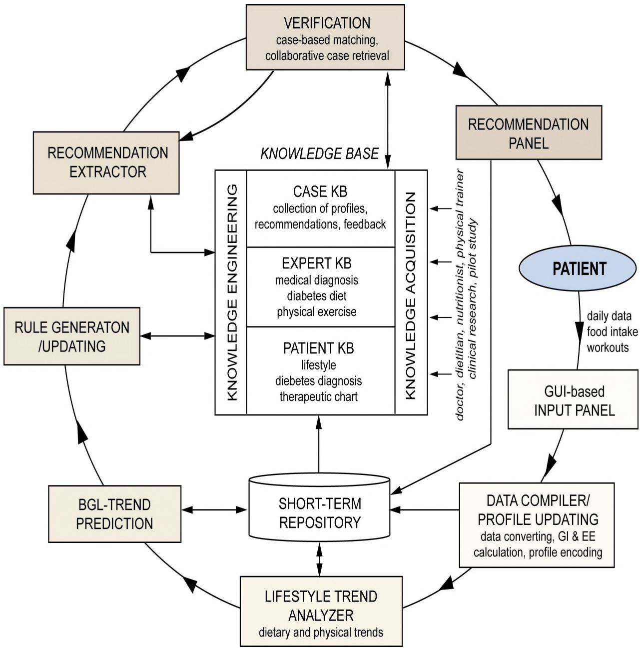

Figure 2: Architecture of METABO Diabetes-Lifestyle Recommender (MED-StyleR)

traction. The data are gathered partly by the patient manually and partly by carried sensors.
The *recommendation extractor* derives practical recommendations for the patients in personalized form. The main part of this module is a rule engine comprising rules based on the knowledge contained in the expert knowledge base, which includes specialized domain knowledge of various experts such as practitioners, nutritionists and physical trainers, about medical diagnosis, diabetes diet and physical exercises. To provide patient-specific recommendations by, for example, personalizing the patients thresholds for hypo- and hyperglycemia by collaborative filters or the Kalman Filter [9], the MED-StyleR also needs to know about the patients. This knowledge includes general demographic information, the diabetes diagnosis, therapeutic charts, food intake and food preferences, exercise schedules and much more besides, and is stored in the patient knowledge base. To validate the generated recommendations, finally, the knowledge base contains a case knowledge base, which is a collection of user profiles, former recommendations and the related feedback of patients and experts.

3.2 Methodological Consideration

An in-depth investigation of structural frameworks for the recommender system, such as the collaborative filtering method, content-based recommendations, and knowledge-based recommendations, reveals that every approach has some limitations in addition to its strengths [3]. Since generating recommendations to assure patients a healthier lifestyle instead of their accustomed one differs from traditional e-commerce applications that aim to satisfy the user's demands and preferences, we have developed a knowledge-based hybrid system that exploits the strengths of existing approaches.

As illustrated in Figure 2, the knowledge management module affects the overall data processing stages. We combine the collaborative and demographic method to analyze similarities between patients by using user-dependent and user-independent data. Whereas the knowledge bases are used to extract rule-based recommendations, the similarity between patients is used to verify the extracted recommendations by a case-based filtering process. The rule-based approach was chosen because of its precise logic and its ability to handle large amounts of data. Furthermore, making decisions by rules offers the possibility of using forward chaining as well as backward chaining. So we are able, for example, to ask the question: "'*If the user is obese and has done no physical exercise so far, what kind of activity is the best to start with?*"'. One possible recommendation could be *swimming*- because it is a low-impact activity. However, we would ask: "'*The user likes to eat cheese. Is this advisable?*"' and if the user doesn't suffer from lactose intolerance the answer could be "'*Yes*" (Figure **??**)'. Additionally, we could also combine both methods and add the question: "'*If eating cheese is advisable, how much would be a good portion?*"'. Finally, the case-based approach was chosen to validate and enhance recommendations by comparison with successful recommendations saved in the database.

```
(defrule lactose-intolerant
    ?user <-(User(lactose TRUE))
    ?meal <-  (Meal(lactose TRUE))
    =>
    (retract ?meal)
)
```

Figure 3: Architecture of prototype

3.3 Rule Engine

As the rule engine is a core component of the MED-StyleR we have developed a prototype rule engine that helps people in general to reduce or maintain their weight and makes it easy to extend to our target application in the METABO specialized for diabetics. Since we wanted to investigate the technical aspects of a rule engine, in the first instance, we focused on the generation of recommendations regarding the food intake.

Concept
Since excessive or unhealthy food intake is one of the main reasons for excess weight and adiposity, we focused on the balance of consumed and burned calories. As all people differ in their calorie requirement, we used the Harris-Benedict equation [5] to calculate the resting metabolic rate of the respective users. We calculated the resting metabolic rate for this weight- in order to reach or maintain their reasonable weight. The desired weight was either input by the user or calculated by the normal body mass index (men: 20-25; women: 19-24) and the user's height. Other information input by the users included demographic data such as name and age, height and actual weight. To filter food with intolerable ingredients in the prototype, the users were also asked to state whether they suffered from allergies, lactose intolerance or gluten intolerance. In addition, the users were

able to name their likes and dislikes in terms of dishes and ingredients in order to increase or decrease the possibility of receiving corresponding meals. All the options available to manipulate the meal plans show that the meal plans were generated in a highly dynamic and personalized way. Certainly, the recommended dishes could be rejected by the users. If the user rejected dishes, he/she was asked to state whether this was just an exception or whether he/she didn't like the dish or ingredients at all. The answer was taken into account when updating the whole meal plan afterwards.
An additional feature of the prototype was a diagram that showed the present change of weight. This was meant to enhance of the user's motivation.

Implementation
The prototype consists of a database with information about some users and some dishes and a Java application that queries and stores this information and contains a Rete engine that is responsible for connection to the rule engine. We decided to use the Jess (Java Expert System Shell) rule engine, which is a further development of the CLIPS expert system shell [6]. One reason for this decision was the excellent performance of Jess due to the use of an optimized RETE algorithm [4]. By using Jess we are also able to manipulate Java objects via rule-based inferences and, because of the separation of the interface, the database and the interference engine, it is very simple to insert new functionalities into the recommender system just by including necessary knowledge formulated as rules (see example below) and by defining corresponding objects and database tables.

```
(defrule lactose-intolerant
?user <- (User(lactose TRUE))
?meal <- (Meal(lactose TRUE))
=> (retract ?meal))
```

The extraction of the recommended meals consisted of several steps and was partly iterative. Initially, the Java application reads out the information about the user and all stored dishes. Afterwards the Rete engine starts the rule engine. All the dishes containing intolerable ingredients were first deleted from the list of possible meals. The remaining meals were then rated by the stored information about the user. If the user, for example, liked or disliked particular dishes or ingredients, then the corresponding rating was increased or decreased respectively by the firing rules. In addition, dishes containing too many or too few calories gained a negative rating. After this rating the best-rated breakfast, lunch and dinner were added to the meal plan of the first day. The procedure was then repeated until the whole meal plan for one week was completed. To ensure a varied meal plan, all dishes already inserted into the plan gained a small negative rating. As mentioned above, the rating for the whole week was repeated- if the user rejected one or more dishes, because the reasons for the rejection could also have an influence on other recommended dishes.

4. CONCLUSION

We presented a model of a lifestyle recommender system for diabetes patients. Research into the effective management of clinical knowledge and patients' records is still challenging work, and the literature so far offers ideas rather than well-defined solutions. Furthermore, the design of a recommender system for clinical purposes needs particular attention compared to general commercial recommender systems that are oriented towards satisfying users' demands. With the clinical recommender, we are trying to change patients' lifestyles and to manage their daily activity based on strictly prescribed recommendations. This means that the system must also be able to reasonably limit patients' daily preferences if they are against the diabetes management program, rather than to recklessly encourage them. It is therefore important to design the system reliably so that patients follow recommendations confidently and, as supporting people or social circles also play a decisive role, the social components for lifestyle management should be taken into account, as well.

Much work remains to be done in the METABO project. For example, the next steps will be the clinical pilot study conducted by our medical partners which is currently running in seven METABO countries concurrently. This study will enable us to extend and validate the MED-StyleR in a practical way by investigating, for example, if collaborative filters really could work in our scenario.

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