

A Personal Assistive System for Nutrient Intake Monitoring

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ABSTRACT

According to the World Health Organization (WHO) statistics, Obesity has reached epidemic proportions, with over than 1.5 billion adults suffering from overweight in 2008. As Obesity and overweight are major risks to human health, obesity treatment has been the focus of a large number of recent studies. Obesity treatment requires constant monitoring of the patient's diet. The smart technologies of today's intelligent environment can be used towards development of such monitoring system for obesity treatment. In this article we will propose a smart system that takes advantage of smartphones to build a platform for the monitoring of the amount of calorie intake for obesity patients. The patient uses the built-in camera of the smartphone to take a picture of any food that he/she wants to eat. The system will then process the images to detect the type of food and portion size, and uses the information to estimate the amount of calories.

Categories and Subject Descriptors

J.3 [Computer Applications] Life and Medical Sciences – Health; I.4.6 [Image Processing and Computer Vision] Segmentation - Edge and feature detection

General Terms

Measurement

Keywords

Food Recognition, Personal Assistive System, Intelligent Monitoring Systems, Calorie Measurement.

1. INTRODUCTION

According to statistics from WHO, worldwide obesity has almost double since 1980[1]. The statistics also states that 1.5 billion adults have suffered from overweight problem in 2008; that is almost ¼ of the world's population while developed countries such as North America are suffering from a much higher percentage of overweight population. As obesity and overweight are associated with a numbers of diseases such as type II diabetes, breast and colon cancer, and heart diseases, they have become a considerable health issue of the world.

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Obesity is caused by increased intake of high calorie foods that are high in fat, salt and sugars but include a low amount of vitamins, minerals and other micronutrients. An effective solution towards prevention of obesity is to limit the amount of calorie intake from fats and help the patients to achieve a balance in their diets in terms of getting enough vitamins and minerals while avoiding fat and sugar. Human body requires a certain amount of energy to perform several activities. Energy is measured in Calorie unit. This energy is obtained from several sources of nutrition that we take. Carbohydrate, protein, and fat are three main sources of calorie intake. A healthy diet should include proper calorie portions from each of these sources. Such ration depends on several parameters such as patient's gender, age, height and weight. According to US department of Agriculture (USDA), around 50% of calories should be coming from carbohydrates; while fat should be the source of around 30-35% of calories and 15-20% of the intake calories should be coming from proteins. Keeping this balance requires constant monitoring of food intake by the patient under treatment. Obese people typically fail to evaluate their energy intake [2] [4]. Therefore, they don't succeed in their diet plans unless they have some kind of assistance in their diet monitoring process.

This paper introduces a personal assistive system called Nutrient Intake Monitoring System (NIMS) that helps users in measuring their daily nutrient intake. The major contribution of this approach is to provide the users with an intuitive and easy to use application, essentially requiring the patient to simply use their smartphone to take a picture of the food before eating it, where context is taken into account in order to perform a better prediction of the type of food present inside the dish. An important part of the application is the simple calibration method of using the thumb of the patient inside of the food image, as a measurement pattern. The thumb in this case will replace the calibration card or any other type of specific equipment, and allows the users to measure their food intake in any kind of environments such as their homes, restaurants or food courts. To accommodate disabled persons who might not be able to use their thumb, a coin can be used as a common measurement pattern inside of the image, to calculate the real size of the portions. Today's smartphones have multiple features such as built-in camera and the ability to execute different kind of applications. Therefore they are best suited for the application of vision based food intake monitoring system. The user of the system is asked to take a picture of the food with his/her smartphone before and after eating to compare the sizes of the portions before and after the food intake. The system will then process the taken images of the food to detect different types of food and their respective portion sizes. Figure 1 shows the diagram of the proposed system that will be discussed in the paper.

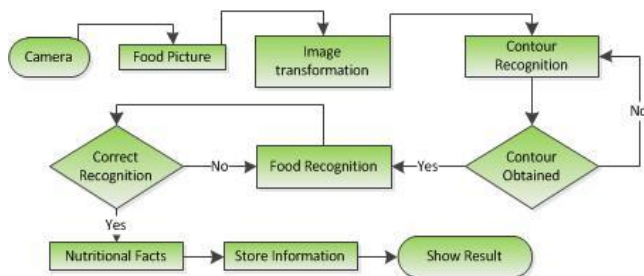


Figure 1: Diagram of the Nutrient intake monitoring system

Through the rest of the paper we will explain our image processing approach to segment the portions of food in a plate and obtain an approximation of the real life size of the portions, and finally perform the calculations of the nutritional facts with the information obtained from the image processing procedure.

2. Related Work

The assessment of food intake in adolescents has been previously performed using a number of methods like food record (FR), the 24-hour dietary recall (24HR), and a food frequency questionnaire (FFQ) with external validation by doubly labeled water (DLW) and urinary nitrogen [5] [6]. These methods are mostly based on manual recording of the intake nutrients. For instance, the approach used in the 24-Hour Dietary Recall is the listing of the daily food intake by using a special format for a period of 24 hour while a brief activity history may be incorporated into the interview to facilitate probing for foods and beverages consumed [7].

The main disadvantage of the 24HR is the delay and inaccuracy of reporting the eaten food comes from several factors, such as age, gender, education, credibility and obesity. Harnack, et al. found significant underreporting of large food portions when food models showing recommended serving sizes were used as visual aids for respondents [8]. It is also difficult to apply the previous assessment methods for measuring the daily food intake of adolescents under age 11-14 years, with several drawbacks. The most important drawback is adolescent resistance of parents control and being under the physician monitoring. There are also approaches where the idea was to analyze how the hunger and gender is a key aspect, in the calorie consumption; the digital images in this case were used to store this kind of behavior [9]. Other studies analyze the gender, age and perception, to predict the calorie intake [10] [11], but this is highly related with the sample used to perform the analysis.

The introduction of Modern technologies and smart devices has enabled a new set of solutions to the nutrient monitoring problem. The use of image processing in food analysis has been addressed in [8] [12]. The basic idea is to take a picture of the food before and after food consumption and use image processing to recognize the type of food and the portion size. The portion size is estimated by the help of predefined and premeasured patterns inside the picture that is used to translate the size in pixels of the portions of food [12] [13], into an approximation for the real life size. In order for these approaches to work properly, the user must adhere to several requirements which make the task of taking the picture of the food a difficult task for the user. In order to avoid such difficulties, Martin et al. [14] proposed a system where the user captures the images and sends them to a research center to be analyzed. This will, of course, come with its own shortcoming of offline data processing.

There are also methods where the food is weighted before and after the consumption, or a modified table or kitchen appliances with a built-in weighting scale will measure the plate and the portions before and after the food intake [15] [16]. The user typically does not like this and is prone to forget or prefer not to use this kind of measurement procedures, as weighing systems are not available everywhere and are not easy to carry around. Chang et al. [17] proposed a dining table equipped with different sensors located within the table and RFID tags, the RFID identifies the food, and the sensors weight the amount of the portion. But this requires the user to eat only at that table, such environments are therefore impractical, if we intend to apply this kind of measurement in common situations such as food courts or restaurants.

In our proposed system, we aim at using smartphones as monitoring tools as they are widely accessible and easy to use. We will take advantage of image processing for analysis. However, we will try to improve the quality of the processing compared to the existing literature and alleviate the need for a calibration component.

3. System Overview

The proposed system aims at helping people who suffers from obesity to keep a record of the amount of daily nutrients they have consumed without the need for recording this data manually. To accomplish this, we will develop an interface that runs on a smartphone and take advantage of the built-in camera, processing power and communication capabilities of the smartphone in the system design. The function of our method is to calculate the amount of calories and the nutrients information using image processing. We will use image segmentation and analysis, in order to extract shapes of the different portions of food present in the image. The details of this system are discussed in the following subsections:

3.1 User Interface

Figure 2 shows a snapshot of the user interface of the system that has been developed in IOS SDK, which is the user interface of the standard software development kit for iPhone applications released by Apple Inc.

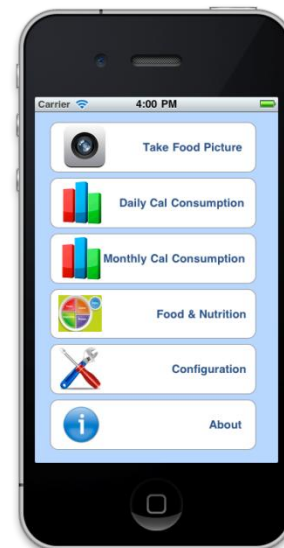


Figure 2: The user interface of the system.

A dietitian enters the patient information and also the information regarding the diet plan of the patient and allowed calorie intake. Figure 3 shows the interface where the doctor enters the patient information.

Before eating a meal the user captures a photo of the food with his/her thumb in a suitable position near the dish. The user's thumb, which is previously calibrated, is used as a reference for calculating the dimensions of food portions. This replaces the use of a calibration card [12] where the user must capture a photo of the food next to the calibration card. This method is attached to the card and the user must have the measurement card to be able to take the pictures. It is inconvenient for the user to carry the measurement board to every place he/she goes.

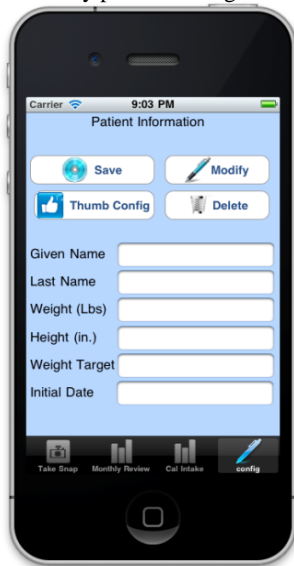


Figure 3: The interface for entering the patient information

Compared to previous measuring methods such as PDAs [18] and the calibration pattern, thumb is more flexible, controllable and stable. In our system the user calibrates the application once by entering the thumb dimensions as shown in Figure 4.

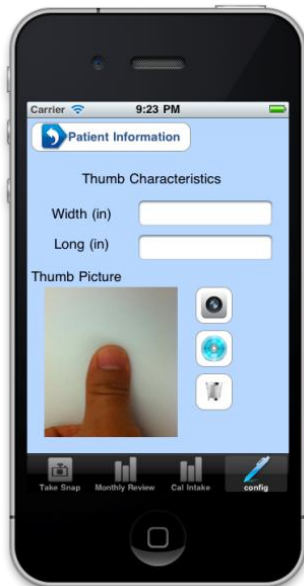


Figure 4: Thumb calibration

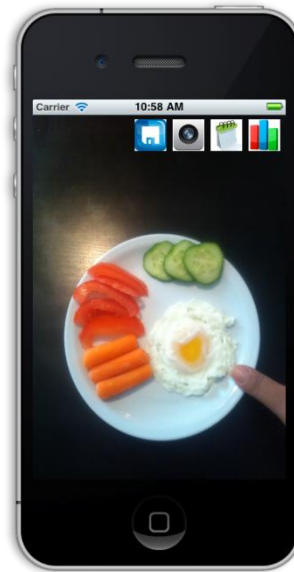


Figure 5: A Snapshot of the system user interface showing the user is ready to take a picture of the food in line with his thumb.

Figure 5 shows the technique of the photo capture using the thumb. After the picture is taken, the system starts processing the image to detect the plate and segments several type of food that might be on the plate. In our application we limit ourselves to a single plate, and note that the case of several plates in a tray has been addressed by Fujiwara et al. where the authors extract all the food present in a tray by using a Neural Network (NN) trained to extract the dish from the region of interest of the picture defined by the tray [19]. The NN needs specific inputs such as the image of the dish, the shape, diameter, width and height to be trained. This application therefore is limited by the fact the dishes must be placed in a tray, and the dishes must be measured, in order to have their data inside of the NN. Moreover, this environment limits the user to be in a controlled environment in order to perform an accurate measurement, otherwise the food cannot be quantifiable. Assuming the case of a single plate in the image, our system processes the image and segments it to several types of food based on different colors and textures that are present in the plate. The system will then look into the database of the foods to find a match for the detected texture and shows it to the user. Such database needs to yet be developed, and is beyond the scope of this paper. For example, the application can consider the time of the day and location where the picture is taken, to perform a narrower prediction. Also, the application can over time customize itself to its specific user through computational intelligence; i.e., by gradually learning what specific food this specific user usually consumes. In order to do so, our system currently provides an interface that allows the user to change the detected type in case the food item has been misclassified by the system. Figure 6 shows a sample of such selection process by the user. Over time and using appropriate computational intelligence techniques, the system can improve itself in determining what food is in the picture.

After the user confirms or corrects the food type, the system estimates the calories in the food using pre-saved calorie tables. The system then stores the calories in line with the date.

The user can see a graph of the consumed calories for a specific interval and compare it to his allowed calorie intake. This has been shown in Figure 7.



Figure 6: The system allows the user define the type of food with default values as automatically determined by the system

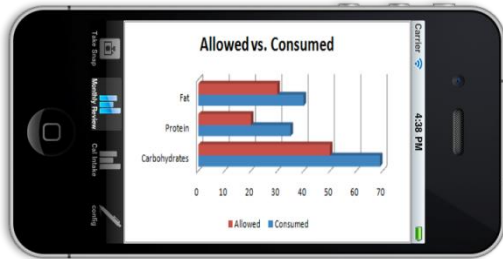


Figure 7: Intake calories and the allowed value.

The system can display the results in different formats as requested by the user. Figure 8 shows a pie chart of the nutrition intake during a specified interval.

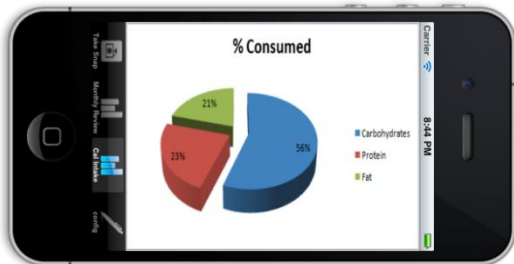


Figure 8: Pie chart of the nutrition intake

3.2 System workflow

In this section we will describe the system workflow using Unified Modeling Language (UML). Figure 9 presents the Use Case Diagram of our proposed system.

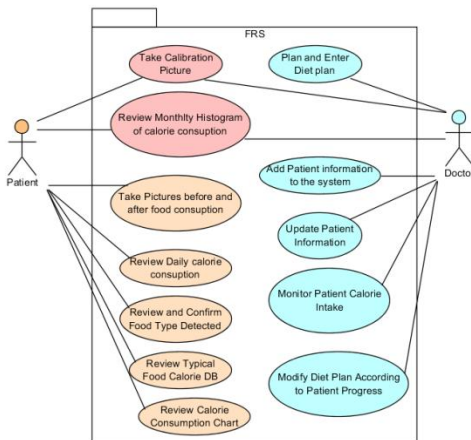


Figure 9: Use case Diagram for NIMS

3.2.1 User Interaction

Figure 10 shows the workflow diagram of the system from the view point of the system. As can be seen in the figure, the user should first take a picture of the food with his thumb in the picture. After the picture is taken and analyzed by the system.

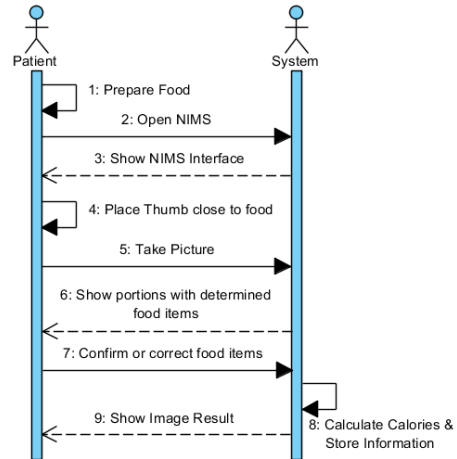


Figure 10: User's interaction with NIMS

The analysis of the image is performed in several steps. After obtaining the picture using the camera of the mobile device, the image is processed and segmented, with the final results displayed graphically to the user. The system then interacts with the patient in order to determine the kind of selected food items. For instance, when the user takes a photo of a steak, the system will first "guess" the food from its previous experience and using food database. It then asks the user confirm its guess. Based on the user's confirmation or correction, the system delivers the final result which is the amount of calories and nutrients of the captured food item. In order to provide a precise result, the previously mentioned procedure is repeated twice before and after eating, the latter used to determine which food portions were actually not eaten.

The user should also be able to view the results in the form of a bar chart or a pie chart for a specified interval and compare them to his allowed value of nutrition intake. Such interaction has been shown in Figure 11.

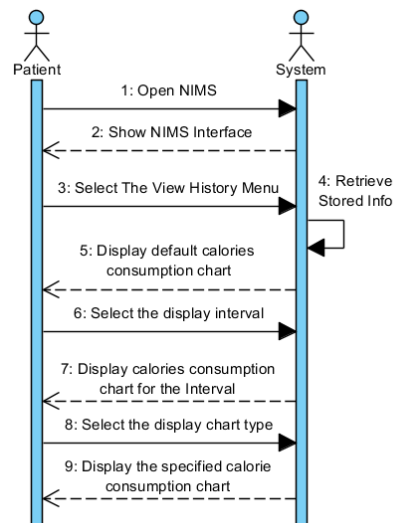


Figure 11: Viewing the nutrition intake record

3.2.2 Dietician Interaction

The dietician can regularly check to monitor the user and verify that calorie consumption has not been violated. Figure 12 shows this verification in NIMS

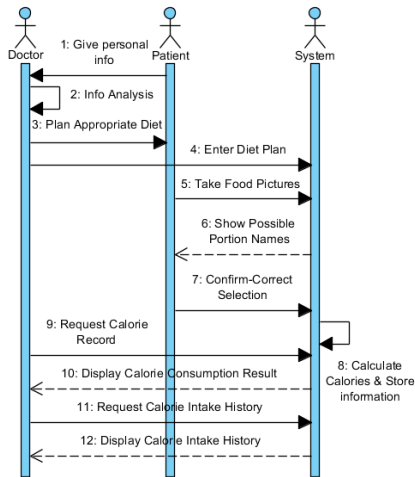


Figure 12: Dietician’s interaction with the system

4. Experimental Tests

We have partially implemented a prototype of NIMS that runs in the iPhone and iPod Touch smartphones. Figure 13 shows two initial images taken using our prototype with the user’s thumb as a size calibration reference. The application has been tested with different types of picture and foods present inside the images. Obviously, as the food variety and image complexity increases, the accuracy of the application decreases. For complex cases, the context awareness of the application and the intuitive user interface can be used to overcome shortcomings. Figure 14 shows the images after being post processed with the average of the colors inside of the image to have a better detection of the natural contours of the food portions. Figure 15 shows how the thumbs have been extracted from the original images. The thumb is segmented based on two criteria. The first one is the segmentation based on human skin color that helps highlight the areas where the thumb can be located and the second criteria is the shape of the thumb that can be used to find the thumb region more precisely. After the detection of the thumb contour, the size of the thumb will act as a known size reference to quantify the real size of the food portions. The food image is then processed and the plate and different types of food inside the plate are detected. Figure 16 shows the segmentation results obtained by the application, where the regions of interest have been defined and enclosed inside of the image with green rectangles; meanwhile the contours of the plate and food portion have been highlighted by the blue and red lines respectively. Finally, with the images processed and the size reference extracted, the calories are estimated based on the calorie table stored in the system.



Figure 13: Original Images taken by the user



Figure 14: The result of image post processing

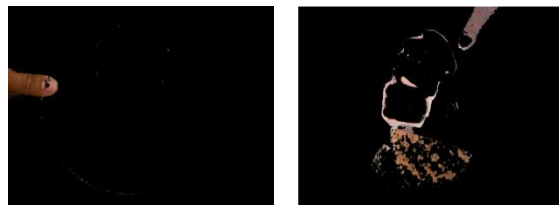


Figure 15: Extraction of the fingers as a size reference.

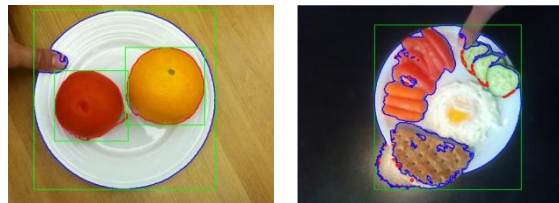


Figure 16: Final segmentation result for both images.

5. Summary and Conclusion

In this article we proposed a nutrient intake monitoring application that can be used as a personal assistive system on smartphones. The system analyzes food images using image segmentation techniques and takes advantage of a database composed by a set of training images, in order to perform semi-automatic recognition of the food present inside of the image. In order to increase the accuracy of the recorded calories, the images and the data stored inside the database are used as templates to recognize the shape, color and texture of the portions inside of the image, to produce a semi-automatic prediction of the basic characteristics of the food present in the plate. The system will ask the user to confirm if the prediction made by the application is correct, otherwise the user can correct any mistake made in automatic prediction. The system then keeps a record of the intake calories for future references.

As the system uses smartphones, it is easy to use and carry around. This will facilitate its use by patients and helps their diet plans to become more effective.

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