

# DIETOS: a recommender system for health profiling and diet management in chronic diseases

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## ABSTRACT

Currently, there is a lack of food recommender systems able to provide high quality nutritional advices to both healthy and diet-related chronic diseases users, eventually exploiting typical regional foods. We present DIETOS (DIET Organizer System), a recommender system for the adaptive delivery of nutrition contents to both healthy subjects and patients with diet-related chronic diseases, including Chronic kidney disease (CKD), hypertension and diabetes. DIETOS builds health profiles of users and provides individual nutritional recommendation. Health profiling is based on user answers to dynamic real-time medical questionnaires, while food recommendation is extracted from the DIETOS catalogue. The catalogue contains typical foods from Calabria, a southern Italian region, because of their beneficial properties. For each food, nutrition facts, and indication or counter-indication for several chronic diseases are reported. DIETOS includes some well known methods for user profiling (overlay profiling) and content adaptation (content selection) coming from general purpose adaptive web systems. A preliminary version (for review purpose only) of DIETOS is available at <http://www.easyanalysis.it/dietos>.

## CCS CONCEPTS

- **Human-centered computing** → **Collaborative interaction**;
- **Applied computing** → **Health informatics**;

## KEYWORDS

Health Recommender Systems, Diet Management, Typical Foods

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## 1 INTRODUCTION

Diet-related diseases are the most common cause of death worldwide due to an excessive sature fat acids, animal proteins and/or free sugars intake [3]. Chronic kidney disease (CKD) [10] is characterized by a progressive and irreversible loss of kidney function and the main determinants of CKD and its progression are hypertension and diabetes, both clinically silent, i.e. asymptomatic [12]. The unawareness of being hypertensive, or diabetic or affected by CKD represents the main obstacle to the management of such patients. Therapeutic diet regimens have been individualized for different disease stages according to Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines [9]. The clinical profiling is a fundamental tool for the correct management of the diet in these patients and the monitoring of clinical responses and compliance to the prescription is the major mission of nephrologists and nephrology-dedicated nutritionists.

In recent years, different food recommender systems have been proposed in literature [5, 11]. Another example is Yum-me [14], a meal recommender that learns fine-grained food preferences without relying on the user's dietary history. However, currently, there is a lack of food recommender systems able to provide high quality nutritional advices to both healthy and diet-related chronic diseases users. Moreover, the impact on clinical outcomes of the available applications for diet and weight management, is not well-characterized [4]. Some recent works have focused on healthiness into the food recommendation by analyzing large Internet sourced datasets of recipes and the most used recommendation process [8, 13]. To the best of our knowledge, none of currently available

systems combine together health profiling, specialized dietary advices with focus to typical regional foods, clinical and compliance monitoring in users affected by chronic diseases.

We present the architecture and functions of a web-based Recommender System (RS) called DIETOS (DIET Organizer System). Early version of DIETOS was mainly devoted to profile tourists visiting Calabria and thus to recommend them regional foods compatible with their health status [1, 2]. This paper presents a revised and extended version of DIETOS that allows a deeper profilation of people affected by chronic diseases and may be used also in a clinical context for long term diet monitoring. Main innovative aspects of DIETOS are:

- The system provides individualized nutritional recommendations according to user health profile collected through several medical questionnaires provided by nutrition specialists and nephrologists and accomplishing to World Health Organization and KDOQI guidelines.
- The ability to profile not only healthy users, but also patients affected by CKD, hypertension and/or diabetes. For CKD users the system also provides glomerular filtration rate estimation using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula for disease staging.
- To the best of our knowledge, DIETOS is the first RS containing a catalogue of typical regional Calabrian foods. DIETOS provides to the users beneficial properties of typical Calabrian foods as well as benefits and side effects.
- DIETOS is able to achieve high quality health profiling because users also provide several clinical measurements (e.g. creatinine, blood glucose, blood pressure).

## 2 DIETOS

DIETOS (DIET Organizer System) is a web-based RS that profiles both healthy users and users with chronic diseases, including CKD, diabetes and hypertension. Based on user health profile, DIETOS provides individualized nutritional recommendations, also considering beneficial characteristics of the typical Calabrian foods. In order to define user health profile, DIETOS submits to the user a series of medical questions requiring the entry of different answers, including laboratory and vital parameters data. Users health profile is built by analyzing the answers given time to time by the user and by providing dynamically the next question for the user. The methodologies implemented in DIETOS make possible to obtain very accurate users' health profile that matches with the diagnosis made by the doctors using standard clinical procedures.

### 2.1 DIETOS Architecture

Figure 1 depicts the DIETOS architecture and its main modules: *DIETOSUserProfiler*, *DIETOSReminder*, *DIETOSHistory*, *CKDCalculator*, *DIETOSFoodsFilter* and *DIETOSSecurity*. The DIETOS Database contains several data tables about user profile, foods, pathologies, questionnaire, that are used by the software modules described below.

*DIETOSUserProfiler* by giving specific questions about clinical parameters (i.e. blood pressure, blood glucose and so on) to the users, can infer the user's health status. A set of questions used to profile a specific pathology is called questionnaire. Questionnaires

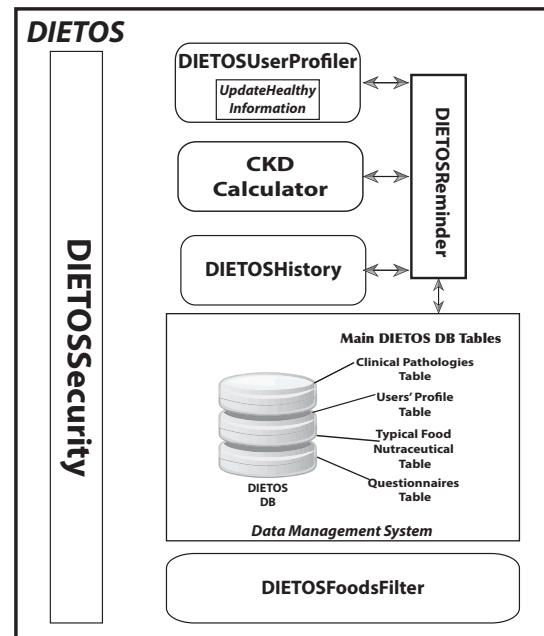


Figure 1: DIETOS Architecture.

are modelled by using a tree, where nodes are the questions while an edge connects two nodes related to them by a particular value (answer) to the current question. Questionnaires are adaptive, that is, the next question to submit to the user is obtained by analyzing the child's node of the current node of the questionnaire tree. This solution allows conveying to the users only relevant questions related to their real health status, making it possible to define the health profile accurately. Thus, the system gives to the user more accurate alimentary advice, related to his/her health status, avoiding to provide unsuitable advice. It is worthy to note that, the system described so far has the potential to provide alimentary advice only whether users are willing to answer the questions submitted. The questions to provide to the users are built upon the profiling methods provided by the medical team, as well as composing the results of querying the database that contains the information related to the pathologies.

*DIETOSHistory* saves all changes made by the user so that the data can be used to monitor the user's health status. DIETOS through the *DIETOSReminder* module can detect possible incongruence related with the newly entered values and the stored data. In the case that the entered values are probably incorrect, the system points out the potential incongruence to the user that can decide to revise or not the entered value. In this way, the system taking into account the user's history can suggest the most suitable foods, about his/her up to date state of health, as well as can provide to the users an automatic assisted procedure to manage his/her personal profile.

The *DIETOSFoodsFilter* can advise from the food list submitted by the user, the foods compatible with his/her health status, that can be eaten without side effect. The food selection is performed through a well known adaptation strategy of adaptive web systems

called "content selection". The *DIETOSFoodsFilter* selects all the foods that are labeled as *Recommended* or *Use Moderately* (see Table 2) according to the user profile (e.g. the disease). The results are conveyed to the users in a graphical format, specifying the correct quantity of each food that can be eaten daily, furthermore, advising alternative foods that can help tackle the health problems.

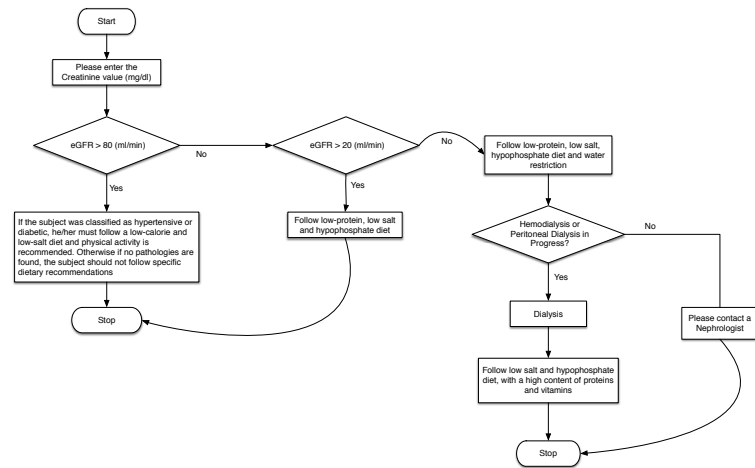
## 2.2 DIETOS Functions

The adaptive part of the recommender system uses well known techniques for user profilation and for content adaptation. In adaptive web systems [6, 7], information for building user models can be gathered by observing users, thus adopting the Automatic User Modeling (or Implicit Acquisition) or allowing users to directly intervene in the process of modeling, through content rating, questionnaires and explicit data provision. Such Co-operative User Modeling or Explicit Acquisition has been adopted in DIETOS system for user profilation. Specifically, the information gathered is used to build a so called "overlay user profile", described through a set of attribute-value pairs. In DIETOS, food recommendation is performed on the basis of user-specified health characteristics rather than past history of the users, as usually happens in RSs. A second aspect of adaptive web systems is the adaptation of contents and web structure to the user. In DIETOS a "content selection" strategy is used, as illustrated in the following subsections.

**2.2.1 User's profiling.** DIETOS dynamically builds a health profile for the user, necessary to determine which typical Calabrian foods are compatible or not with the user's health condition. The acquisition of the health profile is based on a simple, unidirectional and comprehensive set of questions called questionnaire, provided by the medical specialists that would categorize the screened subject as a diabetic, an hypertensive or a CKD patient. User profiling in DIETOS is done through the implementation of the guidelines used by doctors during the clinical investigation procedures. Guidelines are provided by the doctors in form of flow-charts. Currently DIETOS implements a sequence of three flow-charts for profiling diabetes, hypertension and CKD. As an example, Figure 2 show the last flow-chart for CKD profiling.

Flow-charts are implemented in DIETOS as questionnaires. It should be noted that the questionnaires employed in DIETOS are original, thus they cannot be found in the literature. In fact, although they are based on the international guidelines, flow-charts and related questionnaires were designed by medical specialists in our group. Questionnaires are represented in DIETOS as a tree whose nodes are all the questions used in the guidelines, whereas the edge connecting two nodes represents the answers.

**2.2.2 Food recommendation.** After the user has been profiled, the system recommends what typical foods can be consumed. DIETOS gives to the users information on typical Calabrian foods in three different ways: *i)* by automatically suggesting foods according to the user's health profile; *ii)* by displaying on a map the locality where the Calabrian foods are produced; finally *iii)* by showing the nutritional properties for each food stored in the database, including benefits and side effects on pathologies and specific health conditions. For example, Table 1 conveys the characteristics of some of the typical foods while Table 2 shows the beneficial effects of



**Figure 2: Flow chart used to profile a kidney user. This chart follows hypertensive and diabetics charts, thus the results of the left branch of this chart depends on the profile obtained by using the previous charts.**

the foods and the categories for which the typical product is recommended, should be used moderately or not recommended. To give users advice, DIETOS uses health status data of the profiled user, diseases data, and foods data. In particular, the *DIETOS Food-Filter* (see Figure 1) uses health-based, diseases-based, foods-based information to advise users.

**Table 1: Some examples of typical Calabrian foods (quantity 100 g) stored in database with relative nutritional facts**

Food	Nutrients			
	Calories (kcal)	Protein (g)	Fats (g)	Carbohydrates (g)
Cipolla di Tropea	26	1	0.1	83
Caciocavallo silano	439	37.7	31.1	2.3
Capocollo	450	20.8	40.2	1.4
Patata	77	2.02	0.09	17.46

**Table 2: Beneficial effects of the red onion of Tropea and the categories for which it is recommended, should be used moderately or not recommended.**

Beneficial effects	Recommended	Not recommended Use moderately
Hypoglycemic	Diabetes	Gastro-Duodenal Ulcer
Hypolipidemic	Hypertension	
Antioxidant	Cardio-Vascular Diseases	
Adjust the intestinal flora	Stipsi	
Diuretic effect	Dyslipidemias	
Laxative effect		
Digestive effect		

## 2.3 DIETOS Database

The DIETOS database stores data about users' health status and foods, linking personal health information with nutrition facts and effects of Calabrian foods. The food information and user data contained in DIETOS are archived into a MySQL database that includes the following tables: *Clinical Pathologies Table*, *Users Profile Table*, *Typical Food Nutraceutical Table*, and *Questionnaires Table*.

*Clinical Pathologies Table* stores pathologies identified by using the International Classification of Diseases<sup>1</sup>, 9th Revision, Clinical Modification (ICD9-CM) along with a description of the stored disease. Using ICD9-CM as identifier makes it possible to uniquely identify pathologies among all users around the world.

*Users Profile Table* stores all the personal and health information of the user, including the answers to the questions of the questionnaires and some indicators automatically computed (e.g. the eGFR - estimated Glomerular Filtration Rate, for CKD patients).

*Typical Food Nutraceutical Table* contains extensive information on many typical Calabrian foods. The database stores the Calabrian foods classified as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI). Tables 1 contain some examples of stored foods.

*Questionnaires Table* has been designed to store several different types of questionnaires provided by the medical group, which are used by DIETOS to profile the health status of each profiled user. In details, the database stores heterogeneous data such as the questions and the answers record.

## 2.4 DIETOS Prototype

All the information stored in the database are accessible to the user through a user-friendly web-based interface (let see Figure 3). In particular, the graphical interface is written in HTML5, CSS, and JQuery, whereas the server sides of DIETOS data querying and presentation are written by using the PHP (5.5.31 version) language. Information are archived into a MariaDB Server 10.1.19, developed by the original developer of MySQL with the aims to guarantee the open source nature of the database. The core algorithms and data structures of DIETOS are implemented by using PHP (version 5.5.31). The main advantages to use PHP is that, it runs on various platforms (Windows, Linux, Unix, Mac OS X) and it is compatible with almost all server like (Apache, IIS), as well as makes it possible to execute the user's call server-side efficiently and independently from the user web-browser.

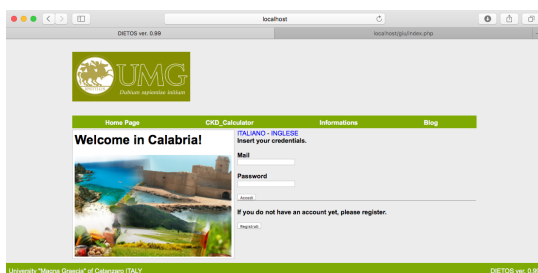


Figure 3: DIETOS home page.

<sup>1</sup><http://www.cdc.gov/nchs/icd/icd9cm.htm>

## 3 CONCLUSIONS

We presented DIETOS, a RS able to profile health status of both healthy people and individuals affected by chronic diseases (CKD, hypertension, and diabetes), and able to recommend typical regional foods, according to the health profile. Using the nutrition facts and annotations of foods stored in the database, DIETOS recommends to the users the foods compatible with their health status and, at the same time, discourages the eating of foods with negative side effects on their health status. The DIETOS prototype is currently under testing by the medical staff at the Department of Nephrology and Dialysis, University Hospital, Catanzaro (Italy), for long term monitoring of CKD patients and for evaluating the role of food suggestion on disease progression. As future work we plan to support user preferences using an hybrid approach that combines explicit food preferences and preference learning during DIETOS use.

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