A METHOD FOR FRUITS RECOGNITION USING IMAGE PROCESSING TECHNIQUES

Pham Xuan Thuy
Hanoi Le-Quy-Don Technical University; thuy.phxuan@gmail.com

Abstract - Pattern recognition has been, and continues to be, the subject for extensive research and development due to its wide range of applications in the real life. In this paper, we introduce a fruits recognition system that can recognize some types of fruits, which are common food in our life, and make corresponding sounds. By analyzing image processing algorithms and taking into account the features, which are extracted from the images for classification purpose, we establish a vision system using a few feature set. The output of our system is a "saying", which matches the result of the classifier – a correct kind of the fruits. In order to validate the effectiveness, we have tested the designed system with some plant fruits such as apple, kiwi, lemon, orange, strawberry, and tomato in the supermarket with a success rate of around 91%, and haved compared this system with other works in recent years.

Key words - recognition system; image processing algorithms; minimum distance classifier; extracted features; sounds

1. Introduction

In recent years, several researchers have implemented fruit recognition systems. Harsh S Holalad, Preethi Warrir and Aniket D Sabarad [1] developed a fruit identification system based on FPGA technology. They built a system that identified fruits such as apple, banana, sapodilla, and strawberry. However, they used offline images for training and testing because of no camera interfacing. In addition, three features including mean, variance, and shape were used to characterize the fruits with an accuracy of 85% only. Moreover, the output of the system was LEDs. Woo Chaw Seng, Seyed Hadi Mirisaee [2] proposed a classification system for fruits spherical pattern. In this system, the combination of three different features, including color, shape, and size,was designed to perform the sequential pattern recognition. The results of experimentation were greatly affected by the fruit size scalar values, which were selected by users. The accuracy of the recognition mainly depended on the number of fruit images for each type of fruit, collected and used to test the system. Dr Vishwanath. B. C, S. A. Madival, Sharanbasa. Madole [3] proposed a methodology for recognition and classification of fruits in fruit salad image samples. The fruits including apple, chikku, banana, orange and pineapple**,** were considered. A K-mean classifier was used and had the classification efficiency of around 98%. The features using for classifying the different kinds of fruits were color and texture – the property that represents surface and structure of an image. R. M. Bolle, J. H. Connell, N. Haas, R. Mohan, G. Taubin [4] presented an automatically-produce-ID system, intended to ease the produce checkout process. In this system, a variety of features such as color, texture (shape, density**)** was extracted and integrated to classify the products. The experiments were performed in several supermarkets and grocery stores, where are hostile, robust, and rugged environments in terms of images. S. Arivazhagan, R. Newlin Shebiah, S. Selva Nidhyanandhan, L. Ganesan [5] also proposed an efficient fusion of color and texture features for fruit recognition. This was done by using the minimum distance classifier based upon the statistical and co-occurrence features derived from the Wavelet transformed sub bands. The method used to analyze images has many potential applications for automated agricultural tasks. Jyoti A Kodagali and S Balaji [6] presented the recent development and application of image analysis and computer vision system in an automatic fruit recognition system. The paper revealed that still much of work needed to be concentrated on the fruits recognition, for instance, the quality of the lighting system, image processing, the recognition performance, and ease of use. A. M. Aibinu, M. J. E. Salami, A. A. Shafie, N. Hazali and N. Termidzi [7] proposed a method for the development of automatic fruit identification and sorting system by using both artificial neural network (ANN) and Fourier descriptor (FD) techniques. The features that were used to recognize and sort different fruits were color and shape.

From the published research works, it is observed that color, shape, and texture are frequently used and have high accuracy of the recognition system. However, the solution of designing a fruit recognition system still needs to be improved. In this work, we have performed a fruit identification system. We have considered six types of fruits, including apple, kiwi, and lemon, orange, strawberry, and tomato as typical fruit samples. The system recognizes given 2D query fruit image by extracting features, including color, shape, texture, size (perimeter and area) and computing their values to measure the distance between the computed values of the query image with the stored mean values of training fruits. A minimum distance classifier based on the Euclidean distance is then constructed. Finally, the sound that corresponds to the certain kind of fruits is spoken out.

The rest of the paper is organized as follows: Section 2 describes the implementation of the system, which gives some basic information about the system, the proposed methodology, feature selection, feature extraction, designing classifier and sound player. Section 3 gives the results of implementing system, including the results of different stages and the final output. The discussions and conclusion of this work are given in section 4 and section 5, sequentially.

2. The implementation of fruits recognition system

2.1. Hardware description

The system of our design included five components: lighting system, a camera, personal computer (including loudspeaker), real-time controller, and software, which were connected to each other with proper settings (Figure 1).

The first component is the lighting system. The system was carefully designed and set up because it mainly affects the quality of the whole system – it helps to provide a consistent picture, eliminate the appearance of variations such as shadow, distort colors and low contrast images.

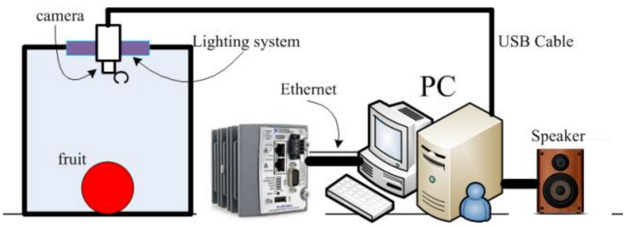

Figure 1. *Overall structure of the system*

The second component is a camera. The image sensor uses solid state charged coupled device (CDD) technology. The speed of image acquisition is up to 30 frames per second.

The third component is CompactRIO, which provides the flexibility, capability, and ease of deployment of image processing program.

The fourth component is the personal computer. The rest of the system, the software is programmed and run on.

For communication issues between components to exchange data, the computer is connected to the real time controller via the Ethernet port and the camera linked to the personal computer via the USB port.

2.2. The fruits recognition algorithm

We propose the algorithm of fruits recognition including six stages: image acquisition, segmentation, feature extraction, classifier, sound player, and evaluation. Most of the stages are developed in the way that they can be implemented in embedded platforms – the further step of our research. The designed process is strictly serial order in the sense that there can be feedback from later stages back to earlier ones.The realization of each stage is pointed out so that the software can be developed by benefiting multithreading programming techniques to reduce the processing time of the whole system.

In the image acquisition stage, image capturing is designed to continuously transfer pictures from digital camera to the personal computer via the USB port. The next stage is segmentation, which extracts the fruitfrom the background. The feature extraction stage determines which calculations have to be performed on the calibrated data coming from the camera. During the classifier design stage, an algorithm is devised to compare the feature vector calculated from the previous stages with the feature vectors, defined by the specific fruits. Finally, based on the result from the previous stages , the specific sound will be produced.

2.2.1. Segmentation

The goal of this stage is to extract three kinds of images.

The algorithm - edge detection-based algorithm - is implemented based on the following steps:

- The color images are first converted to gray scale images. After that, the enhancement of the image is performed.
- The edges of the filtered (enhanced) images are then extracted by using Canny Edge Detection algorithm.
- The images are converted to binary images by using Morphology and ConvexHull functions.
- Then, almost small particles and the part of the image connected to border are removed so that the clean area fruit images (Figure 2), which is one of the sources to calculate necessary features, can be given.
- Finally, the clean edge fruit images – the second type of images needs to be extracted - are produced by using an Edge Detection algorithm. Moreover, the gray scale fruit images – the last source - arealso extracted by using the Mask function (Figure 2).

2.2.2. Features for classification

For the design of the fruit classification system, the issue is noticing not only which features – color, texture, and shape are the obvious choices – but also how to tailor the features and their representations to suit the application [4, 7]. The representation for a fruit should be invariant with respect to rotation, translation and the number of fruit presented. Secondly, because it will be necessary to train the system, the representation and the classification mechanism should be simple.

As a result, there are five features selected for fruit recognition, including color (average and variance intensity), texture, and size (perimeter and area).

2.2.3. Feature Extraction

The developed algorithms are used to extract five features mentioned above from fruit sample images. All calculations are performed by using the real time controller, CompactRIO.

a. Color Feature Extraction

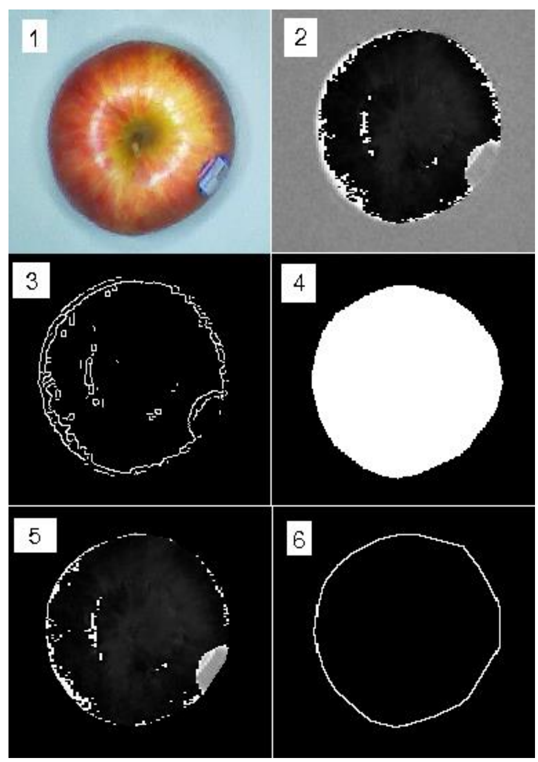

Figure 2. *Source images in segmentation stage*

The image 1 - the original image
The image 2 - the extracted hue image
The image 3 - the edge image after using the canny filter
The image 4 - the area image
The image 5 - the final extracted hue image
The image 6 - the final edge image

Color captures a salient aspect of the appearance of fruit, and does not depend on the position or orientation of the fruit. Many color descriptors (spaces) can be found in the literature, including:

- The Hue/Saturation/Intensity (HSI) space [8].
- The opponent color space [9].
- The Red/Green/Blue (RGB) space [8].

Our system builds its single color from the three-dimensional HSI space. While Saturation is the "depth" or "strength" of the color, Intensity is the gray level. However, Hue is spectral shade, which varies continuously from red through green to blue. Moreover, the most profound difference between fruits is in the Hue component. Two parameters, average intensity and variance intensity, have a substantial impact on the efficiency and are simple to implement as follows.

For a given set of input data:*x = [x(1,1), x(1,2), .., x(m,n)]*, according to Harsh S Holalad [1], these parameters are calculated with the following formulas:

$$average = \frac{1}{m*n}\sum_{i}^{m}\sum_{j}^{n} x(i,j) \quad (1)$$

$$\text{variance} = \frac{1}{m*n}\sum_{i}^{m}\sum_{j}^{n}\left[x(i,j) - average\right]^2 \quad (2)$$

Where, $m \times n$ – the size of the image.

x(i,j) – the gray intensity of the pixel in the image.

a. Perimeter and Area Features

Area and perimeter of an object are convenient measures of the object and easily computed during theprocess of segmentation. The area depends on the boundary of the object and a measurement of area disregards variations of graylevel inside the image. In addition, the perimeter of an object is particularly useful for discriminating among objects with either simple or complex shapes. Based on the computing method of area and perimeter mentioned in [10], we propose a new one, which is much easier to process as follows.

$$area = \frac{\sum \text{intensity of pixels in area fruit frame}}{m*n} \quad (3)$$

$$perimeter = \frac{\sum \text{intensity of pixels in edge fruit frame}}{m*n} \quad (4)$$

b. Texture Features

Texture is important for classifying fruits, because many fruits cannot be reliably discriminated by color.

Texture is a visual feature that is much more difficult to describe. The authors in [11] developed a method of measuring the inhomogeneity of the distribution of the grey values on the surface - image. This measurement is defined as the "lumpiness" of the image data – the ratio between uniformity of the image intensities and their mean value . Adapting from that, we propose a formula for calculating texture as below:

$$texture = \frac{1}{m*n}\sum_{i}^{m}\sum_{j}^{n} x(i,j)^2 \quad divides \quad \left[\frac{1}{m*n}\sum_{i,j}^{m,n}\left|average - x(i,j)\right|\right]^2 \quad (5)$$

2.2.4. Classifier Design

Classifier uses color (intensity and variance), size (perimeter and area), and texture parameters. For the sake of simplicity, the ease of implementation and processing speed, we opted for a minimal distance classifier. Classification algorithms typically use two phases of processing: training and testing.

In the training phase, when an image of fruit is captured, the characteristic properties of typical image features are separated and a training class is created. After collecting the feature data, the average value vector for each kind of fruit is defined by applying approximately scale values and then used to classify unknown image data.

In the testing phase, the distance between the input feature vector and the feature vectors of the defined fruits is calculated to classify unknown image data.

The distance classifier that has been implemented employs the modified Euclidean distance given by,

$$distance = \sqrt{\frac{\sum \alpha_t\left[x_t(i,j) - x_{0,t}\right]^2}{\sum \alpha_t}} \quad (6)$$

Where, $x_t(i,j)$ – the feature of the t^th^ class from test sample and $x_{0,t}$ – the feature of the t^th^ class from the center is obtained by the test samples. α_t- the posistive constants,which are selected by the trial and error method, making the contribution of each feature to the classifier effective.

Training Algorithm

- Step_1 - Consider an image of a fruit belonging to a class.
- Step_2 - Extract the Hue, perimeter, and area components of the images.
- Step_3 - Transfer three images simultaneously from the computer to the real time controller.
- Step_4 - Compute the mean, the variance, and texture of Hue component using Equation 1, 2 and 5. Then, calculate the area and perimeter of a fruit image using Equation 4,5.
- Step_5 - Repeat the steps from 1-4 for different images of a class.
- Step_6 - The central values are found in each feature (color, texture, and size). Then, the mean of each feature (means of 200 images of a class) is calculated. All values are automatically saved to a standard format file such as excel, text and binary file.
- Step_7 - Repeat the same for the remaining classes.

Testing Algorithm

- Step_1 - All Steps1_6 from the training algorithm without saving values to excel files are performed.
- Step_2 - The Euclidean distance between the test values obtained from Step_2 and that of the already stored center values obtained from training are calculated using Equation 4.
- Step_3 - Find out the minimum distance among all the distances (each class) and assign the test image to the class with minimum distance.

2.2.4 Sound Player

The sound player is designed to play a specific sound file (*. wav), which is the corresponding output of the classifier. More specifically, the content of the sound file that is'saying' carries information about a certain fruit that is more convenient for users. For example, "*This is apple*" is content of the sound file corresponding to the output of the classifier: an apple.

2.2.5 The evaluation of fruits recognition system.

For evaluation, the system was tested byusing many fruits in the supermarket. Proper evaluation of the system could not be done with the test set obtained during data collection, so a new set of fruits is required for two reasons. Firstly, the test set has already contained the calculated features for every fruit. Secondly, the test set only contains data from the fruits that also provide the training set.

Two characteristics of the system are evaluated: error recognition rate and recognition speed. The recognition success rate was evaluated for six types of fruits simultaneously. In addition, the recognition speed is evaluated based on the number of frames processed per second. Excellent recognition speed is expected as the system can process at the speed of 24 frames per second.

3. Results

3.1. Recognition success

Table 1 summarizes the recognition results of fruits recognition system on the fruit images that are being sent in as input images during testing the system. The table lists out the test results of the system, including the fruit name, the numbers of test fruits, and the test result.

The overall efficiency of recognition and classification of fruits is found to be around 91%. The results are greatly affected by the fruits, which are selected by users. If the fruits are more carefully selected, there will have an increase in the recognition and classification efficiency.

Table 1. *The recognition results on the test fruits of fruits recognition system*

Fruit	The number of input fruits	Testing results (Correct)
Apple	30	28/30
Kiwi	30	27/30
Lemon	30	29/30
Orange	30	28/30
Strawberry	30	25/30
Tomato	30	27/30
Total	180	164/180 (91.11%)

3.2. Recognition speed

The fruit recognition system can process the average seven frames per second. The processing speed depends on some aspects, for instance, the speed of image acquisition, the speed of image segmentation, the speed of feature calculations, and the duration of classification. In addition, the synchronization of different parts and transferring data between the personal computer and real time controller also affects the overall speed.

As can be seen from the Table 2, the speed of the system is greatly affected by the segmentation. Because the duration of the synchronization and the time of transferring data (using TCP/IP protocol) are non-deterministic, the speed of the whole system is done by measuring the duration of the whole system - around 7 frames per second (120 ms).

Table 2. *The durations of different processing stages*

The stages	The average time (ms)
Image acquisition	20
Image segmentation	80
Feature calculations	70
Classification	50

4. Discussion

4.1. Tuned parameters

The recognition success rate can be affected by the scale values in feature calculation stage. The scale value for each feature needs to be chosen carefully. If the balance of contribution of each feature is not equal, some features will have less influence than the others will. As a result, in some situation, some features do not play any role at all. In the future, we will investigate the way of finding out optimal values for those parameters.

4.2. Adding features

One of the clearest improvements is to use additional features for our fruit recognition. At this moment, only five are used. As seen earlier, this makes distinguishing certain fruits more error-prone. By understanding physical meanings of the features mentioned in [7] and using trial and error method, we can select additional features in the classification in order to improve accuracy.

4.3. Classification methods

Because the classifier, which is used in the fruit recognition system, is developed by the minimal distance method ,which is easy to implement but has some limitations. For instance, if two kinds of fruits have different values of features, but the same distance, the incorrect recognition will occur.

In order to reduce the classification error rates, some methods can be used to make improvement such as tree decision method [12]. Any decision tree will progressively split the set of training examples into smaller and smaller subsets. For each branch, the decision is to continue to split and accept, or select another property and grow the tree further. As a result, the quality by applying the distance classifier can be improved.

4.4. Choosing fruits

By observing the fruits during the tests, we notice that the mistaken recognition usually happens when the fruits are much different from others in the same type. So, to increase the success rate, fruits should be pre-classified beforehand.

5. Conclusion

We have set out to implement an automatic visual recognition of fruit with high accuracy. By properly setting up designed lighting and carefully designing edge based detection algorithm, a precise segmentation of fruit from the background is done. From these segmented images, recognition clues such as color, size, and texture are extracted and calculated. According to the results, the success rate is higher than 91% with the speed of seven frames per second. In comparison with other works, such as [1, 2, 13], our designed system has the same as, or even higher accuracy. In addition, this is a completed system and is much more convenient for users. This system could be used for multiple purposes, in education or for blind people.

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(The Board of Editors received the paper on 08/14/2015, its review was completed on 12/22/2015)