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Calorie estimation model for Indian elderly persons using image processing and convnets techniques

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Abstract--Nutrition is a basic human necessity as well as a requirement for a healthy lifestyle. Especially in elderly people, nutrition is an essential modulator of health and well-being. Nutritional intake in older people is sometimes hampered by a variety of circumstances like isolation depression, weak muscles etc. which increases the risk of various diseases. An effective Food Assessment system that classifies and estimates calorie requirements from a cooked food image is highly recommended, allowing a person to discover what foods contain and how healthy it can be. In this paper a dietary assessment system is developed which classifies the given Indian cooked food image and further estimates its Calories and nutrients by obtaining food region. The proposed method was tested on certain fruits and cooked foods, yielding an average error rate of 8.31, which is highly acceptable.

Keywords--CNN, Indian datasets, image processing, calibration object, estimation.

Introduction

To live a healthy and fit life we need to consume right amount of nutrient which is also an essential modulator of well being in elderly persons (Krishnaswamy, 2011). Due to lack of food knowledge and difficult computations, manually consuming the correct amount of nutrients is a difficult task. Moreover, in elderly persons Isolation depression weak muscle not only hampers' the nutritional intake but also increases the risk of malnutrition and many diseases (Leena Gautam, 2022). An effective Food Assessment system that defines and estimates nutrient requirements from the given food is highly recommended, allowing

persons to gain a better understanding of food nutrients and their healthiness. Automatic dietary assessment includes two subprocess: Food Image classification which classifies the type of food and food portion estimation which analyse the food portion and calculates the calorie and nutrients. Food portion estimate is a difficult subject to solve since the shapes, ingredients and looks of foods can vary greatly during the preparation process. Diversity of food is also considered as a major factor especially in Indian Foods which effects the estimation process. Researchers employed a variety of classification methods and strategies to complete the recognition and estimation tasks. SVM (Parisa Pouladzadeh, 2014) and later CNN (Pallavi Kuhad, 2015), (Yanai, 2016), (David J. Attokaren, 2017), (Li, 2018), (Wataru Shimoda, 2019) (Yuanyuan Liu, 2020) are the popular techniques used by many researchers for performing food classification. For calorie estimation some researcher relies on web-based services while others had adopted volume based, distance estimation, annotated dataset, attribute estimation etc.

Most used method for calorie estimation is volume-based method. In the paper, (Chang, 2013) the amount of food was estimated by linking food components to geometrical shapes, from which the volume of the meal was computed. The method works well for the food items relating specific geometrical shape. This problem was overcome to some extent in paper (Yanai, 2016), by introducing calibration tool used as a size reference to gauge the real-life size of food portions from an input image. Many researchers adopted faster R-CNN for object detection and classification. Author Yuanyuan Liu et al. (Yuanyuan Liu, 2020) proposed food volume estimation based on the reference item. Combination of R-CNN, GrabCut, and edge filtering algorithms is used to achieve accurate segmentation. The size estimation algorithm was utilized to estimate the food's true height, width, and area, which was then fed into CNN for precise volume estimation, yielding a mean absolute error of 4.5. Author Yanchao Lianga and Jianhua Li (Li, 2018) used faster R-CNN for object detection and GrabCut Algorithm for obtaining contour and volume estimating formulas for estimating calories with minimum dataset giving 25% average mean error rate. Parth Poply and Angel Arul Jothi J (J, 2020) uses R-CNN method for object detection surface area detection and FCN for segmentation. Calorie estimation is calculated from the actual surface area of the detected food item and reference object in this case Plate. Top view images are used for estimation which works well for some food images but for others require depth information. A Method for estimating calories from a given food images using real time calibration approach called distance estimation was proposed by (Pallavi Kuhad, 2015). The method uses reference object and distance calculations for estimating calories giving 50 % accuracy level. Above mentioned methods work well with raw and non-mixed foods like fruits, salads, bread etc. and are providing approximate calorie estimation. Calorie estimation of mixed food was carried out by author (Yunus, 2018) using attribute estimation approach. This approach uses CNN to classify food with an accuracy of 85 percent. For Real-time attribute and ingredient estimation Vector Space Embedding was used to semantically correlate nearby food items. The terms that appear closer in vector space occur more frequently in the text. Other food items from the same cuisine may appear alongside a food item in the text, causing them to be close in vector space giving only approximate calorie and nutrient information.

Two challenges for food region estimation are: 1. Due to preparation variances, invisible/cooked ingredients, measuring the nutrients and total amount of calories present in the food manually or by means of any technical gadget, is rather challenging and will have a great impact on its nutritional value. In this paper we are dealing with Indian food dataset consisting of diverse food items from different regions. Consider a famous Indian snack “Poha” which shows region wise variation in its ingredients. Ex: In Maharashtra is called “Kanda-poha” whereas in Madhya Pradesh it is referred as “Indori-poha” with minor variations in Ingredients and the same is with another famous Indian snack called Idli’s and Vadas. Proper classification of these food items can definitely lead to proper estimation Thus, resolving this issue to some extent. 2. Second challenge is due to the variations in distance from which the image has been captured, it is hard to measure the exact size (area and depth) of the food. As a result, some percentage of error or inaccuracy is acceptable. Keeping this in Mind the paper mainly focuses on developing a

- Food assessment model which perfectly classifies the food from a given Indian food image and
- Enhances the estimation accuracy of Indian cooked food items.

For classification CNN is used which is trained and tested on Indian Food Images. The inputted images are preprocessed and recognized by CNN. Food region is extracted for estimation by using several filters, edge detection, and segmentation approaches. The weight of the food region is calculated by comparing the extracted region to the calibration object (in this case, the thumb). Following that, the calories are retrieved from the dataset based on the weight.

Materials and Methods

This section presents the technical aspects of the proposed system. It includes datasets, Convolutional Neural Network, Image processing techniques and calorie estimation procedure. As a first step the user has to registered itself with some primary information and thumb dimension. Here thumb will be used as a one-time calibration object used for area calculations. User has to captured an image of food item whose size is to be measured with his/her thumb as a reference object.

Datasets

Three datasets are required for this work: Indian Food Image Dataset (IFID), Indian Food Nutrient Dataset (IFND) and, Food density dataset. When food is absorbed or digested, it releases energy in the form of calories. calories consist of several nutrients such as Carbohydrates, Fats, Proteins, Calcium, Vitamins, Iron, Dietary Fiber, Sodium, Potassium etc. Calories along with its nutrient information are included in the Indian Food Nutrient dataset, created manually from sites (MyFitnessPal , 2021), (Cronometer , 2020) . Another dataset, IFID, was utilized to train and test CNN on food images. The images in this collection are separated into snack, meal, dessert, fruit, and dairy categories. The density of food can be fetched from INFOODS density database (Charrondiere UR, 2012).The dataset includes density and bulk density of around 638 food entries in 20 food groups.

Convolutional Neural Network

Convolutional neural networks, also known as ConvNets or CNN, were introduced by Yann LeCun (Sutskever I., 2012) as the most extensively used neural network model for image classification applications. We develop a CNN model of 5 layers comprising of Convolutional layers with ReLU activations, dropout, and softmax layers. pooling layers, subsampling layers and fully connected layer. 20 images were collected and a basic level of data augmentation was applied to increase the data size. Out of 200 images of size (60*60*3) 160 were used for training and 40 images for testing. Each of the above-mentioned layers uses ReLU as an activation function. To lessen the complex co-adaptations of neurons, dropout is applied in all three layers of the neural network. The model was built using the Adam optimizer, which has a learning rate of 0.001. The model is trained with 8 GB, i5 processor using the stochastic gradient approach with a batch size of 16 and epochs of 20, yielding a validation accuracy of roughly 97 percent.

Reference object for Calibration

Any reference object, such as a coin, cube, card, or thumb, whose size is known in advance, can be used as a real time calibration to estimate the food region. In our paper we had used thumb due to its high availability and ease (Parisa Pouladzadeh, 2014). Size of the thumb is already known in advance during registration process and it can be used as a standard measurement for comparing the extracted area of food region from the given image. Food image with Reference object thumb is shown in Figure 1.



Figure 1. Image of food with thumb as a reference object

Image Processing steps

To obtain the outline of food region and reference object following processing steps were applied:

- Edge detection
- Image Thresholding (isolating food region and dish region)

To isolate the food region, plate region and skin region the first processing step is to detect the edges. Various edge detection algorithms have been widely employed in the image processing framework. John F. Canny (Canny, 1986) proposed the idea of employing a multi-stage method to detect a wide variety of edges in photos

in 1986. Using a Gaussian filter, suppression mechanism, and threshold settings, the Canny edge detector methodology detects a wide range of edges in images. (V.Arun, 2012). After detecting edges, the next step is to isolate the food region and skin region from the plate region. A threshold-based Otsu method which binarize the image based on the pixel intensities and separates different intensity level pixels into foreground and background images. (Otsu, 1979) is used for isolating different regions. Otsu method is a global thresholding method which automatically calculates the threshold value T from an image histogram and replaces image pixels into white regions where saturation is greater than T and into the black in other case. (seth, 2020).

Results and Discussions

Food region, Plate region, and Thumb region comprise the captured food image (skin region). The given image is initially submitted to CNN for Recognition. The plate region is then removed using filtering, contouring, and segmentation methods, and the food region is extracted as shown in Figure 2. The same procedure is again applied to obtained skin region as shown in Figure 3. We use the size of the registered user's thumb to improve the accuracy of the approximated area calculation. We now have the size of the user's thumb, the pixel area of the Food region, and the pixel area of the Thumb region. Estimated area is calculated by formula

$$EFRA = (FRPA * Thumb\ dimensions) / TRPA \quad (1)$$

Where EFRA is Estimated Food Region Area, FRPA is Food Region Pixel Area, and TRPA is Thumb Region Pixel Area.

For volume calculations we adopted the method of Khanna and Chang (Chang, 2013). As a first step we matched the shape of the food with any of the standard geometrical shapes like cone, Cylindrical, sphere etc. and after obtaining exact match we apply their standard formula of volume calculations. In our case, the shape is circular. Formula for volume estimation of sphere is: $V = 4/3 * r * r * r$. To obtain calories we need to figure out the mass of a food item which is a result of volume and the density of food.

$$M = V * F_{den} \quad (2)$$

Where, M is mass, V is volume and F_{den} is the density of the food. When it comes to the food measurement, mass and weights are similar i.e., we got mass, we got weight. The name of the food with its weight is searched in IFND to obtain required calories. The method was experimented with fruits and cooked foods giving average error rate of 8.31. Table 1. Shows the details of results obtained with our proposed method.

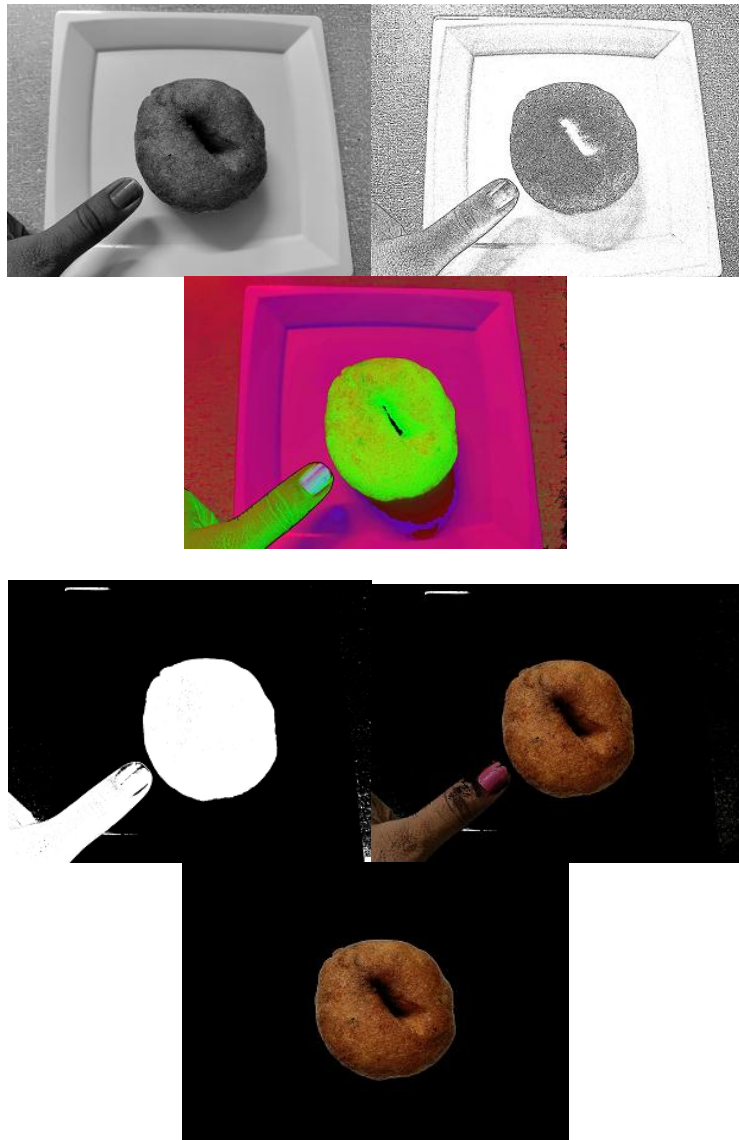


Figure 2. Image Processing steps for obtaining Food Region

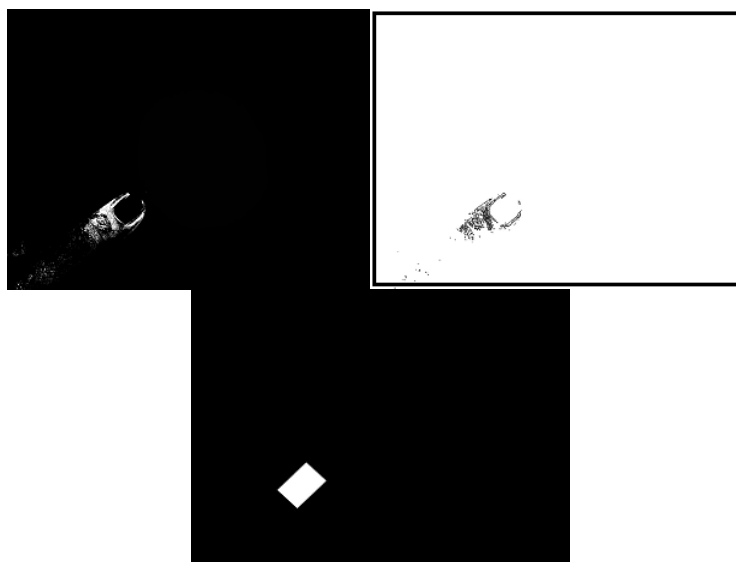


Figure 3. Image Processing steps for obtaining Skin Region

Calories and Nutrient values

Calories computed from nutrient values are typically known accurately and with certainty when the food has been processed and packed in a precise and stable manner (for example, oil, sugar, biscuits, etc.). For all other items, the nutrient content for 100 g of a commonly referred food (for example, "apple," "white bread," or "potatoes") might vary widely depending on the circumstances. The amount of carbohydrates in 100 grammes of apple, for example, varies depending on the apple variety and ripeness level. Even when ripening and variety are controlled, soil and growing circumstances might cause differences. Calories vary depending on the nutrients present. Many of the elements in prepared Indian food are hidden or cooked, affecting the nutrients and calories.

Table 1
Comparison of estimation result obtained with previous methods

Author	Method	Images/dataset	Food type	Average Error (%)
(Chang, 2013)	Multiview Volume	19 Images	Fruits	10
(Parisa Pouladzadeh, 2014)	SVM+ Area and Volume	8	Simple food	14
(Pallavi Kuhad, 2015)	Deep Learning+ Distance Measurement	1	bread	4.05
(Yanai, 2016)	CNN+ Quadratic curve	Annotated dataset (60)	All Types	21.3

(Yunus, 2018)	Attribute Estimation	2	Cooked food	----
(Wataru Shimoda, 2019)	RCNN+ Segmentation Mask and quadratic curve	3	Multiple food	5.5
(Yuanyuan Liu, 2020)	CNN+ Distance measurement	6	Fruits	4.5
Proposed Method	CNN+ Area and Volume	7	Indian Fruits, cooked Foods	8.31

Distance of image from user

The calculation of area depends on number of pixels which surrounds the food region or skin region. Slight change in distance of image and lighting from where the photo has been clicked can change the pixel count and can affect the area calculations. Considering all these things 20 to 30 percentage of error is fairly acceptable in this work.

Conclusion

In this paper, we have presented a food estimation model specially designed for Indian elderly persons. The main contribution of this work is to develop Indian Food dataset containing diverse collection of Indian Foods. For calorie estimation one image with thumb is inputted to CNN for Recognition. The model recognition accuracy is 97% which greatly improves the estimation results. Image processing techniques are then applied which isolates food region plate region and reference object region. The recognized food region undergoes region estimation process in which weight estimation is performed using obtained pixel area of thumb, pre-captured dimensions, estimated area, volume density and, mass. The calories is fetched according to the given weight from the IFND. We had tested 7 images for food region size estimation obtaining 8.31. This idea can be further improved on more Indian food types covering liquid and more complex foods. Moreover, the work can be further improved by providing list and values of nutrients along with its calorie information.

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