Electronic Monitoring of Nutritional Components for a Healthy Diet

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Abstract

Obesity and other diseases related to unhealthy diet are problems of near epidemic proportion and become a growing issue every year. This paper presents a solution to this issue by proposing the use of a computer application that is able to suggest the appropriate products related to one's diet, and to keep track of nutritional intake. The paper also describes the principle of the solution, system architecture and implementation and presents testing results. If the application's instructions are followed by users it is expected that an optimal diet will be achieved resulting in users good health.

Keywords: Healthy diet, e-health, utility function, nutrition control

1 Introduction

Some of the most serious social issues of our time are obesity and dietary problems. Approximately 39% of Irish adults are overweight and 18% are obese [1]. Approximately two thousand premature deaths are attributed to obesity annually, at an estimated cost of €4bn to the Irish State, expressed in economic terms [1]. People are not conscious of the gravity of these issues and consequently the situation is worsening. In order to combat this growing problem it is necessary to bring it to the attention of society. One way to achieve this is an application that enables people to monitor and control nutritional value in a fast and simple way while shopping.

The aim of this research is to propose computer based solution which will assist users in controlling the nutrition values of the food products they buy. The application will include several diet plans suitable for potential users from simple ones which focus on the energetic values of the products (expressed in calories), to more complex ones which also consider other nutritional components such as proteins, carbohydrates, sugars and fats. By using a utility function, the proposed solution will select a set of products from a range of products considered by the user for purchasing based on their nutritional values and the user's selected diet plan.

An important goal was also to build a highly usable and portable application as possible. In order to achieve this, an application was developed to be used not only on a laptop or desktop PC but also on smart phones, PDAs and gaming consoles. Consequently a web browser accessible application was designed, implemented and tested. It uses a server-located database to minimize the memory consumption on the client devices and give higher flexibility. With this approach users may work with information held in an in-shop database, which is customized for each individual shop to reflect the products available there.

This paper is structured as follows: Section 2 summarizes related work, section 3 describes the design of the proposed solution as well as the algorithm, whereas section 4 presents the testing process and related results. The paper finishes with section 5 which focuses on conclusion and future work.

2 Related Work

The diet monitoring problem is not a new one, as software for computing calories or nutrition diaries have been developed since 1980's. There were many such applications such as "The diet balancer" [2] or "MacDine II" [3], but they differ in approach and target audience.

In 1999 a diet calculation software called FUEL Nutrition Software was released [4]. This application was capable of calculating the nutrition values for professional athletes. FUEL allows the access to applied sport nutrition information on topics such as nutrition during regular training, food appropriate for pre- and post-exercise meals, eating for recovery, hydration, eating strategies during trips or in forezign countries and vitamin and mineral supplements. The program is suitable only for fit and healthy individuals. Anyone with special health conditions such as diabetes, osteoporosis, etc. will require individualized professional advice [4]. The program itself offered many interesting solutions but was targeted at professionals and was developed for stationary computers.

An other electronic system is eHDNAS – electronic Healthy Diet and Nutrition Assessment System [6]. This recently developed software was created to fight malnutrition and other nutrition related disease over a sustained period of time. Its aim was to inform people about the nutrients of certain foods in restaurants and it is mainly based on the food pyramid described in [5]. The system specifically targeted elderly people. This is a major limitation as such applications should take into account people of all ages. Another drawback of the system is that it operates on full meal level, rather than a product level, which makes it very inflexible as regards to individuals eating habits.

The report on "The Food We Eat" [7] found that it is more user friendly to work with barcode scanners than voice recording, while using electronic self monitoring application. This observation influenced the decision to use barcode scanning for this application. Those results were gathered by tests carried out on a group of participants with an average age of 52 and using the *DietMatePro* [8] and *BalanceLog* [9] applications.

DietMatePro is a commercial web application designed specifically for PDAs, that uses the expandable *USDA*-based nutrient database [10] and supplemental databases for restaurant and brand name foods. It addresses the needs of researchers and dietitians. While a very powerful dietary tool a major drawback of this application is that it was developed for scientific purposes, and as such lacks the simplicity for more general use.

3 Design and Solution

3.1 Architectural Design

The main aim when designing this application was to create user-friendly, portable software for calculating nutrition values. It is supposed to also be flexible and customizable. To fulfill these requirements it must have different diet plans and must enable the creation of user specific diets. Many previous attempts to solve the diet monitoring problem resulted in diet diaries or calorie counters. While it was desirable to include calorie counter functionality it was also wished to go a step further and create a diet validator: i.e. given a set diet plan to which an individual is to adhere to the application can verify if a users food shop falls within the nutritional parameters of this plan. Another design prerequisite was to enable the user to run the application not only on a PC, but also on mobile devices such as smart phone, PDA and portable game consoles. MySQL database, Java Server Pages and Tomcat web server were used in order to achieve these goals.

Information about the products and diet plans is stored in the database. There is a server side administration interface enabling the modification of the database to reflect the products available.

In order to provide a degree of flexibility to users, the solution was deployed into a web application which can be accessed using any web browser. This makes the application accessible for any owner of a networked mobile device.

The application was placed in a Tomcat web container which enables multithreading, allowing multiple users to access the application simultaneously at the same time.

Figure 1 illustrates the proposed system architecture. It can be seen clearly that the user connects to an in-store Wi-Fi network and then by means of a web browser on their mobile device can communicate with the Tomcat web server that maintains the web application which communicates with the database in order to retrieve the data. It is believed that the best solution is to have a separate database in every shop so a user entering the shop would use that shop's database which contains only the products available there. Alternatively a shop ID can be used to select the products within a particular shop from a larger central-located database.

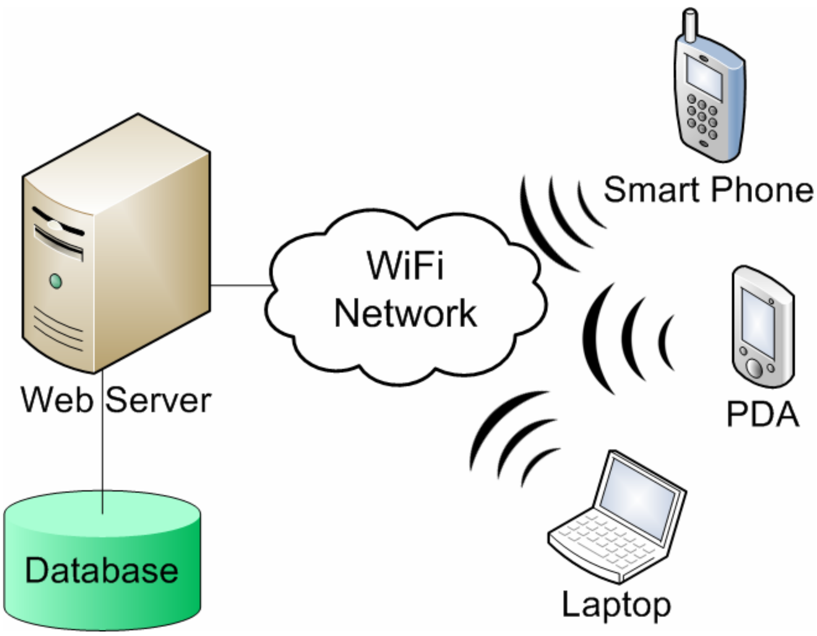

Figure 1 Architectural Design

3.2 Algorithm Description

A novel algorithm is used for verifying the compliance of products with users' diet plans. The algorithm is based on a modified Knapsack problem, which takes into consideration all nutritional values: energy, as well as carbohydrates (including sugars), proteins and fats. The algorithm's goal is to ***optimize the selection of products in order to maximize their utility to users, according to their diet plan***.

A novel utility function was introduced to describe the usefulness of the product to users. This utility considers grades computed for each nutrition component, weighted according to the importance of that particular component for a user diet plan.

Below equation 1 presents the function for calculating the utility of a product *i*.

$$Utility_i = \frac{w_1 * G_{i\,proteins} + w_2 * (G_{i\,carbohydrates} - G_{i\,sugars}) + w_3 * G_{i\,fats}}{w_1 + w_2 + w_3} \qquad (1)$$

In equation (1) w_1, w_2 and w_3 are weights which depend on the diet type and express the importance of the nutrients in any specific diet plan. $G_{i_{proteins}}$, $G_{i_{carbohydrates}}$, $G_{i_{sugars}}$, $G_{i_{fats}}$ represent the grades computed based on the quantity of a particular nutrient and are expressed in the [0:1] interval.

Equation (2) presents the formula for calculating individual grades.

$$G_{i\,nutrient} = \frac{Q_{i\,nutrient}}{Q_{i\,proteins} + G_{i\,carbohydrates} + G_{i\,fats}} \qquad (2)$$

In equation (2), $Q_{i_{proteins}}$, $Q_{i_{carbohydrates}}$, $Q_{i_{sugars}}$, $Q_{i_{fats}}$ represent the quantities with which each individual nutrient component is present in the product *i*. The nutrient component grade $G_{i_{nutrient}}$ describes the ratio of certain nutrients in comparison to all nutrients within the given food item.

The equation for calculating the utility parameter of the product was based on the healthy diet pyramid as presented in Figure 2. It states that the healthiest products are those which contain the smallest possible amount of fats and sugars. This equation gives the highest values to products containing the most protein and carbohydrates (excluding sugars) and the lowest to those with high levels of fats and sugars.

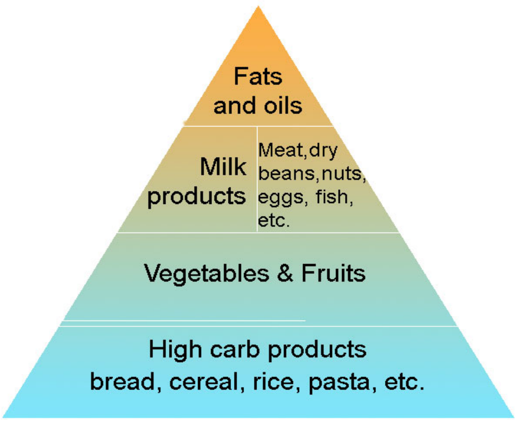

Figure 2 Healthy diet pyramid

Having calculated the utility of every product, the benefit of the product in terms of value to a particular user is computed as the ratio between the utility and the calorie amount suggested to the user by their diet plan. Next all the products are sorted in descending order based on their value to the user. The products whose energy values are exceeding the user's calorie limit which is computed based on their physical parameters (weight, height, age, gender) are discarded and are not shown.

The Knapsack problem uses as limit a **daily energy requirements (DER)** expressed as a calorie amount, but this number is different for every user as people are characterized by different physical parameters. To calculate the amount of calories to be "spent" by each user the Mifflin formula was used [11]. This equation expresses Resting Daily Energy Expenditure (RDEE) and uses parameters such as weight, height, age and gender.

These formulae were used as they give a very high accuracy (over 80%) [12]. They are presented in equation (3):

$$RDEE_{male} = 5 + (10 * weight) + (6.25 * height) - (5 * age) \quad (3)$$

$$RDEE_{female} = (10 * weight) + (6.25 * height) - (5 * age) - 161$$

In order to calculate users' DER, a formula that factors in the so-called **activity factor** was used. This is essentially a number based on the level of physical activity the users have interactively selected. The users can choose between: sedentary, lightly active, moderately active, and extremely active. This activity factor is multiplied by the RDEE value and the result expresses DER. DER is used as limit by the Knapsack problem.

4 Testing

The proposed algorithm was deployed in a system that conforms to the description made in section 3. The application was tested in a number of different settings which included variable diets and different user parameters (weight, height, gender, etc.).

The application provides user choice between several diet plans and different diet consideration modes. After running the application in the web browser user may choose one of the following options: Weekly Shopping or Diet Check. Weekly shopping is an option enabling user to do the shopping for a specified number of days. It involves using calculated DER as a limit for calorie counter per each day. The application adds up the energy values of each product in the cart and if the limit is reached prints the notification. Another option is Diet Check, where application uses the algorithm described in section 3.2. The System creates a list of most diet suitable products from those in the users' cart.

Name	Energy	Proteins	Carbohydrates	Sugars	Fat
Dark Chocolate	487	6.0	55.0	49.0	27.0
Chinese dish	277	9.9	47.8	1.0	5.2
Golden Syroup	310	0.5	77.5	77.5	0.0
Sweet'n'Sour	363	0.4	20.8	10.0	0.1
Fish in oil	329	16.3	0.1	0.0	29.3
Hot dogs	295	10.8	4.0	0.2	26.2
Raisins	326	3.0	71.0	71.0	0.7
Ketchup	140	2.4	31.5	27.8	0.1
Popcorn	487	15.1	69.9	4.4	16.4
Hellmans	722	1.0	1.3	0.0	78.6
Pasta Spagetti	355	12.5	73.0	2.4	1.4
Rice Vinegar	21	0.4	4.9	0.3	0.0
Bread	210	8.7	43.0	0.1	1.4
Hazelnut spread	570	3.8	54.4	52.4	37.2
Kitkat	531	5.2	61.6	49.0	29.3

Table 1: Test 1 - Input products

Name	Energy	Proteins	Carbohydrates	Sugars	Fat
Hellmans	722	1.0	1.3	0.0	78.6
Hazelnut spread	570	3.8	54.4	52.4	37.2
Hot dogs	295	10.8	4.0	0.2	26.2
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Table 2: Test 1 - Sorted products

Currently the application offers two specified diet plans: normal diet plan and protein diet plan. Normal is suitable for most healthy people and assigns higher level of importance to products that are described as significant for each healthy person. Second diet plan is based on protein diet, in which more valuable are proteins. This diet plan could be addressed to athletes wishing to build muscle mass.

The first test used the ***diet check mode*** and the ***normal diet type*** the utility value of products was calculated and is presented in Table 1.

As presented, the above algorithm works successfully on the chosen group of products. It can clearly be seen, that in Table 1 there are products in the order in which they were added to the cart. Table 2 includes the same products sorted in the order of their significance to the user diet. On the bottom of the table there are flavor products with high value of carbohydrates and proteins while on the top are products with sugars and fats. Results are correct as the layout of the table corresponds to the pyramid of healthy diet which was presented in Figure 2.

The second test involved the ***diet check mode*** and the ***protein diet type***, where the most valuable products are those with significant amounts of proteins and the smallest amount of fat. The test produced the following results, as shown in Table 3 and Table 4.

Name	Energy	Proteins	Carbohydrates	Sugars	Fat
Chinese dish	277	9.9	47.8	1.0	5.2
Golden Syroup	310	0.5	77.5	77.5	0.0
Sweet'n'Sour	363	0.4	20.8	10.0	0.1
Hot dogs	295	10.8	4.0	0.2	26.2
Fish in oil	329	16.3	0.1	0.0	29.3
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Hazelnut spread	570	3.8	54.4	52.4	37.2
Bread	210	8.7	43.0	0.1	1.4
Dark Chocolate	487	6.0	55.0	49.0	27.0
Kitkat	531	5.2	61.6	49.0	29.3

Table 3: Test 2 - Input products

Name	Energy	Proteins	Carbohydrates	Sugars	Fat
Hellmans	722	1.0	1.3	0.0	78.6
Hazelnut spread	570	3.8	54.4	52.4	37.2
Kitkat	531	5.2	61.6	49.0	29.3
Dark Chocolate	487	6.0	55.0	49.0	27.0
Golden Syroup	310	0.5	77.5	77.5	0.0
Raisins	326	3.0	71.0	71.0	0.7
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Pasta Spagetti	355	12.5	73.0	2.4	1.4
Bread	210	8.7	43.0	0.1	1.4

Table 4: Test 2 - Sorted products

In this test the same products were used, but the results presented in Table 4 correspond to a different diet type, which places the products rich in proteins at the top of the table.

It can be clearly seen that there is a distinct difference between the arrangement of the products in the results for the normal and protein diets. While the normal diet selects mainly products full of carbohydrates, the protein diet gives precedence to products with high protein values. At the same time it is possible to observe that most of high energy products are at the top of the table.

5 Conclusion and Future Work

This paper proposes an intelligent system which will assist users while shopping by suggesting the appropriate products related to people diets, and by keeping track of their nutritional intakes. The system is capable of verification of the chosen products and includes an option of calorie counter. Simple navigation and use of web browser minimizes maintaining difficulties. In-store database with clear administration interface enables user friendly management of in-stock products.

Future extensions may allow the addition of new diet plans which require other parameters than those used at the moment. The application needs further testing with different diet types and different user parameters. Verification by medical staff in terms of correctness of the approach and exactness of the results is also envisaged. Medical approval is crucial because it may have high influence on the future of the proposed solution. The application may be extended to make use of barcode scanner.

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