First Joint Congress on Fuzzy and Intelligent Systems
Ferdowsi University of Mashhad, Iran
29-31 Aug 2007

Intelligent Systems Scientific Society of Iran

A NEW AND ROBUST APPLE EVALUATION METHOD USING IMAGE PROCESSING

H. Mirzaei, M. Saraee
Electrical and computer engineering department, Isfahan University of technology
mirzaei.hamid@yahoo.com, saraee@cc.iut.ac.uk

Abstract: Fruit evaluation is a necessary component of vegetable and fruit sorting system. Recently, machine vision applications for sorting and inspecting some fruit vegetables have been studied by many scientists. In this paper a new and robust computer vision based system for apple evaluation using image processing is presented to automatically grade apples. The process of segmentation of apples is performed by applying a threshold and a few morphological operations such as opening and closing. Next each apple gets a label using run-length algorithm. Now calculating the measure properties of the apple can be done easily. The next step is detecting the apple skin bruises and the defected areas of apple skin that can be done performing tophat operation on the image. By comparing the results of our approach with the standard apples we can clearly see that our approach will produce good results for sorting the apples.

Keywords: Apples, color, image processing, machine vision.

1 Introduction

Computer vision is a young technology starting from 1960s [1]. From 1970s it began to grow in both theory and application rapidly. It is reported that more than 1000 papers are published each year in various fields of this technology like medical diagnostic, automatic manufacturing, robot guidance, remote sensing and etc [2]. The main core of machine vision systems is image processing and image analysis with numerous methods to achieve various properties. Recently the usage of computer vision is growing rapidly in many applications to substitute visual senses of human [3], [4], [5], [6], [7].
Traditionally evaluation of food products is performed by humans. These manual operations are time consuming. Moreover the accuracy of this operation cannot be guaranteed [8]. For example a human must grade at least 20 apples in a second that can produce lots of errors and it relates to subjective factors. During the last decade scientists have studied on several methods for automatic evaluating the quality of food products and fruits [9] and numerous works in this category have been reported [10].

Nowadays, because of the advances in electronic technology, machine vision technology can be applied to the development of an automatic fruit evaluator. Machine vision enables to handle a large amount of raw data and perform remote judgment. Computer vision based food evaluation is a hard but necessary task for increasing the speed of sorting food products and reducing human errors in this process. This technology can provide a reliable judgment system independently from human subjective factors.
In Japan fruit vegetables are generally sorted into grades based on size or weight before marketing[11].
But these properties are not the only factors which can be used to describe the quality of fruits. Among them the shape and color are extremely important but unfortunately these properties are mostly neglected and grade sorting based on shape, damage and color (for example in the case of orange, apple, and cucumber) is still in the initial stage and in most cases performed manually.
This paper presents a new and robust grade judgment system with a high performance rate using image processing technology. The simplicity

of this method makes it a practical method. This method uses only a simple webcam which is commonly available everywhere as a peripheral device.
The rest of the paper is organized as follow: We discuss the proposed method in Section 2. Section 3 describes our experimental results. Finally in the last section, we summarized the paper and give the conclusions.

2 PROPOSED METHOD

In this section we discuss our methodology. We divide this into 5 subsections which include the process of image inputting, threshold determination, closing the image, opening the image, labeling and finally detecting the bruises of the apple.

2.1 Image Input

The input image contains a number of webcam photos of clean apples. This method is also tested on some red apple pictures adopted from the net. Figure 1 shows a sample input image.

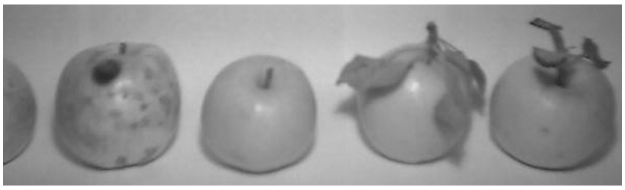

Figure 1: Primary input image

2.2 Thresholding

To determine the apple location in the image HSV color space is applied which it seems likely more appropriate with human vision structure. Then thresholding is applied to get a binary image.
The result of this step on figure 1 is shown in figure 2.

Figure 2: Binary image

As you can see thresholding operation on the image produce some noise pixels which we don't want to have them. In the next step you see our solution for this problem.

2.3 Closing the Image

In this step the image is closed with a structuring element as shown in figure 3 which accounts for removing small noise pixels. We see performance of closing in figure 4.

Neighborhood:								
0	0	1	1	1	1	1	0	0
0	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	0	0

Figure 3: Structuring element for closing

Figure 4: the closed image

Now we have a binary image have no noise pixels.

2.4 Opening the Image

The image is opened with a binary image at the same size of available apples as a structuring element. It causes a smooth bound for image. Also the leaves and extra elements that we don't need them are almost omitted if they weren't so large that can be considered as a part of apple image. As regards the structuring element is large so even one noise pixel can cause omitting the whole image.

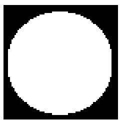

Figure 5: Structuring element

Figure 6: Opening operation result

2.5 Labeling

In this section the object labeling is used on the image resulted from previous step. The labeling algorithm is shown in table 1.

TABLE 1: The Labeling Algorithm

Run-length coding	The input image is coded using run-length algorithm.
Checking the iterations	The iterations are checked and get their first label and the equivalent labels are entered in a table.
Correcting the table	The errors in the table are corrected.
Final labeling	Based on results of previous step each object gets a new label.

Now each object can be distinguished by a label. So the number of objects and these region properties can be calculated:

Area: The actual number of pixels in the region.

MajorAxisLength: The length (in pixels) of the major axis of the ellipse that has the same normalized second central moments as the region.

MinorAxisLength: The length (in pixels) of the minor axis of the ellipse that has the same normalized second central moments as the region.

Orientation: The angle (in degrees) between the x-axis and the major axis of the ellipse that has the same second-moments as the region.

EquivDiameter: The diameter of a circle with the same area as the region Computed as sqrt(4*Area/pi).

Solidity: The proportion of the pixels in the convex hull that are also in the region Computed as Area/ConvexArea.

ConvexArea : The number of pixels in ConvexImage.

Extent: The proportion of the pixels in the bounding box that are also in the region Computed as the Area divided by the area of the bounding box.

Figure 7: Labeling result

By applying this result on primary image we get figure 8.

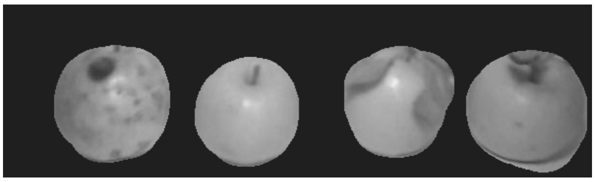

Figure 8: Result picture

2.6 Detecting the Bruises of an Apple

For finding the skin bruises we use closing tophat filtering, returning the image minus the morphological closing of the image as u see in the formula. This operation can amplify the darkness's of the image.

$$t\text{-}\phi_b(f) = \phi_b(f) - f$$

This figure shows the result of performing closing tophat.

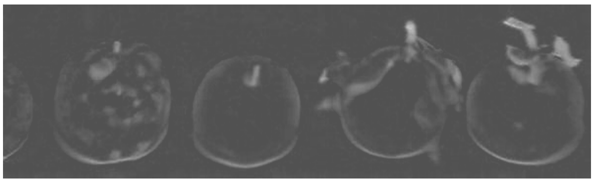

Figure 9: Result of performing closing tophat

For making a binary image of aforementioned section thresholding is used as shown in figure 10.

Figure 10: Binary tophat

Closing tophat performance in bound of the apple image because of shadow, produce extra brightness which must be removed. At first the binary image is eroded with a structuring element (figure 11). We want intersect of binary tophat and erosion result (figure 12) since we prefer to achieve inside bruises of the image.

Figure 11: Result of erosion on image

Fig.ure 12: Intersect of figure 10 and 11.

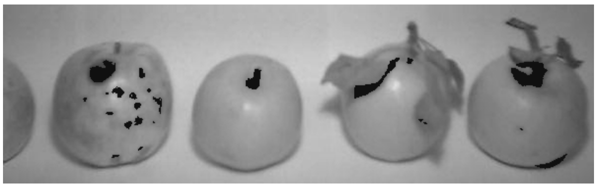

Figure 13: Bruises achieved from previous step shown on first image.

3 RESULTS

Calculated measure properties of the apple shown in figure 14 resulted by our approach are presented in table 2.

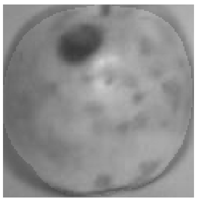

Figure 14: First image

TABLE 2 : Properties of the first image

Area	11370
MajorAxisLength	122.7915
MinorAxisLength	118.0965
Orientation	48.0293
FilledArea	11370
EquivDiameter	120.3193
Solidity	0.98595
Extent	0.80971

In figure 15 we can see the result of applying the same algorithm on a red apple. In figure 16 the implementation of our algorithm in MATLAB 704 is illustrated. We get the original image and apply the proposed algorithm on it. As it can be seen in figure 16 in this implementation result of each step and the properties of each apple can be seen in output.

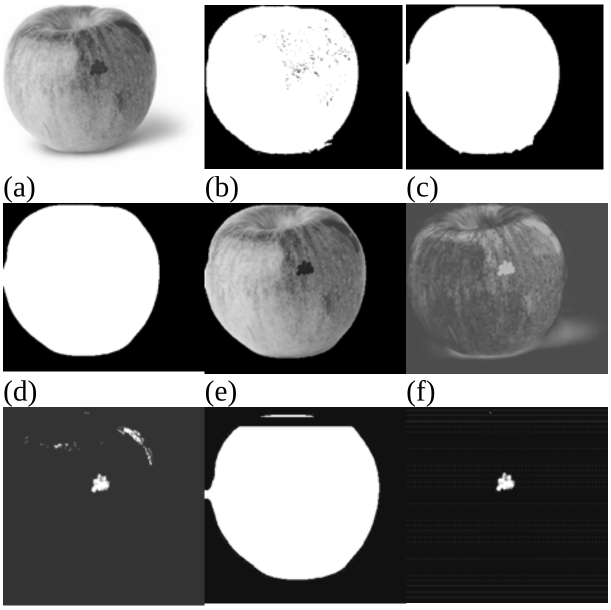

Figure 15: The result of different steps of the proposed algorithm. (a) The input image. (b) Binary image produced by thresholding. (c) . Result of closing. (d) Result of opening. (e) The separated image. (f) Result of closing. tophat. (g) Binary closing tophat. (h) Erosion result. (i) The bruises on binary tophat.

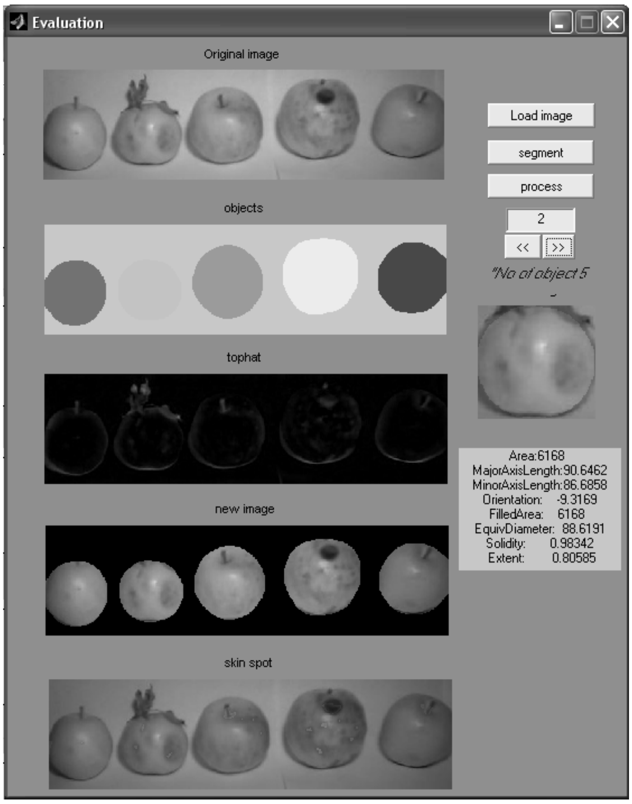

Figure 16: Implemented algorithm in MATLAB704

To evaluate the proposed method quantitatively, the image of 10 apples is analyzed by a human expert and their defected areas are determined. Using these specified areas each pixel of the image can be classified as defected or healthy. Then the class determined through the vision based evaluator is compared with these classes. The result of this experiment shows that False Alarm (FA) and Detection Rate (DR) are respectively equal to 14% and 79.5%.

4 CONCLUSION

In this paper an easy and robust computer vision based apple evaluation system using image processing technology is presented. The input images of apples are segmented using a few morphological operations like closing and opening. This helped us to locate different apples in the input image. The next step is labeling the apples. For this step a suitable algorithm is run-length which makes calculating the properties of each apple very easy. The defected areas of skin are detected in the apple image by performing closing tophat operation on the image. Finally comparing these results with standard apples we can sort the apples.

In summary these investigations lead to the following conclusions: Our approach performs well in fruit evaluation. It is also easy to setup and can be used with a webcam. The simplicity of this method makes it more efficient and therefore it can be used extensively in fruit industry.

References

[1] Baxes, G.A., Digital image processing principle s and applications, Willy, New York USA, 1994.

[2] Sonka, M,Hlavac, V, Boyle, R., Image Processing, Analysis, and Machine Vision. PWS Publishing, California, USA, 1999.

[3] Marchant, J.A., "Tracking of row structure in three corps using image analysis", Comput. Electron. Agric., Vol. 15, No. 2, pp. 161-179, 1996.

[4] Marchant, J.A., Hague, T., Tillet, N.D., "Row-following accuracy of an automonous vision-guided agricultural vehicle", Comput. Electron Agric. Vol. 16, No. 2, pp. 165-175, 1997.

[5] Davies, E.R., Machine Vison: Theory, Algorithms, Practicalities, 2nd edn. Academic Press, New York, 1997.

[6] Mcfarlane, N.J.B., Tisseyre, B., Sinfort, C., Tillett, R.D. Sevila, F., "Image analysis for pruning of long wood grape vines", J. Agric. Eng. Res. Vol. 66, No. 2, pp. 111-119, 1997.

[7] Sun, D.-W., "Inspecting pizza topping percentage and distribution by a computer vision method", Journal of Food Engineering, Vol. 44, pp. 245-249, 2000.

[8] Park, B. Chen, Y.R., Nguyen, M., Hwang, H., "Characterizing multispectral images of timorous, bruised, skin-torn, and wholesome poultry carcasses", Transactions of the ASAE, Vol. 39, No.5, pp, 1933-1941, 1996.

[9] Locht, p., Thomsen, K., Mikkelsen, P., "Full color image analysis as a tool for quality control and process development in the food industry", Paper No. 973006, ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, 1997.

[10] Abdulla, M. Z., Aziz, S. A., & Mohamed, A. M. D. "Quality inspection of bakery products using a color-based machine vision system", Journal of Food Quality, Vol. 23, No. 1, pp. 39-50, 2000.

[11] D.M. Bulanon, T. Kataoka, Y. Ota, T. Hiroma, "A Machine Vision System for the Apple Harvesting Robot," Agricultural Engineering International; the CIGR Journal of Scientific Research and Development, Manuscript PM 01-006, Vol. III, pp. 1-11, 2001