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A PERSONALIZED FOOD ADVISORY SYSTEM FOR CHRONIC DISEASE PATIENTS

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ABSTRACT

Chronic diseases, such as diabetes, heart disease and stroke, are the leading cause of mortality in the world. Recent studies show that 382 million people have diabetes in 2013 and the number will rise to 592 million by 2035. To mitigate the effect of chronic diseases, patients are advised to follow strict nutritional rules. However, with the widespread of processed food, it is hard for the chronic disease patients to recognize what kind of food that must be avoided. In this paper, we present a personalized food advisory system that can be used by chronic disease patients to manage and control their food intake. The proposed system evaluated by using interview approach with 15 experts from medical domain. The preliminary result confirms the importance of having such system to assist chronic diseases patients to follow the nutritional rules. Almost all the participants are willing to recommend the proposed system to their patients.

Keywords: *Mobile Application, Chronic Diseases, Food Ingredients, Recommendation*

1. INTRODUCTION

Chronic diseases, such as diabetes, heart disease, and stroke, are the leading cause of mortality in the world. Recent studies show that 382 million people have diabetes in 2013 and the number will rise to 592 million by 2035 [1].

The term of "processed food" refers to those that are chemically processed [6]. Processed foods are usually found in the grocery store and are more likely to contain ingredients that are difficult to be recognized. They often have long ingredient lists such as vegetable, milk, sugar, cereals or grains represented by different symbols and names. The chronic disease patients are advised to avoid these foods since their negatively impact in the patients' health [24]. However, with the widespread of processed food, it is hard for the chronic disease patients recognize what kind of food that they must avoid.

Preventing diseases through improving nutrition is a global health priority [30]. Patients of diabetes, as well as patients of many other chronic diseases, need to follow strict nutritional rules to avoid deteriorating their case. Also, people with congenital potential of having certain chronic diseases need to follow preventive diets to avoid having these diseases. There is increasing evidence that chronic disease risks begin in fetal life and continue into old age [4, 9]. Therefore, pregnant and breastfeeding women should receive more attention regarding nutritional and dietary concerns.

The rapid growth in the use of smartphones has opened new and innovative approaches opportunities for enhancing human healthcare. Mobile applications (app) are available for a variety of useful tasks such as symptom assessment, psych education, and tracking of treatment progress [18]. According to [14], approximately 500 million smartphone users worldwide will be using a healthcare application by 2015. Moreover, it is expected that around 50% of the smartphone users will have downloading mobile health applications by 2018.

In this paper, we present a personalized food advisory system that can be used by chronic disease patients to manage and control their food intake. That is, we suggest to develop a mobile application (app) that can be used to determine which kind of food are safe for chronic diseases patients. Simply, the application reads a given food product ingredients and access a database that has a list of diseases associated with a list of disallowed food to decide if the product is safe or unsafe for the current patient. Our proposed system architecture are described and evaluated using the interview approach.

The reminder of this paper is organized as follows. Section 2 reviews several related work and applications in the literature. Section 3 describes

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our proposed system and how does it differ from the reviewed applications. Section 4 shows system evaluation and our discussion has described in Section 5. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

People in medical domain are one of the earliest adopters of personal mobile technology for assisting with their daily routine practice. Electronic portable devices and specialized software have been exploited for health research, communication, and patient care. They were from the very earliest commercially examples in the 1990s such as Apple Newton [23, 25], Palm Pilots [11, 26] to the current revolution in multifunctional smartphones. Examples of medical uses cited in the literature range from diabetes management [8, 21], infectious disease management [10, 19], and immunization management [16], to highly specialized uses in radiology [3] as well as digital imaging and bio-optical sensing [5, 15].

Nowadays, several mobile applications have been developed to help dietary and healthy food seekers. GoodGuide [20], for instance, is a mobile application for food and beverage shoppers to decide their purchases on scientific basis [17]. The user needs only to scan the barcode of the item and the application will search its database to tell him its rating based on health factors, social responsibility, and scientific ratings.

Similarly, Fooducate [28] alerts its users to high amounts of sugar, controversial additives such as artificial food colorings, and misleading claims. It grades the product on a A-to-D scale based on nutrition facts, and ingredients list as well as the amount of chemical processing (the lower the better).

Locavore [27] serves as a directory of healthy food stores. It determines the user location and guides him to the nearest stores. Chemical Cuisine [7] features a searchable and filterable list of food additives, their descriptions, and safety ratings to help user make healthy decisions. It serves as a decipherer for food additive codes and rate its safety on a (Safe, Caution, Cut Back, Certain People Should Avoid, Avoid) scale.

FoodFacts [12] provides user with nutritional information on thousands of different products with their ingredients, food label information, nutrient content information, protein, fat and carb information. It helps user track his food allergies and sensitivities for things like peanut allergies, egg allergies, dairy allergies, gluten sensitivity and gluten content. A dieting user will find valuable information on calories, fat, and carbohydrates. A user who is concerned about what he is eating will find helpful information on food additives and controversial ingredients.

MyFoodFacts [2] is a mobile application which lets the user scan the barcode of the edible item then provides him with an instant list of easy to read ingredients information. It also alerts the user if the item contains potential allergens or allergen derivatives. The user can also personalize the application to his specific food allergens.

MyFoodFact is the most similar application to our proposed system. It can be considered as the only application that can be classified as personalized, as each user can enter substances that suffer allergic ones and the application will search for these substances in all ingredients that patient scan to give the user permission to use this product or not. Our proposed system extends upon this application by creating local and global forbidden list of foods (we call it as a black list later on in this paper). While the local copy will let the user utilize the system offline (not connected to the server), the global copy will enhance the capability of the system by supporting the collaborative-work between the users to share disallowed products (black list) for each group of patients (e.g. diabetes). Also, having the global copy will help to avoid scanning the same product repeatedly, hence minimize the time to deliver the result to the user.

Generally, our proposed system combines most of the features of the previous applications. The proposed system will be described in details in the next sections.

3. PROBLEM FORMULATION

To explain our research problem, suppose that we have a product P that has list of ingredients I where I={i1, i2, .., in}. Suppose also that we have a set of diseases D where D={d1,d2,…,dm}. Now, let us assume that a User U has suffered from disease d1 and his doctor gave him a restriction food rules. For example, U may suffer from diabetes and the doctor warns him from having any kind of food that has a sugar. Unfortunately, the sugar may be represented by various names and be part of ingredients of many products. This makes the job of the U harder as it will be so difficult for him to avoid the sugar and his health case might be detrained.

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In this paper, we aim to assist U to follow the nutrition rules by developing a system that discover if a given product P is safe or not for the user U. More specifically, given a product P with a set of ingredients I and a set of diseases D that U has suffered from, the objective is to determine if P is a safe product for U.

4. PROPOSED SYSTEM

4.1 System Architecture

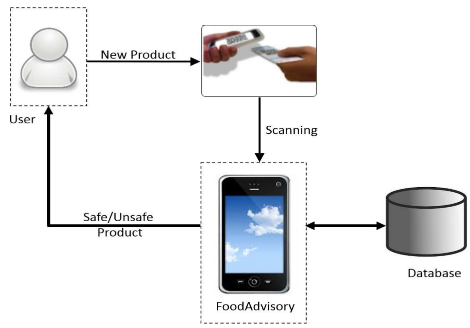

Figure 1: Proposed System.

Figure 1 illustrates our proposed system. As the figure shows the system consists of four main components: User, Database (DB), Product reader and mobile application. The system is personalized because each user can configure his own information during creation of user's profile. That is, the user can add a list of diseases he suffers from. For example, a new user can configure his profile by simply add a list of disease/s that he suffers from such as diabetes or heart disease. The user profile information will be utilized by the proposed system to decide if a given product is safe or not. To do so, the system will access the database where a list of diseases are associated with a list of disallowed product or ingredients and if the given product/ingredient matches with any disease in the user profile, the product will be classified as unsafe. Over time, the system will keep a list of disallowed products for the user (i.e. products' black list) which consequently enhances the performance of the proposed system as it will not need to access the DB repeatedly.

To improve the efficiency of proposed system, two copies of black list products are introduced: local and global. The global copy will be existed in the DB and shared for all users that have suffered from the same disease. It will be expanded over time by adding new disallowed products that scanned by the users. The local copy, on the other hand, is reside on the user's device (mobile phone) and accessible by only ta single user (i.e. not shared).

The local copy has three main advantages. First, the local copy will make the proposed system works offline (i.e. no Internet access). The user can scan a new product, and the system will be able to make a decision for the suitability of the product based on the local copy (i.e. offline processing without having an access to the centralized database). Note that while the local copy will make the user utilizing the system offline, it is limited to the current recognized products (black and white lists). If the scanned product is a new product, the system will not be able to make a decision for this product based on the local copy.

Second, the local copy will improve the performance of the proposed system. Note that each time the user scan a product, the system will not search in the global copy unless the given product/item is not in the local copy. That is, the system will make the search in the local copy firstly, then move to the global copy if necessary.

Finally, there are many reasons that make a given product not preferred for the user. These reasons are not necessarily related to his health. For example, for some religious issue Muslims are disallowed to intake any kind of food that has alcoholic or ham meat as part of its ingredients. Additionally, the reason might be stemmed simply from personal preferences (e.g. the user would not like to eat any kind of food that has milk as part of its ingredients). In such cases, the user can add none preferred items or products in his own profile in the local copy. In the other words, having the local copy will give the users opportunity to customize their black list.

4.2 FoodAdvisory Algorithm

To determine whether a given product P is a safe or unsafe product for the user U, we introduce FoodAdvisory algorithm in this section. The algorithm takes product id (PID) and user id (UID) as input and then access the database (DB) to decide if the product P is a safe product for U. Algorithm 1 describes how our proposed system works.

When the system reads the product Id, it will search for the product in the user's blacklist which can be retrieved from the user profile by UID (Line 1). If the product is in the blacklist, the system will return a message to the user telling him that the product is not safe (Line 2). Note that all the safe products that have been scanned previously will be stored automatically in the database (lines 4

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& 5). If the product P is not found in the database (Line 6) then it is a new product. For the new product, the system needs to read its ingredients (Line 7) in order to decide if its reliability for U or not. To do so, the system must retrieve all items that either disallowed due to disease reason (Line 9) or un-preferred items for whatever reason (Line 10). If there is a match between the ingredients of P and the list of items that have been retrieved by the system (Line 11) the user will be informed by a message (Line 12) and the product will be added to the blacklist (Line 13). Otherwise, the product is safe to intake (Line 15), the system will add the product into the database (Line 16).

Algorithm 1: Pseudo-Code for Food Advisory

```
Input: UID, PID, DB
Output: Safe / Unsafe
Process:
1.  If PID ∈ Blacklist
2.      Return "Unsafe Product";
3.  Else
4.      If PID ∈ DB
5.          Return "safe Product";
6.      Else
7.          Read I;
8.          Set1 ← I;
9.          Set2 ← Ingredients Related to diseases of UID;
10.         Set3 ← Ingredients that UID do not preferred;
11.         If Set1 ∩ Set2 ≠ ∅ | set1 ∩ set3 ≠ ∅
12.             Return "Unsafe Product";
13.             Backlist ← PID;
14.         Else
15.             Return "Safe Product";
16.             DB ← PID;
17.         End If
18.     End If
19. End If
```

4.3 System Implementation

To launch the system, the user must identify list of dieses that he suffers from as well as the items that he does not like to eat during user account creation phase. This can be achieved through a mobile device recognition phenomenon. More specifically, the identification might be conducted via the Near Field Communication (NFC) [13] standard/sensor or a digital certificate. Once the user profile has been created, a HTTP request is sent to the web service which is responsible for the identification task. Both IDs, the user ID and the item ID, are transferred with the HTTP request. The web server communicates with a centralized database, Relational Database Management System (RDMS), via a JAVA query [22] to verify the IDs. Once the IDs have been verified, a message will be sent back to the application interface. The message will be transferred via Simple Object Access Protocol (SOAP) [29] in form of an Extensible Markup Language (XML) format. The message will include the possible accesses that the user is authorized to deal with, which are in the form of different interfaces depending on his needs. If the agent, for example, has to scan a barcode of an item then he will have access to the database interface.

To scan a product barcode, an access to the system database is required. Searching for a specific item involves an automatic HTTP request to a second web server that deals directly with the system database. The web server will communicate with the database to obtain the required information and a message will be sent back via the SOAP protocol to the prescription interface. Consequently, the user will get a list of the substances items based on the written keywords. To decide whether a given item is safe or not to the current user, a specific web service will communicate with the system and deliver the answer to the user.

5. EVALUATION

To evaluate the proposed system, a preliminary study has been conducted using an interview approach with 15 medical experts. Table 1 shows number and specialist of the participated experts.

Table 1: NUMBER OF REVIEWED EXPERTS AND THEIR SPECIALTY.

Chronic Diseases Specialty	Number of Experts
Allergies	2
Diabetes	4
Diabetes and blood pressure	5
Diabetes and heart disease	1
Heart disease	1
Heart disease and blood pressure	1
Breast cancer	1

We have designed a review form that consists of three main questions. Following are the result of our interview with the medical experts.

First, the participants were asked about the relationship between food and disease and Figure 2 shows their responses.

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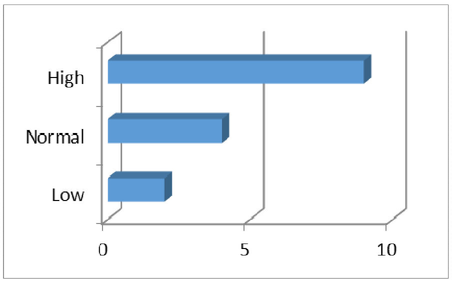

Figure 2: Food-Disease Relationship.

It is obvious that the majority of participants confirmed the relationship between the food and chronic diseases. Around 60% of the participants indicated that they strongly advice chronic disease patients to avoid some kind of foods (i.e. follow strict nutrition rules). Only one participant (breast cancer expert) highlighted that the relation between breast cancer disease and food may be lower than other diseases.

Second, the participants were asked about to what extent their patients follow strict nutrition rules. Figure 3 displays the result.

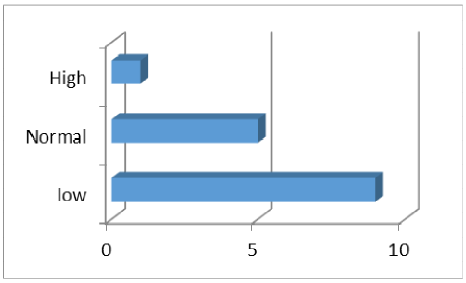

Figure 3: To What Extent Chronic Diseases patients follow the Nutritional Rules??

As can be seen from Figure 3, more than 50% of the experts expressed that their patients did not follow the nutrition rules. One of the participants said that "*I think, my patients will be happy if this kind of application is ready to use.*"

Finally, the participants were asked if they will recommended the proposed system to their patients. The result has shown in Figure 4.

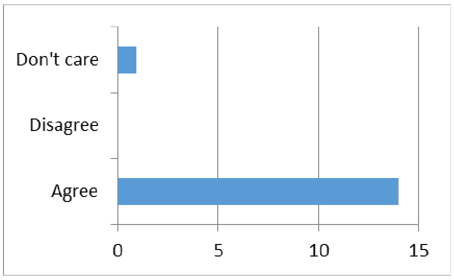

Figure 4: Do You Recommend the Proposed System to Your Patents?

As can be seen from Figure 4, almost all the participants will recommend the proposed system to their patents. They believe that having such system will help the patients to follow and control their food intake. In doing so, they hope that the rate of daily visit by chronic disease patients will decrease over time. Only one participant indicated that he does not care about the system and he would not bother to recommend the system to his patients. This is because his patients (breast cancer) do not affected by food.

6. DISCUSSION

There are many issues need to be considered in developing the proposed system. First, how to model the relation between diseases and food. Many experts from various domains such as medical and food need to be involved in determining diseases-food association. This is an important issue as the result of our proposed system will be directly affected by such relationship.

Second, in producing the result for the user (safe or unsafe), the result will be classified as either true positive or true negative. The true positive (also called sensitivity) means that the system is correctly identified unreliable product (i.e. disallowed) as unsafe for the patient while the true negative (also called specificity) means that the system is correctly identified a reliable product as safe for the patient (i.e. allowed). A perfect predictor would be described as 100% sensitive (i.e. predicting all unreliable products as unsafe) and 100% specific (i.e. not predicting any product from the reliable group products as unsafe); however, theoretically any predictor will possess a minimum error bound known as the Bayes error rate. In our context, we must pay more attention to have a perfect sensitivity as disallowing patients

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from having a reliable product is less consequences from allowing them of having a non-reliable one.

Third, the usability of the system interface must be considered by make it easy to use for all users. This is because numerous users that have different background and skills would be a potential users for the proposed system. For example, elderly people and less educated users may struggling to use a non-friendly user interface.

Fourth, using mobile devices have introduced the possibility to consume services irrespective of location. However, the performance of the system may be detrained due to the connectivity between the patients and the database. Having local and global copies of the database will help to improve the performance of the proposed system. Although having the local copy will ease the habitual interaction process and make it faster and simpler, the capacity of mobile devices will be consumed. Hence, a trade-off between saving mobile device storage and enhancing the performance of the proposed system must be considered.

Finally, a trusted exchange of information between the patients and the system is a compulsory requirement. The system must ensure a secure connection. Meanwhile, privacy of patients should not be broken and their information not be exposed to any unauthorized person.

7. CONCLUSION AND FUTURE WORK

In this paper, we investigated several mobile applications in managing food consumption. Then, we proposed FoodAdvisory, a personalized health care system for chronic diseases patients. It is personalized since it allows a different users to configure their profile then utilize it to control their food intake. We described the system architecture and implementation. The system was evaluated using an interview approach with 15 medical experts. The result was promised as the experts supported developing the system and they are willing to recommend it to their patients.

In a future work, we intend to model and implement food-disease relationship then utilize the model by implementing the FoodAdvisory algorithm and making it available to the users via mobile application software (app). We also intend to evaluate the proposed system using real data. This can be achieved by asking the chronic disease patients to download the app and use it. Then, the system can be evaluated by examining its accuracy through scanning list of products and test the result produced by the system (safe or unsafe product). The objective of this phase is to ensure that the sensitivity and specificity of the proposed system are perfect (i.e. as high as possible).

Also, we will evaluate the usability of the system (i.e. acceptance testing by the target users – chronic diseases patients in our context). To do so, we will prepare a short questionnaire to get users' feedback after using the system. This is required installing the system into users' mobile phones and ask them to use the system and provide their feedback about usefulness of the system.

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REFRENCES:

[1] Al-Nozha, Mansour M., et al. "Diabetes mellitus in Saudi Arabia." *Saudi medical journal* 25.11 (2004): 1603-1610.

[2] Arens-Volland, Andreas, Lübomira Spassova, and Norbert Rösch. "Review of Mobile Health (mHealth) Solutions for Food-related Conditions and Nutritional Risk Factors." eTELEMED 2013, *The Fifth International Conference on eHealth, Telemedicine, and Social Medicine*. 2013.

[3] Baerlocher, Mark Otto, Roland Talanow, and Adrian F. Baerlocher. "Radiation passport: an iPhone and iPod touch application to track radiation dose and estimate associated cancer risks." *Journal of the American College of Radiology* 7.4 (2010): 277-280.

[4] Barker, David JP, et al. "Weight in infancy and death from ischemic heart disease." *The Lancet* 334.8663 (1989): 577-580.

[5] Barsam, Allon, et al. "Anterior segment slitlamp photography using the iPhone." *Journal of Cataract & Refractive Surgery* 36.7 (2010): 1240-1241.

[6] Block, Seymour S. "Definition of terms." Disinfection, sterilization, and preservation. Philadelphia: Lippincott Williams & Wilkins (2001): 19-28.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[7] Center for Science in the Public Interest. Chemical Cuisine Mobile Application. Http://Www.Cspinet.Org/Reports/Chemcuisine.Htm.

[8] Ciemins, Elizabeth, Patricia Coon, and Christopher Sorli. "An analysis of data management tools for diabetes self-management: can smart phone technology keep up?." *Journal of diabetes science and technology* 4.4 (2010): 958-960.

[9] Delisle, Hélène, and World Health Organization. "Programming of chronic disease by impaired fetal nutrition: evidence and implications for policy and intervent ion strategies/prepared by Hélène Delisle." (2001).

[10] Focosi, Daniele. "Smartphone utilities for infectious diseases specialists." *Clinical infectious diseases* 47.9 (2008): 1234-1235.

[11] Garrett, Bernard Mark, and Cathryn Jackson. "A mobile clinical e-portfolio for nursing and medical students, using wireless personal digital assistants (PDAs)." *Nurse Education Today* 26.8 (2006): 647-654.

[12] Harris, Jennifer L., M. B. Schwartz, and Kelly D. Brownell. "Evaluating fast food nutrition and marketing to youth." New Haven, CT: *Yale Rudd Center for Food Policy & Obesity* (2010).

[13] Haselsteiner, Ernst, and Klemens Breitfuß. "Security in near field communication (NFC)." *Workshop on RFID security*. 2006.

[14] Jahns, R. "The market for mHealth application reached $ US 718 million in 2011." Retrieved June 2 (2012): 2012.

[15] Jonathan, E., and Martin Leahy. "Investigating a smartphone imaging unit for photoplethysmography." *Physiological measurement* 31.11 (2010): N79.

[16] Kaewkungwal, Jaranit, et al. "Application of smart phone in "better border healthcare program": A module for mother and child care." *BMC medical informatics and decision making* 10.1 (2010): 69.

[17] Karpischek, Stephan, and Florian Michahelles. "Digitizing consumer opinions and comments about retail products." (2011).

[18] Luxton, David D., et al. "mHealth for mental health: Integrating smartphone technology in behavioral healthcare." *Professional Psychology: Research and Practice* 42.6 (2011): 505.

[19] Oehler, Richard L., Kevin Smith, and John F. Toney. "Infectious diseases resources for the iPhone." *Clinical infectious diseases* 50.9 (2010): 1268-1274.

[20] Olsson, Thomas, and Markus Salo. "Online user survey on current mobile augmented reality applications." Mixed and Augmented Reality (ISMAR), 2011 *10th IEEE International Symposium on. IEEE*, 2011.

[21] Rao, Anoop, et al. "Evolution of data management tools for managing self-monitoring of blood glucose results: a survey of iPhone applications." *Journal of diabetes science and technology* 4.4 (2010): 949-957.

[22] Reese, George. Database Programming with JDBC and JAVA. " *O'Reilly Media*, Inc.", 2000.

[23] Schweitzer, W., and T. Hardmeier. "Digital handwriting recognition in data collection for autopsy reports with an Apple Newton." Der Pathologe 17.5 (1996): 399.

[24] Shikany, James M., and J. R. GEORGE L WHITE. "Dietary guidelines for chronic disease prevention." *Southern Medical Journal* 93.12 (2000): 1138-1152.

[25] Stratton, R. J., et al. "Comparison of the traditional paper visual analogue scale questionnaire with an Apple Newton electronic appetite rating system (EARS) in free living subjects feeding ad libitum." *European journal of clinical nutrition* 52.10 (1998): 737-741.

[26] Vishwanath, Arun, Linda Brodsky, and Steve Shaha. "Physician adoption of personal digital assistants (PDA): testing its determinants within a structural equation model." *Journal of health communication* 14.1 (2009): 77-95.

[27] Young, G., (2008) Report on Design Research with Urban Local Food Customers.

[28] Zamula D.,Kolchin M. and Mnemojno. "Design and Deployment of A Semantic Web Service and A Mobile Application." *14th Conference of Open Innovations Association* (FRUCT), 2013.

[29] Waleed, Ghossoon M., and R. Badlishah Ahmad. "Security protection using simple object access protocol (SOAP) messages techniques." *IEEE International Conference on ICED*, 2008.

[30] Waxman, Amalia. "Why a global strategy on diet, physical activity and health?". Vol. 95. Karger Publishers, 2005.