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OBJECT WEIGHT ESTIMATION FROM 2D IMAGES

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ABSTRACT

Recently, there has been an increase in the usage of personal mobile technologies such as smart phones or tablets, which users carry with them practically all the time. Via a special calibration technique, using the built-in camera of such mobile devices the user can record photos of the objects. By using these images, the weight of the object can be calculated. This method can be used in different applications such as finding calorie and nutrition in food items, estimating the amount of each raw material required to make a concrete mix etc. The proposed system uses the 2D images to estimate the weight of the object in the image. This system is build based on image processing and object recognition. The proposed system extracts important features such as shape, color, size and texture. Using various combinations of these features and adopting computational techniques, such as Mahalanobis Distance classifier (MMDC), the objects are classified. One time calibration technique is used to estimate the real size of the object. Then the volume of each object is calculated and using density table the weight is estimated.

Keywords: image processing, segmentation, feature extraction, classification, real-size estimation, weight estimation.

INTRODUCTION

The volume calculation and weight estimation of objects is a major step in many real world applications. There are several existing methods for object volume calculations. But the major works are done based on 3D images, which is difficult to obtain in real time and the equipments for obtaining the 3D image are very expensive. A method to calculate the volume of an object from 2D images finds to be important in order to implement many such applications. Nowadays, the use of built-in cameras of smart phones and tablets has been rapidly increasing to capture images of objects. By using these images, the weight of the object can be calculated and this can be used in different applications. Few of these applications include finding calorie and nutrition in food items, estimating the amount of each raw material required to make a concrete mix, etc.

The proposed system uses image processing and segmentation to identify objects, measures the volume of each object, and calculates weight portion from its measured volume and matching it against existing density table. The segmentation features are enriched by involving texture as well as color, shape, and size of the objects. Color and texture are the fundamental characters of natural images, and play an important role in visual perception. Color has been used in identifying objects for many years. Texture tries to discriminate different patterns of images by extracting the dependency of intensity between the pixels and their neighboring pixels, or by obtaining the variance of intensity across pixels.

This method proposes something as simple as the thumb of the user for one time calibration process. Initially an image of the thumb will be captured and stored with its measurements. To estimate real size of the object, extract the thumb portion from the input image and find the thumb size. Then perform the scale and calculations needed to find actual size of the object. As an alternative option, the user could use a coin instead of the thumb; this will add an extra degree of freedom, in the use of the application.

BACKGROUND

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The Canny edge detector is one of the most widely used edge detection algorithms due to its superior performance. The original Canny algorithm relies on frame- level statistics to predict the high and low thresholds and thus has latency proportional to the frame size. In order to reduce the large latency and meet real-time requirements, a novel distributed Canny edge detection algorithm is used, which has the ability to compute edges of multiple blocks at the same time. To support this, an adaptive threshold selection method is used that predicts the high and low thresholds of the entire image while only processing the pixels of an individual block [1].

K-means algorithm is a very popular clustering algorithm which is famous for its simplicity. In K-Means algorithm, we calculate the distance between each point of the dataset to every centroid initialized. Based on the values found, points are assigned to the centroid with minimum distance. Hence, this distance calculation plays the vital role in the clustering algorithm. Cityblock, Euclidean, Cosine and Correlation are the distance measurement techniques for distance calculations in the K-Means algorithm [2].

Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately. It is the term for methods of constructing combinations of the variables to get around these problems while still describing the data with sufficient accuracy.

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Table-1. Sample of a typical nutritional table.

Food name	Measure	Weight (grams)	Energy
Apple with skin	1	140	80
Potato, boil, no skin	1	135	116
Orange	1	110	62
Tomatoes	1	123	30
Bread white, commercial	1	100	17
Cake	1	100	250
Egg	1	150	17
Cucumber	1	100	30
Banana	1	100	150

Mahalanobis distance is a well known statistical distance function. Here, a measure of variability can be incorporated into the distance metric directly. Mahalanobis distance is a distance measure between two points in the space defined by two or more correlated variables [3]. In mathematical terms, the Mahalanobis distance is equal to the Euclidean distance when the covariance matrix is the unit matrix. The Mahalanobis distance is the distance between an observation and the center for each group in m-dimensional space defined by m variables and their covariance. Thus, a small value of Mahalanobis distance increases the chance of an observation to be closer to the group center and the more likely it is to be assigned to that group. Mahalanobis distance between two samples(x ,y) is defined as:

$$d_{Mahalanobis}(X, Y) = \sqrt{(X - Y)^T \sum^{-1} (X - Y)} \quad (1)$$

Unlike most other distance measures, this method is independent upon the scale on which the variables are measured. MMDC requires less training samples and does not suffer from overfitting problem [4].

There are several existing methods for object volume calculation for images. But major works are done based on 3D images, which is difficult to obtain in real time and the equipments for obtaining the 3D image are very expensive. Method to calculate the volume of an object from 2D images finds to be important in order to implement man applications. It is most widely used in applications much as finding calorie and nutrition from food images, estimating the amount of each raw material required to make a concrete mix, etc. There are several methods for calculating object weight from 3D image. 3D slicing is one of the common methods used. Here 3D image is sliced into 2D images and area is calculated in each image. Later combining these areas in each 2D image final volume is calculated.

Calorie is a typical measuring unit, which is defined as the amount of heat energy needed to raise the temperature of one gram of water by 1 degree Celsius at atmosphere pressure [18]. This unit is commonly used to measure the overall amount of energy in any food portion that consists of the main food components of carbohydrate, protein, and fat. In addition to gram units, calorie units are also adopted in developing nutritional facts tables. Each person should take a certain amount of calories daily. If this amount is increased, it will lead to gain weight.

Table-1 shows a small sample of a typical nutritional fact table. Such tables are readily available from international or national health organizations around the world. Our proposed system relies on such tables as a reference to measure nutritional facts from any selected food photo [7]. The amount of calorie and nutrition of each food portion can be derived using nutritional tables, such as TABLE 1, and based on the formula:

$$\text{Calorie in the photo} = (C_T * W_P) / W_T \quad (2)$$

Where C_T is the calorie from the table, W_P is the weight in the photo and W_T is the weight from table.

METHODOLOGY

The proposed project "Object Weight estimation from 2D images" is used to estimate the weight of individual objects for 2D images and can be used in real time applications. This system is build based on image processing and object recognition. The volume of each individual objects is estimated from both the top and side images of the object of interest. Using the density table weight of the object is estimated.

The proposed system consists of following steps:

Image Preprocessing

Image Preprocessing is the first step of the proposed project 'Object weight estimation from 2D images'. It includes the color rasterization of the input image. Color rasterization is performed with a 4^{th} level pyramid, it allow increasing the differences between the objects present in the image, reducing the poor illumination effect over the entire scene. The pyramid simplifies the characteristics and physical attributes of the objects present inside the images, the colors are defined as one per object, and the textures of the food that can produce wrong effects over the final result are removed.

Figure-1. One time calibration of thumb image.

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Segmentation

Image segmentation is done in-order to segment objects from the input image. As the pre-process for segmentation, the input color image is first converted into HSV color space because HSV color space more resembles the human vision. K-means algorithm is used for segmentation of HSV image. Output of this module will be a segmented image.

Feature Extraction

The segmentation features are enriched by involving texture, color, shape, and size of the objects. Using these four features for the classification phase will improve the result of object classification. Color and texture are the fundamental characters of natural images, and play an important role in visual perception [7]. Color feature is extracted from segmented image using color histogram.

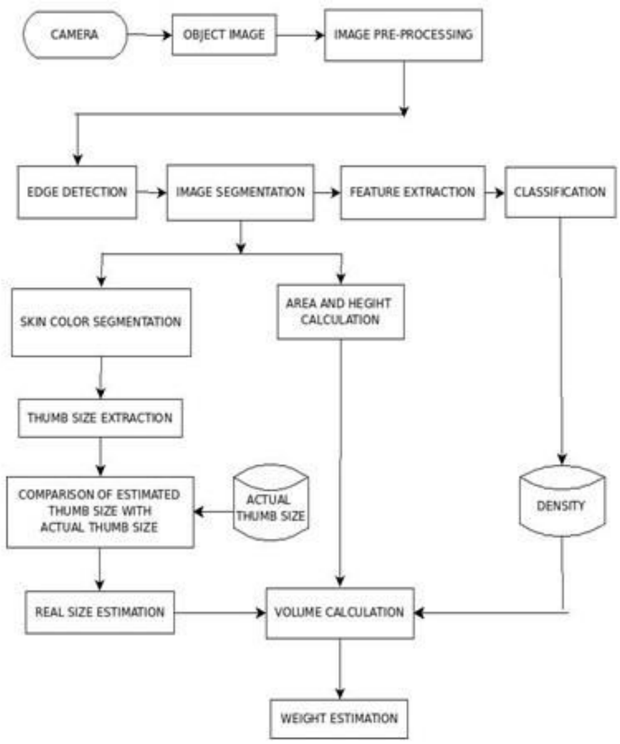

Figure-2. Overall block diagram of the proposed system.

Gabor filter is used for texture segmentation of the image. To do this, a bank of Gabor filters with different orientations and wavelength are applied to an image. The outcome of each of these Gabor filters is a 2-D array, with the same size of the input image. The sum of all elements in one such array is a number that represents the matching orientation and spatial frequency of the input image [7].

Shape is identified using various properties of the object such as roundness, eccentricity, extent, major axis length, minor axis length etc.

Figure-3. (a) Test image with object and thumb (b) Calculation of the thumb dimensions.

Classification

Classification module is done for classifying and identifying each object from the image. MMDC classifier is used for the classification. It has two phases, a training phase and a classification phase. Mahalanobis distance between two samples(x, y) is defined as equation (1). Color, texture, shape, and size features are given as the input for the classification phase. Unlike most other distance measures, this method is independent upon the scale on which the variables are measured. MMDC requires less training samples and does not suffer from over fitting problem.

Real size Estimation

This is used to estimate the real size of each object from the image. It is done by using a onetime calibration process. Actual size of the thumb will be stored in a data base, which is measured from the thumb image. The input image is taken such that the users thumb is placed beside the object. The thumb portion from the input image is extracted and the size of the thumb portion is compare with the actual thumb size from the database, in order to obtain actual size of the object.

To extract the thumb portion from the image, first the image has to convert into YC_bC_r color space. Skin color detection and extraction is best possible in YC_bC_r color space. A bounding box is drawn around the thumb. Height and width of bounding box gives the measurement of the thumb portion.

Volume and Weight Estimation

Volume calculation of the object is done by estimating area and height of the object. Top view image is used for area calculation and side view image is used for height calculation. The volume of the object is determined as:

$$\text{Volume} = \text{Area} * \text{Height} \quad (3)$$

Boundary Tracking

Distributed canny edge detection method is used for finding strong edges in the image and then connected edges are tracked to determine the boundary of the object.

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Table-2. Comparison of actual weight and estimated weight.

Object	Actual Weight (grams)	Estimated Weight (grams)	Accuracy (percentage)
Apple	105	102.68	97.79
Bread	27	26.253	97.23
Orange	130	127.12	97.78
Egg	56	75.436	97.43
Cucumber	145	139.66	96.317

Distributed Canny edge detection algorithm is used, which has the ability to compute edges of multiple blocks at the same time. To support this, an adaptive threshold selection method is used that predicts the high and low thresholds of the entire image while only processing the pixels of an individual block.

Area Calculation

To calculate the surface area of the object superimpose a grid of squares onto the image segment so that each square contains an equal number of pixels and, therefore, equal area. Using grid method for area calculation will match with irregular shapes.

Height Calculation

The height of the object is calculated from side view image. A bounding box is draw around the segmented image and height of the box is taken as height of the object.

Weight Calculation

Using the volume of the object the mass can be determined using general mathematical equation:

$$M = \rho * V \quad (4)$$

where M is the mass of the object and ρ is its density. The density of each object is stored in the database. The output of classification phase is used to retrieve corresponding density from the stored density table.

The Weight of the object is calculated by using the equation:

$$W = M * G \quad (5)$$

Where W is the weight of the object, M is the mass and G is the gravitational force which has the value 9.8m/sec.

ANALYSIS

A comparative analysis was done with the real object weight and with the obtained weight. The analysis was done by considering the metric 'accuracy'. The accuracy of a system is the degree of closeness of measurements of a quantity to that quantity's true value. The accuracy percentage is calculated as:

$$\text{Error}_{\text{percentage}} = (\text{actual}_{\text{value}} - \text{estimated}_{\text{value}}) * 100 / \text{actual}_{\text{value}} \quad (6)$$

$$\text{Accuracy}_{\text{percentage}} = 100 - \text{Error}_{\text{percentage}} \quad (7)$$

From the TABLE II, it is clear that approximately 97 percentage of accuracy is obtained in estimating the weight of the object using the proposed method. From the results, it is clear that nearly an equivalent weight is obtained for each object.

CONCLUSIONS

The proposed method for weight estimation of objects from 2D images is build based on image processing and object recognition. Various feature extraction technique are used to extracts important features such as shape, color, size and texture. Using these features, Mahalanobis Minimum Distance Classifier (MMDC) classifies the objects into different classes. This method uses top view and side view images of an object to calculate the volume and using density table the weight is estimated. One time calibration technique is used to find the actual size of the object. Image of user's thumb is used for calibration.

This system provides approximate weight estimation of the object from input image. Proposed method of weight calculation gives approximately 97 percentage accuracy.

The performance of the proposed system can be improved by using a better shape recognition method where actual 3D shape of the object can be recognized. So that volume can be calculated from a single image using appropriate volume calculating formula, which can result in accurate volume and weight calculation.

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