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A Novel Method for Measuring Nutrition Intake Based on Food Image

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Abstract- **In this paper, a food nutrition and energy intake recognition system for medical purposes is proposed. This system is built based on food image processing and shape recognition in addition to nutritional fact tables. Recently, countless studies suggested that the usage of technology such as smartphones may enhance the treatments for obesity and overweight patients. Via a special technique, the system records a photo of the food before and after eating in order to estimate the consumption calorie of the selected food and its nutrients components. Our system presents a new instrument in food intake measuring systems which can be useful and effective in obesity management.**

Keywords: Image processing, Calories measurement, Shape recognition, obesity management.

I. INTRODUCTION

Obesity has become a widespread phenomenon all over the world. The World Health Organization (WHO) defines obesity based on the Body Mass Index (BMI) of an individual. A person is considered obese when the (BMI) is higher than or equal to 30 (kg/m2) [1]. According to WHO, in 2008 more than one in ten of the world's adult population was obese [1].According to researches. Obesity and overweight are linked to a numbers of chronic diseases such as type II diabetes, high cholesterol, breast and colon cancer and heart diseases. The lack of balance in the amount of energy spend with the energy intake is the main reason for the increasing rate of obesity [2]. In order to lose weight for obese individuals in a healthy way, as well as to maintain a healthy weight for normal people, the daily food intake must be measured [3], thus, Obesity treatment requires the patient to record the amount of the daily food intake, but in most cases, it is not easy for the patient to measure or control their daily intake due to the lack of nutrition, education or self-control. Therefore, by using a semi-automatic food intake monitoring system. We can assist the patient and provide an effective tool for the obesity treatment.

Nowadays, new technologies such as computers and smartphones are involved in the medical treatment of different types of diseases, and obesity is considered as one of these common diseases. In the last few years, a numbers of food intake measuring methods have been developed. But most of these systems have drawbacks such as usage difficulty or large calculation errors. In addition, most of these methods are applied just for experimental practices and not for a real life usage. One example is the 24-Hour Dietary Recall [4] .The idea of this method is the listing of the daily food intake by using a special format for a period of 24 hours. This method requires a trained interviewer to ask the respondent to remember in detail all the food and drink s/he has consumed during a period of time in the recent past (often the previous 24 hours). The 24HR is a limited method because it requires only short-term memory, and if the recall is unannounced, the diet is not changed. The method is relatively brief (20 to 30 minutes), and the subject burden is less in comparison with other food recording methods [5]. Also, it is really hard for a person to remember the contents and the amount of the daily food intake, especially obese patients, because in most cases they cannot estimate the amount of food intake. Researchers in [6] have been applied a method that depends on the use of calibration card as a reference; this card should be placed next to the food when capturing the image. Moreover, this card must be always present in the photo when the user wants to use the system. The drawback is that the system will not be able to work without the card, which means that in the case of misplacement or absence of the card, the system will not work. A different method to measure food intake by capturing a photo of the dish with the help of the Neural Network was developed by researchers in [7]. This method might be difficult to follow by the user because the user must capture the photo in a tray in order to extract the shape of the food. Moreover, in this method the food image needs to be analyzed by computers and this is impractical for everyday usage. A personal digital assistive (PDA) system has also been adopted for food measuring by M. Warziski et al [8] where patients are use the PDA to record their daily food intake information in a mobile phone .Overall, Beasley's study shows that the result of the portion estimation has an error and also it takes a long time for the user to record the information [9]. Another deployment using Smartphone appears in [10] where researchers apply nutrition data to an HTC phone. In this system, the captured food photos are compared to the photos with known nutritional values which are stored in the database, thus, the main disadvantages in this system is that it does measure food different from the database; also it does not take into account the amount of food intake, which is significant shortcoming. Compared to the above methods, our proposed system addresses most of the shortcoming mentioned. In our measurement system, our goal is to develop and implement an instrument that measures daily food intake using mobile devices with a built-in camera to capture a photo of the food intake before and after eating, in order to estimate the amount of consumed calories. The proposed system depends on a new technique: the usage of the thumb as a calibration reference to estimate the amount of food from the captured photo. This unique method will give the chance to have more accurate results than methods. The rest of this paper is organized as follows; Section II will give a background of the methods used in our system. Section III presents the proposed workflow with explanation of the basic concepts of the proposed system. Section IV presents the system design, and section V shows the system implementation. Section VI covers performance evaluation, and finally we conclude with the discussion of the proposed system and the future work in section VII.

II. BACKGROUND

a. Calories definition and nutritional tables

Calorie is a typical measuring unit which is defined as the amount of heat energy needed to raise the temperature of 1gram of water by one degree[11]. In other words, this unit is used to measure the overall amount of energy in any food portion that consists of the main food components which are Carbohydrate, Protein and Fat. Beside gram units, calorie units are adopted in developing of nutritional facts table. Each person should daily take a certain amount of calories. If this amount is increased, it will lead to gain weight.

Table I illustrates the usage of calorie unit in those tables. The proposed system in this paper relies on there already-established tables as a reference to estimate the number of calories from any selected food photo.

b. Image processing

In this concept an image or a set of images are used as input of the application, these inputs are analyzed by signal processing and the result of the application of image processing is another image or images, or a set of characteristics extracted from the images and the objects present inside each picture. Inside the image processing there is a set of general analysis that can be performed, as the Euclidean Distance between pixels or objects, the image geometry, the segmentation of the objects inside the image, the optical flow in cases where the application is dealing with a sequence of images from the same video, optical occlusion, foreground or background subtraction, to mention just a few. These techniques play important roles inside applications in areas such as science, industry, space and medicine.

c. Shape recognition as a part of Image processing

The shape recognition is a sub area of image processing focused in the definition of different type of characteristics attained from every object present inside an image. The most common characteristics obtained are area, perimeter, size, Euler number E, where E is defined by the number of connected components C and the number of object holes, H given by E=C-H and the geometric attributes shown by the shape if the silhouette of the object is closely related to a standard geometrical form like circle, square or triangle, among others. From probability theory, the (m, n) moment of the probability density given by f(x, y) and applied in the Hu's seven moments for the visual pattern recognition can also be calculated for a specific object, and its shape will define closely the numbers obtained by this calculation. This subset of results will define results uniquely related for each shape.

d. Support vector machine (SVM)

A support vector machine (SVM) is a computer algorithm that learns by example to assign labels to objects. The SVM is successfully used for pattern recognition in various fields. The method is a very useful classifier since it determines a hyperplane that separates classes with the largest margin between the vectors of the two classes [12]. The problem here is how obtain a linear separation. SVM can solve the problem by using a kernel that shifts the feature space into a higher dimension. The linearly separable hyperplane in the higher dimensional space gives a non-linear decision boundary in the original feature space.

The sample set is:

$\{(x_i, y_i) | i = 1,2, \ldots, k\}$

Where $x_i, (i = 1,2, \ldots, k)$are input value and

$y_i, (i = 1,2, \ldots k)$ class value of the SVM method.

After apply kernel function the corresponding classification is

$$f(x) = \mathrm{sgn}(\textstyle\sum_i a_i^* \, y_i \text{Linear function} + b) \qquad (1)$$

SVM could also be used in nonlinear regression analysis.

Now we replace the $(x_i, x)$by$\Phi(x_i)$.

$$K(x_i, x_j) = \Phi(x_i).\Phi(x_j) \qquad (2)$$

So nonlinear regression will be:

$$f(x) = w.\Phi(x_i) + b = \textstyle\sum_i (a_i - a_i^*) y_i K(x_i.x) + b) \qquad (3)$$

In this formula if:

$\sum_i (a_i - a_i^*) = 0$

Then $0 \leq a_i \leq C$, $a_i^* = 0$

x_i is called standard support vector. b could be calculated from

Constraint condition.

Commonly used functions are:

Linear function

$$K(x_i.x) = x_i^T.x \qquad (4)$$

Polynomial function

$$K(x_i.x) = (\gamma x_i^T.x + r)^d \qquad (5)$$

Where $\gamma > 0$

RBF (Radial Basis Function)

$$K(x_i.x) = \exp(-\gamma\|x - x_i\|)^2 \quad (6)$$

Two layer nerve function

$$K(x_i.x) = \tanh(\gamma\, x_i^T.x + r) \quad (7).$$

γ, r, and d are kernel parameter.

III. PROPOSED WORKFLOW

In the following section, we describe the basic concepts that we depend on to build our system.

a. Obtaining volume by utilizing area size

The proposed Food Recognition System (FRS) is based on a new measuring technique which involves the user's thumb in the captured photo. Since volume measurement of food is the most demanding part, this technique has an important contribution in our system. Besides ease of use and availability everywhere, a person's thumb can be used to calibrate the image and analyze the dimensions of the selected food item. In this section, we will describe the adopted methodology to find all values resulting from image analysis and estimate the amount of calories in the selected photo. In details, the user will capture the photo of the selected food from the top and one side of the dish, with his/her thumb placed in the photo. The application, which already has the dimensions of the user's thumb (one-time calibration) then analyzes the pixels of both the thumb and the food from the first photo (top view), then use this the area s will be used with the other dimensions of the food from the second photo (side photo) to generate the volume. Figure 1(a, b) shows a captured food image with the correct position of the thumb, while (c) shows the method identified and dimensions calculated.

(a) (b) (c)

Figure 1: (a, b) Test Images with Food and Thumb
(c) Calculation of the thumb dimensions

In details, the calculation steps will start by finding the area by using the length and the width of the selected food in the image, taking into account that the mathematical equation for the area calculation is differ from one shape to another. For example, if we want to compute the bread slice in the picture that we tested ,We will find that the bread slice is irregular in shape, Therefore, as known, to calculate the area of irregular shape, the selected shape must be simplified to regular shapes such as triangles, rectangles, circles, squares and so forth, so , we can find the area by applying the suitable mathematical formula for any shape, then integrate all the small parts together so, We divided the bread in the picture into two known shapes semi-circle and a rectangle. And by reference to the mathematical equations for these two shapes we find that:

Area of the rectangle= W. H (8)

Area of the semi circle =1/2πr2 (9)

Where W is the width of the slice, H is the height, π is an constant value and r is Radius of the circle. After that, the system uses the results to find the volume of the image, which also varies from one form to another. For example, to calculate the volume of the bread so we must apply the suitable equation to calculate the rectangle volume which is :

Rectangle volume= Length X Width X height ( )

Figure 2(a, b) illustrates the method of calculating area and volume in a set of images that contains a different food items. Finding the volume of the food in the photo allows us to calculate the amount of the calories from the aforementioned nutritional tables, as described next.

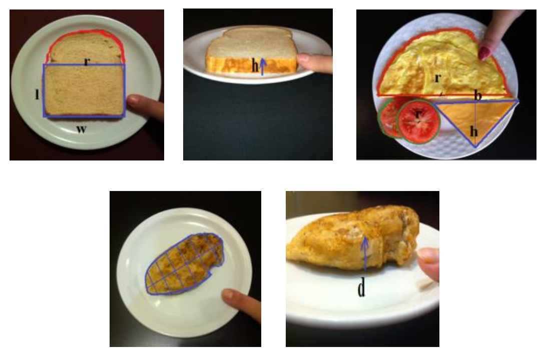


Figure2 The method of calculating area and volume in the image

b. Nutrient tables adoption

The structure of the food database is the main component for building and testing the food recognition system[14].The data of the nutritional values of foods are stored in the system database in the form of tables through specialized programs. Table I. Image of Nutrient Table Sample show a sample set of Nutrient Facts for some food from Health Canada[15]. This database helps or system to calculate the amount of calories in a quick time and without reference to the Internet.

TABLE I. IMAGE OF NUTRIENT TABLE SAMPLE

Food Name	**Measure**	**Weight**	**Energy**	**Protein**	**Carb**	**Fat**
		(g)	***(kcal)***	***(g)***	***(g)***	***(g)***
Apple with skin	1	138	72	N/A	19	N/A
Potato, boil, no skin	1	135	116	2	27	N/A
Chicken, Ground, Lean	75	75	153	16	0	9
Orange	1	131	62	1	15	N/A
tomatoes, raw	1	123	22	1	5	N/A

Bread white, commercial	1	35	93	3	18	1

IV. System Design

The system environment has two main components:

a. The system user (patient)

The system user starts by placing his/her thumb on a suitable position on the dish. Then, the user captures a photo of the food. The measuring technique that uses the thumb in a photo has a significant importance in our system. Compared to previous measuring method such as PDAs and the calibration card, the thumb is more flexible, controllable and stable because our system is designed to store patient's thumb in the one-time calibration stage .for patients with thumb disability or in other cases of inability to use the thumb, the patient can use another finger or a coin. Finally, the user is responsible for selecting the type of food from the stored data in the mobile.

b. The food recognition system

The Food Recognition System (FRS) captures a photo of the food and uses the patient's thumb as a measurement reference to calculate the amount of calories and nutrients from nutrition fact tables. FRS is a combination of image analyses, classification by using Support vector machine (SVM) method, and nutrient database. Figure3 shows the overall diagram of the basic functionalities of the Food Recognition System.

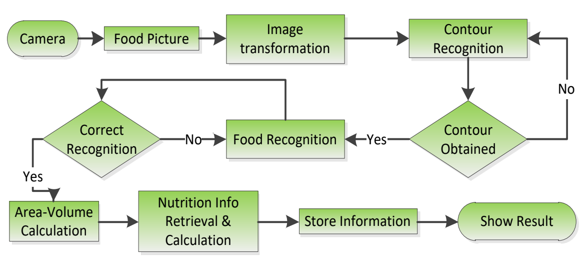


Figure 3: Overall functionality of FRS

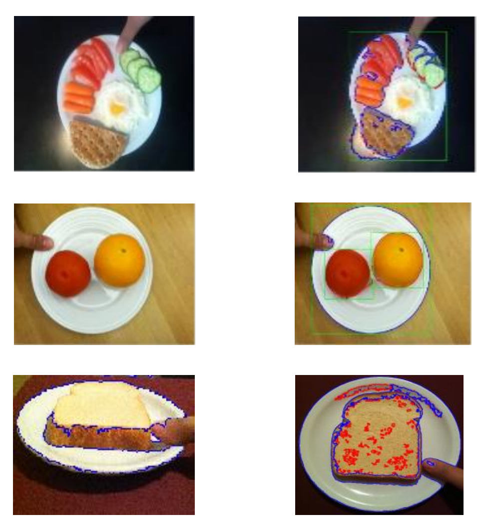
V. System Implementation

This section describes the interaction between the user and the system, and within the system itself. First, the user captures the images of the food in the manner mentioned before. The system then identifies various portions of the food, as described in [16], and calculates their volume from the image dimensions. Then, the system interacts with the patient to determine the kind of food portions. For instance, it will ask the user if a certain portion is meet or not, and if the former, what kind of meet it is (chicken, duck, turkey, etc.). This part can also be semi-automated by using approaches such as [6] to "guess" the food portion and have the user double-check the result to make sure the food is identified correctly. After that, the system uses the nutrition facts tables to deliver the final result which is the amount of calories and the nutrients facts of the food. If after the user is finished with the food, the entire food was not eaten, the procedure is repeated after eating to calculate how much of the food and therefore how many calories should be taken out.to determine the portions, the system tries to determine the type of food: either if it is pure or mixed food, such as one type of food (an orange) or salad (lettuce plus tomato plus cucumber). After the calculation of the dimensions and translation of measurement units to fit with each other automatically, the system will identify all the nutritional facts. The system can also be enhanced by adding a component that would suggest to the user if this type of food will fit with his/her diet or not

VI. Performance Evaluation

a. Image processing and analyzing

We have an initial implementation on IPod Touch and IPhone where we have performed successfully the definition of the images and the contour of the portions inside of the dish. Once the portions and its corresponding contours are defined, we extract one by one each portion and analyze them. For analyzing, we have used Support Vector Machines (SVM) a set of 80 images have been selected as a training set, and then another 20 Images are selected as a testing set. In the first level, every image is segmented, and then recognition is done by the SVM. In the experiment, the color, size and shape properties of the fruit and food images are extracted after pre-processing. We then checked the result with only one feature which was color; and we had low accuracy, and so we tried to test it with more than one feature. Finally, we used the SVM based on color, shape, and size properties. Figure 4 shows the images of different types of food before and after detection.



a) b)

Figure 2: a) After color analysis. b) After contour detection

The three recognition results are contrasted, and we see that SVM based on all color, shape and size properties for recognition is working well. The accuracy of our system in the recognition part was approximately 89 percent.

b. Calories estimation

in addition to image processing and color detection. The knowledge of the food dimensions inside the image as mentioned before will give the system the ability to calculate the mass of the food in the image through applying the following general mathematical equation;

$$M=\rho V \tag{10}$$

Where (M) is the Mass of the food in the image, while (ρ) is the Density of a food item and (V) is the is the Volume of the portion as calculated from the image plus user's thumb inside the photo (notice that thumb size is always fixed in the picture). After obtaining Mass, the system starts to calculate the calories by comparing the inputs from the image (mass) with the inputs from the nutrient tables(mass and calorie amount)which are already stored in the application's database. The following equation describes how to find the amount of calories for any selected food image.

$$\frac{\text{food weight (gm)(from table)}}{\text{number of cal (from table)}} = \frac{\text{Mass of food(pxl) in photo}}{\text{x (number of cal in the photo}} \tag{11}$$

the proposed method was experimented on a variety of simple food items such as bread. our experimental results have shown that this method achieves a reasonable error equal to 4.22%.

VII. CONCLUSION AND FUTURE WORK

In this paper, we proposed a measurement method that estimates the amount of calories from a food's image by extracting the volume of the food inside the image by using the thumb as a reference . As we indicated, our application is designed to aid dieticians for the treatment of obese or overweight people, although normal people can also control more closely their daily eating without worrying about overeating and weight gain. Our initial effort has focused on identifying food items in an image by using shape recognition and image processing and classification by using SVM, and as a result we reach a reasonable measurement error for our method.

now, our experiments covered simple type of food and we are working on escalating it by testing more food types.

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