DISYS: An Intelligent System for Personalized Nutritional Recommendations in Restaurants

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ABSTRACT
In modern urban lifestyles the consumption of prepared food in restaurants and fast foods is increasing constantly and is becoming a habit among citizens. One side effect of this way of life concerns the increase of the Body Mass Index because citizens tend to choose more foods with high amounts of energy, fats and saturated fats and less healthy foods such as vegetables and fruits. In this paper we describe an intelligent application called DISYS that aims to offer personalized information to consumers when visiting a restaurant in order to support them to select a dish or a meal that is within their preferences but at the same time is healthy for them and in line with their dietary targets and their health conditions. DISYS is operated by restaurant managers who configure the meals and dishes their establishment offers, as well as the nutritional characteristics of each meal. Moreover, dieticians can support their customers by analysing their actions and interactions with the DISYS application with respect to food consumption habits.

Categories and Subject Descriptors
H.3.3 [**Information Search and Retrieval**]: Information filtering, Selection process. H.3.5 [**Online Information Services**]: Web-based services.

General Terms
Algorithms, Design, Human Factors.

Keywords
Recommender Systems, Information Personalization, Nutrition, Mobile and Web-based applications.

1. INTRODUCTION
In modern urban lifestyles the consumption of prepared food in restaurants and fast foods is increasing constantly and is becoming a habit among citizens. One side effect of this way of life concerns the increase of the Body Mass Index because citizens tend to choose more foods with high amounts of energy, fats and saturated fats and less healthy foods such as vegetables and fruits [1]. Main reasons for this include the lack of proper information provided to citizens and the inadequate education with respect to the value of the various nutritional elements. However, as people already want to consume healthier foods, restaurants are beginning to include the nutritional information of the foods they offer in their menus and to offer healthier meals [2]. The chain of stakeholders in shifting citizens' habits is long as such endeavours require cross sectorial collaborations that involve the food industry, the food suppliers, dieticians, the public at large and politicians.

DISYS is an intelligent application that aims to offer personalized information to consumers in restaurants in order to support them to select a dish or a meal that is within their preferences but at the same time is healthy for them and in line with their dietary targets and their health conditions. In addition to consumers, DISYS is also addressing various stakeholders by offering relevant functionalities. Restaurant managers are able to configure the meals and dishes their establishment offers, as well as the nutritional characteristics of each meal. Dieticians can support their customers by analysing their actions and interactions with the DISYS application with respect to food consumption habits. The system can be accessed by any type of smartphone over the web which renders it usable within a restaurant, when the actual selection of food is made, or even before. Users have the capability to record the foods they consume through a simple and easy to use yet inclusive interface, which means that they can reflect and see their progress towards improving or maintaining their dietary habits.

The remainder of this paper is structured as follows: Section 2 provides an overview of the related work; section 3 describes the architecture of the system with an emphasis on the dietary profile and the recommender component; section 4 provides a typical usage scenario of the DISYS platform per system role; section 5 concludes the paper and provides our plans for further work.

2. RELATED WORK
With the advent of portable computers, including smartphones and tablets, a number of applications have been developed over the last few years which support users in identifying and selecting the meals and recipes they like. Such applications

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commonly suggest recipes and ingredients that are within the users' preferences and their aim is to support users in eating healthier. Related systems can monitor users' actions through e.g. sensors in kitchen utensils and infer the users' capabilities [3]. Other systems consider the number of ingredients involved in a recipe and provide indications of the difficulty in preparing a meal while this knowledge is used in order to gradually introduce more complex recipes and educate the user in a stepwise approach [4].

Other streams of research have focused on understanding the factors influencing user preferences and the ratings of meals and recipes. As expected, common reasons for receiving negative feedback are the lack of ingredients or combinations of ingredients that the user prefers as well as the time that a recipe requires in order to be prepared. On the other hand reasons for receiving positive feedback refer to easy and quick preparation, user preferences for specific ingredients as well as the fact that a meal can be considered as "interesting" or novel for the user [5]. Considering the above, the user ratings for a meal can provide indications regarding the user's preference for the ingredients that comprise the specific meal and vice versa, using ratings on ingredients, a system can generate suggestions on meals. However user preferences inferred from ratings on ingredients have been shown to produce more likeable suggestions [5].

Another line of work focuses on generating suggestions for groups of users, e.g., a family. The main issue in such cases is the selection of meals that are preferred by all the members of the group. Common strategies that are used in such cases involve the summation of group members preferences over the items (either meals or ingredients) which lead to a model that represents the group preferences and can be used to generate suggestions or to first generate a set of suggestions for each individual in the group and then to estimate which of the suggestions make sense for the group as a whole [3].

With respect to applications of personalized meal suggestion systems, related work shows the multitude of their applicability. In hospitals and health facilities such systems have been successfully used to identify meals that patients will like better [6]. In Trevisiol et al. [7] an application for personalized suggestions in restaurants is proposed that leverages user reviews for the restaurants which are available in the web and natural language processing techniques. The application does not include the owners of the restaurant in the loop which is one of the functionalities provided in DISYS. Fudholi et al. [8] designed and developed a system to support the selection of foods and meals in the context of a project for improving citizens' health. The system makes use of an ontology that models users' dietary needs and a number of rules which are used in order to generate suggestions. Users enter their preferences and the ingredients that they are not allowed to consume due to their health status and the system generates suggestions of meals from its database. DISYS extends the proposed rule based approach and combines it with machine learning in order to optimize results by considering users' feedback.

Tumnark et al. [9] describe a food suggestion system for athletes performing weight lifting. The approach is knowledge based and focuses on implementing expert rules. Chang-Shing et al. [10] implemented a web-based expert system based on ontologies that model user preferences and food properties in order to provide advices for healthier eating. Recipes are stored in a database together with the ingredients they contain and the corresponding quantities. Users can search for foods using ingredients and their quantities. A similar system is described in [11] where the authors provide interfaces for cooks and consumers in order to plan healthy meals. The aforementioned systems are not used in the context of a visit to a restaurant but can provide general information on recipes and meals.

Last but not least, there are commercial systems that help users to browse the menu of a restaurant (see e.g. E-Table[1] or eMenu[2]). However such systems are mostly used to automate the ordering and payment processes and not to support users to select a meal based on their preferences.

3. DISYS ARCHITECTURE

The aim of DISYS platform is to provide an intelligent system that offers personalized dietary recommendations by considering the user's preferences, the user's level of physical activity, and a number of selected health indices including sugar level and blood pressure level. The system then suggests the meals that the user can consume in a restaurant in order to not endanger her/his health. DISYS is implemented with the state of the art PLAY web application framework[3] and follows a responsive design which renders the system accessible through any latest generation web browser including mobile phones.

The architecture of the platform is depicted in Figure 1 and comprises of five layers that interact in order to offer the desired functionalities to the end users. In the following subsections we provide a description of the functionalities of each layer.

3.1 Data Layer

This layer contains all the data and information required by DISYS. For the *food ingredients* and nutritional data we make use of the USDA[4] database v.26 which has been extended with additional information required by our platform. The original database has been created by the United States ministry of agriculture and is the reference database for most of the food information and ingredients repositories throughout the world. For the purposes of DISYS, the USDA database has been extended with ingredient items of the Greek Food Ingredient Tables[5]. Moreover, all 14000 entries of ingredients in the database have been annotated with a set of categories in order to enable the selection of entries on the basis of user preferences with respect to a specific category of ingredients.

The *central database* is used to store information related to users and restaurants. In more details, the user profile contains personal data such as demographics, health record related information, dietary information as well as user preferences with respect to ingredients (inclusions or exclusions of certain ingredients). The restaurant profile contains data referring to the restaurant manager and her / his restaurants, including contact details, type of cuisine, recipes along with their ingredients and indication of allergens, as well as cost of meals. Furthermore, the data layer includes the *repository of rules* which are used in order to infer and calculate user characteristics and derive preferences which are subsequently used to generate the suggestions.

[1] http://www.e-table-interactive.com

[2] http://www.emenu-international.com

[3] https://www.playframework.com/

[4] http://ndb.nal.usda.gov/

[5] http://nutrition.med.uoc.gr/GreekTables/Main/main.htm

3.2 Dietary Profile layer

This layer is further divided to the consumer and restaurant manager sub-layers. The *consumer sub-layer* encompasses all the required business logic required for the user to be able to enter personal information and to be able to monitor her/his dietary habits by easily logging the foods s/he consumes. Based on this information, the system is able to calculate various variables which can allow users to reflect on their habits and adjust them towards healthier eating. In more details, DISYS calculates the nutrients (calories, fat, fibres etc.) and the macro and micro nutrients of each ingredient consumed based on the Dietary Reference Intakes (DRI) and calculates the daily intakes per nutrient so that the user can keep daily track of his/her eating habits and how these habits affect the overall nutrient intake. Moreover this layer contains the functionalities that allow users to search for a restaurant based on criteria such as location, type of cuisine and average cost per meal. Once users provide this information the system generates the meal recommendations for the specific restaurant. Finally users can rate the provided suggestions and provide feedback which allows the system to learn and adopt better to user preferences (we provide more details in Section 4).

The *restaurant manager sub-layer* provides the business logic required for users to enter information that describes their restaurants as well as the recipes of the meals that comprise the menu of the restaurant. A structured workflow of recipe's entry has been implemented where users select the set of ingredients that comprise the dish from the USDA database and their quantities. Once the workflow is completed, the user can see information related to the Guideline Daily Amounts (GDA) and Nutrient Reference Values (NRV) of the newly entered dish.

3.3 Recommendation Layer

The aim of this layer is the generation of personalized suggestions based on information stored in the user's profile as well as a set of real time preferences set by the user during the dish selection process. For the calculation of the utility we make use of a set of rules which have been specified by domain experts. These rules include both calculative as well as conceptual rules that regard both the nutrient intakes, as well as the inclusion or exclusion of specific ingredients, based for example on the user's preferences or on medical conditions as described in section 2 (e.g. type 2 diabetes). The process comprises of three steps which lead to a set of recommendations (see also Figure 2).

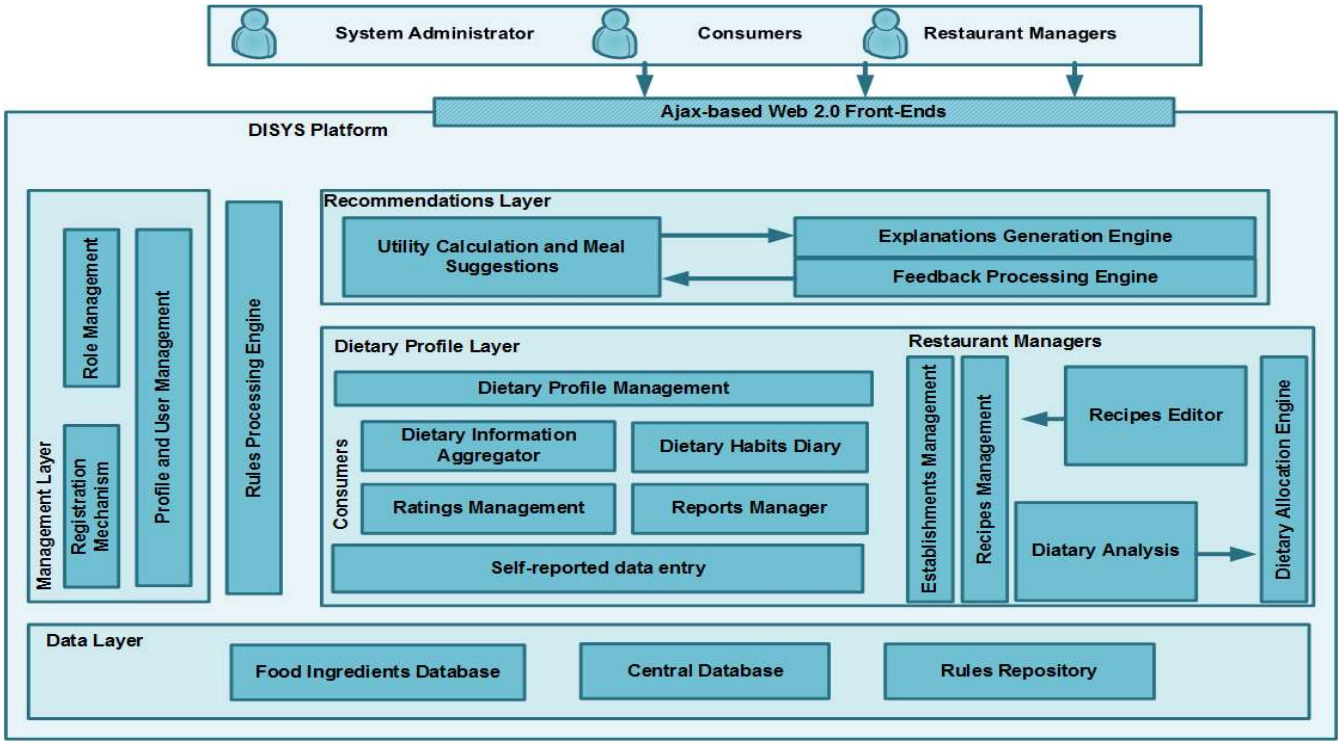

Figure 1: Overview of the DISYS layered architecture.

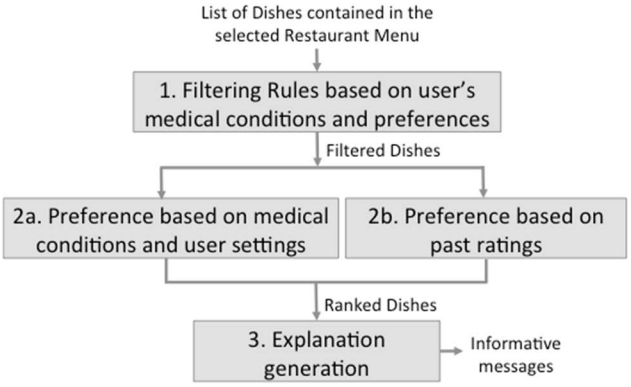

Figure 2: The processing steps of the DISYS recommender.

In the first step we filter dishes that are not relevant for the specific user based on her/his dietary profile. Dishes are excluded if the user has medical conditions which do not permit him to consume one or more of the ingredients contained in the dish, intolerances to certain nutrients which are contained in the

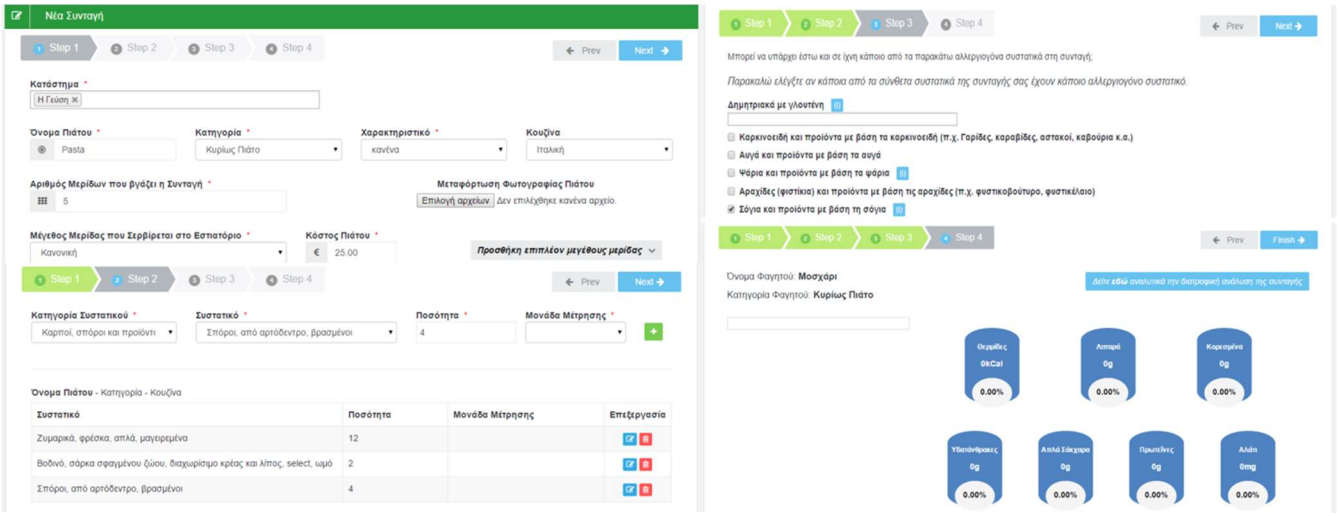

Figure 3: Restaurant Manager view: Entering a new dish and its ingredients in DISYS.

dish (such as gluten) or allergies to certain substances. Note that the modelling of the ingredients in the USDA database allows us to efficiently search and identify dishes that contain ingredients which should not be consumed by the user.

In the second step, a preference value is attached to each dish offered by the restaurant, by combing preference values calculated by two different approaches. In the first approach, a set of rules sets a preference value to each dish offered by the restaurant. In order to infer this value we consider two aspects of the user profile, namely medical conditions which although they allow the user to consume the dish, this should be with low priority over other, more suitable dishes (consider for example the case of a user with high blood pressure who should prefer foods with low salt), and real time preferences of the user as these are expressed in the settings of the meal selection process.

More specifically users have the option to select categories of ingredients which they prefer or do not prefer (the list is comprised of a set of 10 ingredients as follows: eggs, lamp, cheese, soya, veal, shells, pork, wheat, lactose and milk, seeds). In the second approach, we combine information provided by the user as feedback for previous suggestions in the form of ratings. The approach is based on a form of a content based recommender system. When a user provides a rating for a specific dish, we disaggregate this rating to all the ingredients of the dish. This means that as time passes and more ratings are received from the user we gradually create a model of user preferences over ingredients. When we want to estimate the preference of the user for a specific dish, we use the weighted sum of the preferences for the known ingredients. Our recommender is trained in regular intervals in order to be adjusted to user preferences better.

In the third and final step the recommender attaches a small text to the dishes which will be presented to the user, explaining what are the benefits of the specific dish. The approach we follow here is based on a set of rules specified by experts. The rules contain an informative message depending on the ingredients of the dish. The rules of the recommendation layer described above have been implemented in a rule-processing engine as presented below.

3.3.1 Rule Processing Engine

This engine provides the required functionalities for real time calculations and inference of user profile characteristics using her / his dietary profile. For the purposes of DISYS we have selected the open-source JBoss® Drools[6] rule processing engine. The drools engine is designed for fast and efficient real time processing of simple rules which renders this technology a perfect fit for our purposes.

In general, as modern database management systems and rule execution engines are evolving and provide faster data access and lower execution times, there is a trend of persisting knowledge and information instead of encoding it in the source code implementing the business logic of a platform [12].

The inferences and conclusions which are the output of the rule processing system can be divided to three distinct categories:

Inferences concerning the dietary preferences of the end user / consumer. Depending on the preferences that the end user has stated in her / his profile, the corresponding rules may exclude dishes which contain ingredients that the user does not want or allocate a high preference value to dishes that the user prefers.

Inferences which concern the medical history and conditions of the user. If the user has stated that he has one or more of the supported medical conditions (diabetes, anemia, constipation, celiac disease and hypertension) the implemented rules exclude the dishes that the user should not consume. The exclusions can be qualitative, i.e. whole categories of ingredients are excluded or quantitative, i.e. a dish is excluded only if it contains an ingredient at a certain amount or over that.

Inferences that concern the dietary targets of the consumer. These are calculated based on the rules that derive the daily needs of the users in micro and macro nutritional ingredients as well as the total calories the user has consumed. For these calculations user profile characteristics including the users' weight, height and level of physical activity are taken into consideration.

It's important to note that with the use of Drools offers the advantage of live updates of rules without the requirement to re-compile and re-deploy the entire system.

3.4 System Management

This layer supports various management functionalities including: user registration in the DISYS platform (including

[6] http://www.drools.org/

consumers and restaurant manager), user profile management and update and user management (this is a functionality offered to the system administrator).

any special characteristics and the type of the cuisine the dish belongs to. The manager can upload a photo and specify the number of portion which correspond to the recipe which is going to be entered in the next step as well as the price of the dish. In

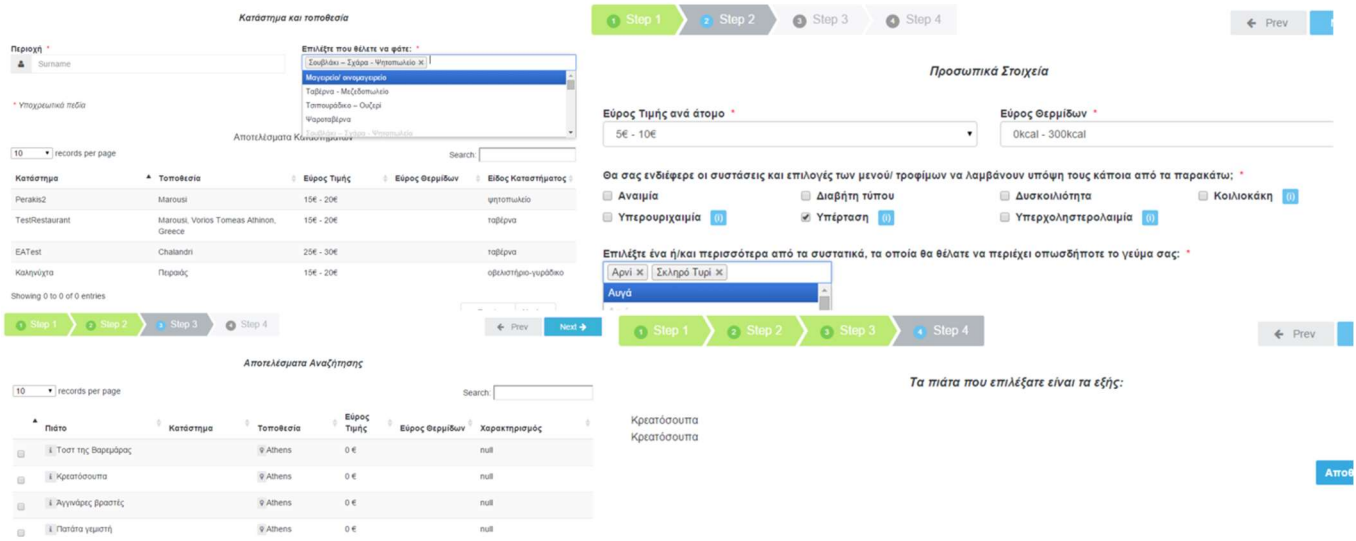

Figure 4: Customer views of DISYS while selecting a dish.

3.5 User Interfaces Layer

This layer provides the set of web pages that are accessible to users. The interface makes use of responsive css elements and related javascript which renders it responsive and accessible by any modern web browser and related device, including smartphones and tables which the user may have in her/his visit to the restaurant. A mobile application implementing all the functionalities of the customer views also been developed. Figure 3 corresponds to the interface of the restaurant manager related to the process of entering a new dish and its ingredients in DISYS, while Figure 4 corresponds to the customer views of DISYS while selecting a dish.

More specifically, Figure 3 illustrates the step-wise approach followed by the restaurant manager in order for him to enter a new dish and its ingredients in DISYS. The restaurant manager has to firstly select the restaurant(s) with which the specific dish is associated (namely where it is served), the dish category, the cost, and define a set of metatags that are associated with the dish. Next to that, the restaurant manager selects all the ingredients that comprise the dish, and once completed s/he can move on to step 3 and specify allergens associated with the dish. In step 4 the process is completed and the restaurant manager can view the nutritional analysis of the dish.

4. USAGE SCENARIOS

In this section we provide three typical usage scenarios of DISYS; one usage scenario for restaurant manager and two usage scenarios for customers. Regarding the customer usage scenarios, the first scenario will be a general one, while the second will involve a customer who has a medical condition present.

4.1 Restaurant manager scenario

One Restaurant managers typically enter the details of the dishes their establishment offers to customers following the workflow presented in Figure 3. In the first step, the manager is asked to provide details regarding the dish including a name, a category, the second step the manager provides the ingredients of the dish, by selecting first the category of the ingredient, the ingredient itself, its quantity and the measurement unit of the quantity. Note that in recipes we meet various types of measurement units (such as a spoon of salt, 10 grams of butter, a cup of oil) so we allow managers to specify the unit used per ingredient. The system then converts all units to grams, using predefined conversion rules (e.g. one spoon refers to 0.5 grams etc.). In the third step the manager selects any allergens which are contained within the ingredients. Note that in DISYS this is an indication which is presented to the user. Finally DISYS computes several dietary indices related to the dish as shown in Figure 5, including the total calories, fats, saturated fats, carbohydrates, sugars, proteins and salt contained in the dish, which allows the manager to understand the nutrients value of the dish.

Nutritional Value of your Meal		
Average analysis of nutrients	**Per 100gr**	**Per portion**
Energy	314.29Kcal (11.49%)	11kcal (0.4%)
Fats	10gr (10%)	12gr (14%)
Saturated	6gr (30%)	8gr (35%)
Carbohydrates	57.14gr (40%)	70.4gr (60%)
Fibers	1gr (20%)	2gr (40%)
Proteins	2gr (10%)	4gr (20%)
Salt	257mg (30%)	532mg (60%)

Figure 5: Indicative Nutritional Analysis of Suggested Dishes.

4.2 Customer scenario - No Medical Record

Customers typically use DISYS while they are selecting a restaurant to visit. The aim is to support them in selecting the restaurant and the dishes to consume. In the first step (Figure 4) the customer selects the area s/he wants to visit and the type of restaurant (e.g. a fish or meat restaurant, a tavern etc.). DISYS retrieves all the corresponding to search parameters restaurants and presents them in a list. The map location of the restaurant can be also be displayed to the user at this step. The user selects

one of the restaurants and is directed to the second step. There the user enters the preferred price per person, the calories range, and any major conditions the user may have (including diabetes, anemia, constipation, celiac disease and hypertension). Moreover the user selects a set of category ingredients which he would like to taste in the restaurant (e.g. lamp, milk etc.). When this information is submitted the recommender selects a number of dishes and ranks them according to the perceived by the system user preferences. The list of dishes is presented in the third step. The user can make her/his final selection by selecting the set of dishes she is going to order and eat. DISYS allows the user to save her/his choice in order to retrieve it when s/he visits the restaurant.

4.3 Customer scenario - Medical Record

The recommendation algorithms of DISYS are capable of suggesting dishes based on the medical conditions of customer, by excluding dishes that are not suitable for the customer's diet from the returned set of suggested dishes. The usage scenario is similar with the one described in the previous section, the difference being that dishes incompatible with the user's condition will now be excluded. In the case of pregnancy moreover, the percentage of nutrients displayed for the suggested dishes will be adjusted to take into account the customer's status (Figure 5).

Furthermore, in the recommendations panel, DISYS will provide basic guidelines for what the customer must take into account when choosing meals (Figure 6). Basic parameters that are taken into account are: a) abnormal values of BMI, b) pregnancy or breastfeeding and c) any of the following conditions: anemia, diabetes type II, constipation, celiac disease, hyperuricemia, hypertension and hypercholesterolemia.

Hypercholesterolaemia
Make sure that your weekly diet contains
- At least two meals with fish rich in fat (consider sardines or mackerel)
- Unsalted nuts
- Olive oil, but be careful in the amount you eat
- Cereals and wholegrain wheat
- Legumes
- Plant sterols and stanols

Make sure to avoid
- Animal fats (including dairy products and red meat)
- Fried foods
- Huge quantities of fats
- Salt and salty foods
- Sedentary lifestyle

Figure 6: Indicative recommendations to customers based on her medical record.

5. CONCLUSIONS AND FUTURE WORK

We presented DISYS, an intelligent application that offers personalized information to consumers when visiting a restaurant in order to support them to select a dish or a meal that is within their preferences but at the same time is healthy for them and in line with their dietary targets and their health conditions.

Currently we are in the process of piloting the system in collaboration with the largest network of dietitians in Greece (controlled by the company Nutrimed) who provide the links to restaurants and end-users. Our aim is to gather feedback on the usability of the system as well as the quality of the recommendations through real life validation and testing by restaurant managers and their customers.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Kant, Ashima K., and Barry I. Graubard. 2004. Eating out in America, 1987–2000: trends and nutritional correlates. *Preventive medicine*, 38, 2, 243-249.

[2] National Restaurant Association. 2013. On the menu: Restaurant Nutrition Initiatives. Nutrition Report. Retrieved May 22, 2015 from https://www.restaurant.org/getattachment/Industry-Impact/Food-Healthy-Living/Nutrition-Report_Final_low.pdf

[3] Wagner, Juergen, Gijs Geleijnse, and Aart van Halteren. 2011. Guidance and support for healthy food preparation in an augmented kitchen. In *Proceedings of the 2011 Workshop on Context-awareness in Retrieval and Recommendation*, ACM, 47-50.

[4] Harvey, Morgan, Bernd Ludwig, and David Elsweiler. 2012. Learning user tastes: a first step to generating healthy meal plans?. In *First International Workshop on Recommendation Technologies for Lifestyle Change*, 18-24.

[5] Freyne, Jill, and Shlomo Berkovsky. 2010. Intelligent food planning: personalized recipe recommendation. In *Proceedings of the 15th international conference on Intelligent user interfaces*, ACM, 321-324.

[6] De Pessemier, Toon, Simon Dooms, and Luc Martens. A food recommender for patients in a care facility. 2013. In *Proceedings of the 7th ACM conference on Recommender systems*. ACM, 209-212.

[7] Trevisiol, Michele, Luca Chiarandini, and Ricardo Baeza-Yates. 2014. Buon Appetito-Recommending Personalized Menus. In *Proceedings of the 25th ACM conference on Hypertext and social media*. ACM, 327-329.

[8] Fudholi, Dhomas Hatta, Noppadol Maneerat, and Ruttikorn Varakulsiripunth. 2009. Ontology-based daily menu assistance system. In *6th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, IEEE, 694-697.

[9] Tumnark, Piyaporn, Leandro Oliveira, and Nonchai Santibutr. 2013. Ontology-Based Personalized Dietary Recommendation for Weightlifting. In *International Workshop on Computer Science in Sports*. Atlantis Press.

[10] Lee, Chang-Shing, Mei-Hui Wang, Huan-Chung Li, and Wen-Hui Chen. 2008 Intelligent ontological agent for diabetic food recommendation. In *International Conference on Fuzzy Systems*, IEEE, 1803-1810.

[11] Chakkrit, Snae and Michael Bruckner. 2008. FOODS: a food-oriented ontology-driven system. In 2nd IEEE International Conference on Digital Ecosystems and Technologies, IEEE, 168-176.

[12] Nikitas N. Karanikolas. Knowledge and Information in Nutrition Software design. Procedia, Social and Behavioral Sciences, vol. 147, 398-404