International Journal of Computer Applications (0975 – 8887)
Volume 45– No.7, May 2012

Automatic Segmentation and Yield Measurement of Fruit using Shape Analysis

H. N. Patel
Associate Professor,
A.D. Patel Institute of Technology,
New V.V.Nagar,Anand, India,

R.K.Jain
Professor,
A.D. Patel Institute of Technology,
New V.V.Nagar,Anand, India,

M.V.Joshi
Professor,
Dhirubhai Ambani Institute of Information and Communication Technology, Gandhinagar
India

ABSTRACT
Efficient locating the fruit on the tree is one of the major requirements for the fruit harvesting system. In this paper, automatic segmentation and yield calculation of fruit based on shape analysis is presented. Color and shape analysis was utilized to segment the images of different fruits like apple, pomegranate, oranges, peach, litchi and plum obtained under different lighting conditions. First the input sectional tree image was converted from RGB colour space into the L*a*b colour space. The resultant image was then applied to the algorithm for fruit segmentation. The Edge detection and combination of a circular fitting algorithm was used for the automatic segmentation of fruit in the image. The resultant edge points were then used for fitting the approximate circular shape. The resultant fitted circles were used as a count of total number of fruits in an image. Hundred sectional tree images of different fruits were used for the segmentation and yield measurement. The results indicate that the proposed method can accurately segment the occluded fruits with the efficiency of 98% and the average yield measurement error was found as 31.4 %.

Keywords
*L*a*b color space, Edge detection, circular fitting.*

1. INTRODUCTION:
Fruit segmentation system was primarily developed for robotic fruit harvesting. However this technology can easily be tailored for other applications such as on tree yield monitoring, crop health status monitoring, disease segmentation, maturity segmentation and other operations which require vision as a sensor. For fruit harvesting system, it is necessary to detect the right maturity fruit on the tree more efficiently. Many researchers have developed the algorithm for fruit segmentation, some are listed here. The fusion of color and texture features was used by the authors in [1] for fruit recognition. Two image fusion approaches: Laplacian pyramid transform (LPT) and fuzzy logic were applied for improving the fruit segmentation efficiency as compared to the fruit segmentation using only thermal image in [2]. A computer vision system capable of detecting defects in the citrus peel was presented in [3]. The author in [4] used the local or shape based analysis for rapid fruit segmentation and were able to detect the fruit at specific maturity stages i.e., fruit with a color different from the background. The on-line estimation of oranges, peaches and apples regarding the quality attributes like size, color, stem location and segmentation of external blemishes was presented in [5]. Based on bayesian discriminate analysis, the effect of drying on shrinkage, color and image texture of apple discs was presented in [6]. Apple discs were classified into classes depending on external image features at different stages of drying by euclidean distance classifier. A machine vision algorithm consists of segmentation, region labeling, size filtering, perimeter extraction and perimeter-based segmentation, for the recognition of orange fruit was presented in [7]. The authors in [8] had developed three types of harvesting robot: strawberry-harvesting robot, eggplant-harvesting robot and tomato-harvesting robot. The survey of different vision based algorithm is presented in [9]. An automatic fruit recognition system and a review of various fruit detection work are reported by the authors in [10]. The methodology used by the authors in [11] was able to recognize spherical fruits in natural conditions facing difficult situations like: shadows, bright areas, occlusions and overlapping fruits. The defects of the citrus peel are segmented by sobel gradient and the flaw is extracted using euler distance, nearest neighbor and k-nearest neighbor classifiers by the authors in [12]. Multiple features were used for the detection of various fruits from the sectional tree images. For the accurate detection of different color fruits, the authors in [13] had used color, intensity, edge and orientation feature vectors of the input image. For gray-scale MR medical and aerial images, a new segmentation method based on gray-scale morphology was proposed in [14].The models for illumination and surface reflectance for use in outdoor color vision, and in particular for predicting the color of surfaces under outdoor conditions was discussed in [15]. Fruit recognition system using color, shape and size based feature analysis with 90% of recognition accuracy achieved by authors in[16]. Color and texture features were used to locate green and red apples by authors in[17].

Our work in this paper presents an automatic segmentation and yield calculation of fruit based on shape analysis. The color and shape analysis was utilized to do the segmentation of the fruits in an input sectional tree image. The images used in our work were of different tree images of variety of fruits like apple, pomegranate, orange, peach, litchi and plum. The input color image was first converted from the RGB color space into the L*a*b color space for the coarse detection of fruit region. The L*a*b color space has been designed to resemble the human visual perception. The idea was to do the coarse processing of the image so that the fruit were visually well distinguishable and then to use the L*a*b color space to segment fruit regions with its perceptually uniform property. (i.e. the colors which are visually similar are close to each other in color space). A good description regarding the L*a*b color space can be found in [18]. The edges were detected from the resultant image using *Sobel* edge detector. These edge points were used for fitting the nearest circular shape. The number of circles fitted to the input image was used as a count value of the fruits in an input image. The paper structured as follows: the next section discusses the material and methods. Section 3 gives the results and discussion. Finally, in Section 4 conclusions of the proposed approach were presented.

2. MATERIALS AND METHODS

Image of the on tree fruit varieties such as apple, orange, pomegranate, plum, litchi and peach were used. The images were captured in different lighting conditions with different background and different camera distances. Total 100 images were used for the implementation and all the images are of different pixel size. Fig 1 shows the complete block diagram of the proposed technique.

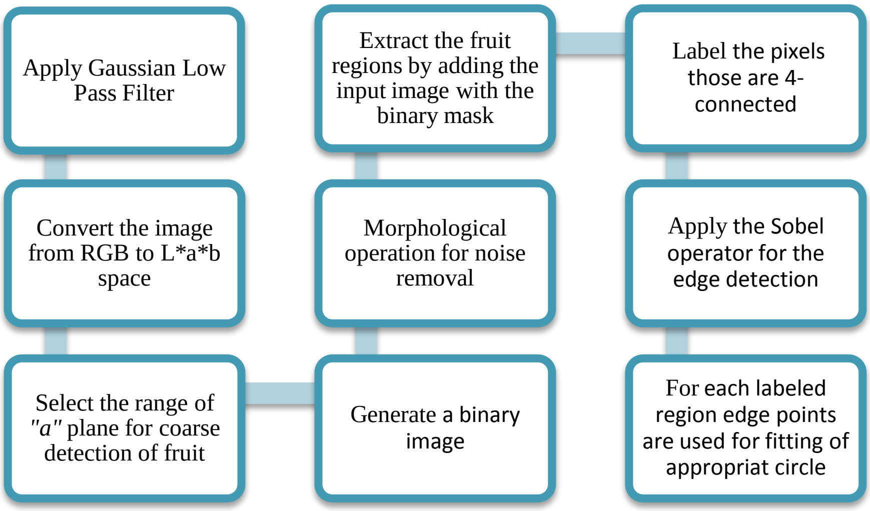


Fig 1: Schematic representation of the proposed approach

The input sectional tree images were having different lighting conditions. The fruit regions in many images were under the shadow of the leaves and branches. So the input image was first applied to the pre-processing step of filtering. The Gaussian Low Pass filter was applied for averaging out the variations in lighting conditions. The pre-processed image then converted from the RGB color space into the L*a*b space. The *"a"* image plane was used for the coarse detection of fruit region. The pixels carries the values higher than the predefined threshold in the image of "a" plane were considered as pixels of fruits regions. So, this step was used for the coarse detection of probable fruit region within an input image. The detected pixels were represented by the value of "1" while the remaining pixels were represented by the value of "0". This resulted in the binary mask image where the fruit regions are represented as white and the background was represented by black colour. Morphological operations were used to improve the binary image. Firstly morphological "clean" operation was applied to remove the isolated pixels and then the morphological "close" operation was applied to get a whole white region which represents complete fruit region. The fruits were detected by adding the improved binary mask to the input image. The improved binary mask image was used for the region labeling of the pixels. For each labeled region the *Sobel* operator was applied. The resultant image contains only edges of each region. These edge pixels for each region were used for fitting the appropriate circles to each labeled region. Since the shape of the fruits are circular, the proposed method uses circle fitting algorithm. The number of fitted circles was used for the estimation of total number of fruits within an input image. The proposed algorithm was applied for different type of fruit images such as apple, pomegranate, orange, plum, litchi and peach. The results of each stage of the proposed methods are shown below:

The test image of orange tree is shown in Fig 2.

Fig 2: Input image of oranges

The algorithm was implemented based on the following steps:

I. The preprocessing of the input image was performed first. A Gaussian low pass filter was used to reduce the noise as much as possible. Noise portend to unequal color intensity distribution in the original images that formed shades and shiny regions in the image. The Gaussian filter was a 5 X 5 pixel mask with the standard deviation of 128, which limit image frequencies to less than 128Mega Hertz (MHz). Filtering the image caused blurring which noise was reduced as shown in Fig 3.

Fig 3: Smoothed image using Gaussian 5 X 5 filter mask

II. Segmentation of a fruit image in to four regions: leaves, fruit, branches and background , was empirically found to be more successful than segmenting in to two or three regions. L*a*b color space, which is one of the two device independent color spaces introduced by the Commission International del'Eclairage (CIE), was used for color segmentation. Both HLS (Hue, Luminance and Saturation) and RGB color spaces are device-dependent: that is, the color co-ordinates depend on the characteristics of the devices used to capture and display the images. L*a*b space is designed in a way such that the colors which are visually similar are adjacent to each other in the color space. This property makes the L*a*b color space more suitable for color image segmentation [18]. Considering its advantages, pre-processed images were converted to L*a*b color space for data extraction and processing. *L* component which indicates the lightness was not taken into account.

III. The range of *a* values represent the fruit region was selected (Fig 4). A MATLAB program was written for extracting fruit region, so that the pixels of the fruit regions can be selected automatically using the pre-defined range of *a* values.

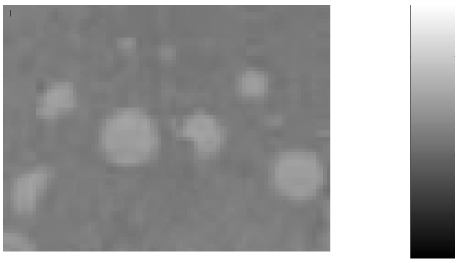


Fig 4: Image showing only *a* values after converting it into L*a*b color space

IV. Filtered images were then converted to binary form in order to be processed (Fig 5).

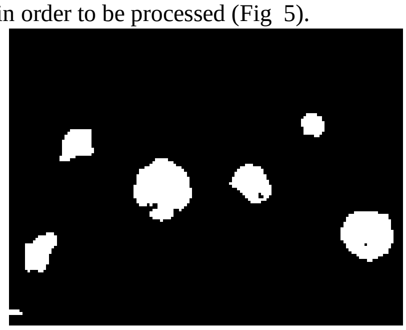


Fig 5: Binary Image

V. Binary images were processed to reduce the existing noise after converting images. In this stage noise was defined as the area detected as features other than the fruit (i.e. apples). Morphological operations were used to improve the binary image. Firstly, if the binary image contains some isolated white pixels whose eight neighbors were all black pixels, the morphological "clean" operation was applied. Finally, if the fruit region was not small and very smooth the white region in the generated binary image will only center on the boundary of the region and the inner of the region was black region in the binary image. so morphological "close" operation was applied to get a whole white region which represents complete fruit region. The resultant binary image shown in Fig 6.

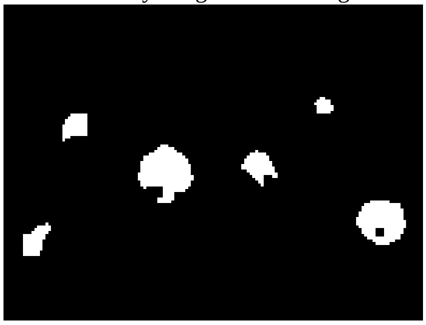


Fig 6: Binary noise removed image

VI. Binary noise-removed image were labeled to extract the fruits (Fig. 7).

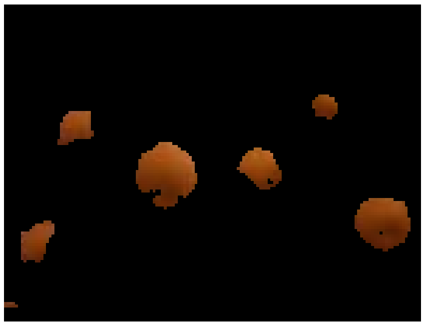


Fig 7: Extracted fruit region

VII. Fit the Circle to the edge points :

The labeled image as shown in Fig 7 was used for the yield calculation. The steps for the yield calculation are listed below:

- For each labeled pixels detect the edges using *sobel* operator: The 3 X 3 *sobel* operator used for the edge detection in horizontal as well as in vertical direction are:

$$Sx = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

$$Sy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

VIII. The result of edge detection operation (Fig 8) shows only fruit outlines.

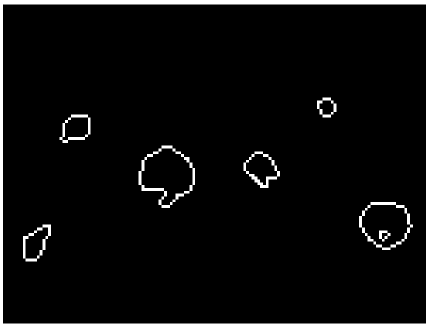


Fig 8: Edge detection result

IX. For each labeled region, the detected edge points were used to fit the circular shape. The number of circles fitted to the input image was the total fruit count for an input image. (Fig 9).

Total no. of Fruits are 6

Fig 9: Resultant image showing yield per image

2.1 Yield Calculation using Shape Analysis:

The proposed method uses the shape analysis for the yield measurement. The binary mask image was used iteratively for mainly three operations: Region Labeling, Edge detection and Fitting Circle to the pixel data.

2.1.1 Region Labeling:

The noise removed binary image was used for labeling the pixels based on its connectivity. The region labeling algorithm scans the entire image raw wise. The steps for region labeling are listed below:

1. For every pixel in a binary image, check the *north* and *west* pixel (i.e. consider 4-connectivity) for a given region criterion. (i.e. intensity value of 1).
2. If none of the neighbors fit the criterion then assign to region value of the region counter. (Initially region counter was set to 0) and increment the region counter.
3. If only one neighbor fits the criterion assign pixel to that region.
4. If multiple neighbors match and are all members of the same region, assign pixel to their region.
5. If multiple neighbors match and were members of different regions, assign pixel to one of the regions. Indicate that all of these regions are the equivalent.
6. Scan the image again and assign all equivalent regions the same region value.

2.1.2 Edge Detection:

The labeled image was used for detecting the edges of fruit regions. The *Sobel* edge detector was applied for each labeled region. The *Sobel* operator does the first order differentiation for detecting the discontinuities in the pixel intensity value. The 3 X 3 *Sobel* operator used for the edge detection in horizontal as well as in vertical direction are:

$$Sx = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} ,$$

$$Sy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

2.1.3 Fitting circle to the pixel data:

The edge points for each labeled region were used as boundary points of each fruit. To fit a circle to scattered data $\{(x_i, y_i)\}$ by orthogonal least squares one minimizes the sum of squares

$$\mathcal{F} = \sum_{i=1}^{n} d_i^2$$

Where d_i is the geometric distance from the data point $(x_i\ y_i)$ to the hypothetical circle. The canonical equation of a circle is

$$(x - a)^2 + (y - b)^2 = R^2$$

Where a and b are the center co-ordinate of a circle and R is the radius of it; then the signed distance is given by

$$d_i = \sqrt{(x_i - a)^2 + (y_i - b)^2} - R$$

Note that $d_i > 0$ for points outside the circle and $d_i < 0$ inside it. Hence

$$\mathcal{F}(a, b, R) = \sum_{i=1}^{n} \left[\sqrt{(x_i - a)^2 + (y_i - b)^2} - R\right]^2$$

An algorithm to fit a circle into scattered pixel data.

1. Find the co-ordinates of the edge pixels.
2. Calculate the mean of pixels.
3. Find the center of the clusters using the mean computed.
4. Compute the coefficients of the characteristics polynomial: $A(x^2 + y^2) + Dx + Ey + F$.
5. Apply Newton's method [20] for fitting the approximate circle into the known data set.
6. Compute the circle parameters (centre and radius).
7. Plot the probable fitted circle on an input image.

The results of shape analysis were able to calculate the yield of the fruits very accurately in clustered background. Some fruits those were visibly far away from the camera were also efficiently detected by the proposed method (Fig 10).

input image Total no. of Fruits are 7

Fig 10 : Yield measurement of fruits for longer camera distance image

3. RESULTS AND DISCUSSION:

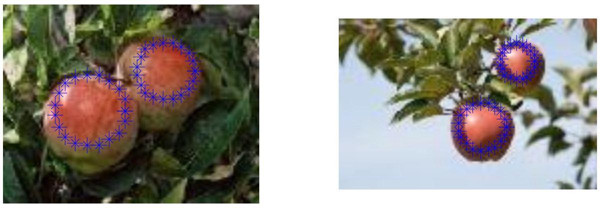
The main idea was to develop a robust algorithm under various natural lighting conditions, camera distances and background conditions for different color and shape fruits. Since the images used were of different lighting conditions, they included tree canopies including tree branches, leaves, fruits, sky, etc.

Total 100 images of different fruits (apple, pomegranate, orange, peach, plum and litchi) were collected from internet; each contains one or more number of fruits. The proposed algorithm detected the image objects in the image better (Fig 11).

input image Total no. of Fruits are 20

Fig 11: Result of proposed algorithm

The proposed algorithm detects the fruits accurately in the different lighting conditions, shadow effects of leaves on fruit and in clustered background (Fig 12).



Total no. of Fruits are 2 Total no. of Fruits are 2

Fig 12: Effect of different lighting conditions and clustered background.

It should be noted that there were very few over estimations and few under estimations by the algorithm.

The main reasons for overestimation [7] were:

1. When a single fruit was hidden by many leaves and the separation was more than 9 (3 X 3) pixels, they were counted as different fruits.
2. Small fruits were not clearly visible in manual counting; however they were counted as fruits by the algorithm.

Reasons for underestimation [7] were:

1. In some cases, many fruits clusters were counted as single fruit in the estimation by the algorithm due to connectivity.

The algorithm was able to detect the fruits in 98 of 100 images. In other words, the accuracy of the algorithm was found to be 98%. The accuracy of the fruit calculation was calculated based on the difference between the manual fruit count and fruit count using algorithm. The fruits were calculated manually from an input image by two different persons. The average manual count was compared with the count resulted from an algorithm. The percentage error was the measure of the yield calculation accuracy. The plot of fruit count using algorithm versus manual count is shown in Fig 13.

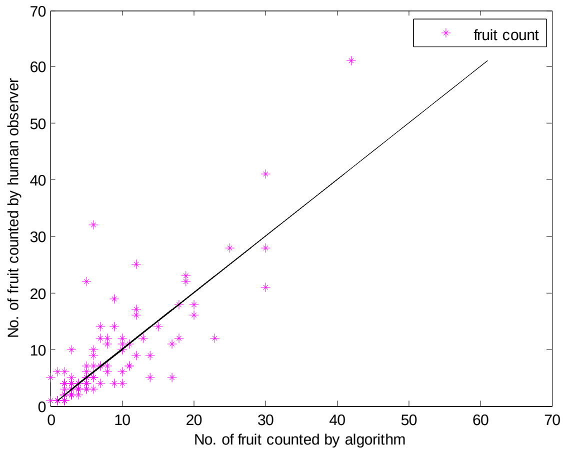


Fig 13: Plot of manual fruit count versus fruit count by an algorithm

The percentage error was as low as 0 % and as high as 72% in cases where there were 1 or 2 fruits and the algorithm identified none. The mean absolute error was determined to be 31.4% for all the validation images. The main reason for this high error was due to the fact that there were many fruits that were very small and clear to the human eye, while the algorithm would have treated them as noise and left them while counting the fruits.

3.1 Comparison

The paper presented by Hannan[7] deals with the machine vision based development system for the recognition of orange fruit. The author uses segmentation, region labeling, size filtering, perimeter-extraction and perimeter based detection. The author in [7] used only single type of fruit i.e. oranges. Our proposed algorithm gives accurate results of fruit detection and yield calculation for the variety of fruits with different colour shades in varying lighting conditions with the clustered background.

4. CONCLUSION

In this paper, the automatic segmentation and yield measurement of fruit was developed and evaluated. The algorithm was composed of edge detection, region labeling and circle fitting based detection. It was designed to solve the problems of varying illumination and fruit occlusion through segmentation and shape-based detection. The proposed algorithm can be improved to design an automatic crop health monitoring in future.

5. ACKNOWLEDGEMENT

The authors would like to thank Head of Electronics and Communication Engineering Department of A.D.Patel Institute of Technology for carrying out the work in the laboratory of Electronics and Communication Engineering Department. Authors also express sincere thanks to Dr.V.S.Patel, Director-SICART for his suggestion, evaluation and encouragement during our work.

6. REFERENCES

[1] Arivazhagan S., Newlin Shebiah R., Nidhyanandhan Selva S., Ganesan L., " Fruit Recognition using Color and Texture Features*", Journal of Emerging Trends in Computing and Information Sciences*, vol. 1, no. 2, Pages: 90-94, Oct 2010.

[2] Bulanon D.M., Burks T.F., Alchanatis V., "Image Fusion of visible and thermal images for fruit segmentation", *Biosystems Engineering*, Vol-103, Issue-1, May 2009, pages: 12-22.

[3] Bulanon D.M., Burks T.F. and Alchanatis V., " Study of temporal variation in citrus canopy using thermal imaging for citrus fruit segmentation", *Biosystems Engineering*, Vol-101, Issue 2, Pages 161-171, October 2008.

[4] Bulanon D.M., Burks T.F., Alcahnatis V. , "Improving Fruit segmentation for robotic fruit harvesting", *ISHS Acta Horticulturae 824: International Symposium on Application of Precision Agriculture for Fruits and Vegetables.*

[5] Blasco J., Aleixos N., Molto E., " Machine Vision System for Automatic Quality Grading of Fruit", Biosystems Engineering , Vol-85, Issue 4, Pages-415-423, August 2003.

[6] Fernández, L., Castillero, C. and Aguilera, J. M., "An application of image analysis to dehydration of apple discs" *Journal of Food Engineering*, vol.67, pp.185-193, 2005.

[7] Hannan M.W., Burks T.F., Bulanon D.M., "A Machine Vision Algorithm for Orange Fruit Segmentation", *Agricultural Engineering International: the CIGR E journal*, vol-XI, Pages: 1-7, December-2009.

[8] Hayashi Shigehiko, Ota Tomohiko, Kubota Kotaro, Ganno Katsunobu and Kondo Naoshi, "Robotic Harvesting Technology for Fruit Vegetables in Protected Horticultural Production", *Information and Technology for Sustainable Fruit and Vegetable Production FRUTIC 05, France.*

[9] Jimenez A.R., Ceres R., Pons J.L., "A Survey of Computer Vision Methods for Locating Fruit on Trees", *Transaction of the ASAE*, Vol. 43(6), pages: 1911-1920, 2000.

[10] Jimenez R., Jain A.K., Ceres R., Pons J.L., "Automatic fruit recognition: A survey and new results using Range/Attenuation images", *Pattern Recognition*, 32 (10), pp. 1719-1736, 1999.

[11] Lopez Jose J. , Cobos Maximo and Aguilera Emanuel, "Computer-based segmentation and classification of flaws in citrus fruits*", Internation conference on natural image processing (ICONIP-2009).*

[12] Leemans, V. and Destain, M.-F, "A real-time grading method of apple based on features extracted from defects" *Journal of Food Engineering*, vol.61, pp.83-89, 2004.

[13] Patel Hetal,Jain R.K., Joshi M.V.,"Fruit Detection using improved multiple feature based algorithm", International Journal on Computer Applications(ISSN: 0975 – 8887)", Vol-13, No-2, pages:1-5,January,2011.

[14] Parvati K., Prakasa Rao B.S. and Das Mariya M., "Image Segmentation using Gray-scale Morphology and Marker-controlled Watershed Transformation", *Hindawi Publishing Corporation, Discrete Dynamics in Nature and Society*, Vol-2008, pages;1-8.

[15] Shasi Buluswar , "*Models for Outdoor Color Vision", Doctoral dissertation, University of Massachusetts, Amherst,*2002

[16] Woo Chaw Seng and Seyed Hadi Mirisaee, "A New Method for Fruits Recognition System", *MNCC Transactions on ICT*, Vol. 1, No. 1, June 2009.

[17] Zhao, J.T., J. Katupitiya, J., "On-tree fruit recognition using texture properties and color data", *International conference on Intelligent Robots and Systems*, pp. 263-268, 2005.

[18] A. Hanbury and J. Serra. "Mathematical Morphology in the CIELAB space.", Image Analysis and Stereology, 21(3) : 201-206, 2002 .

[19] S. Dai and Y. Zhang. "Colour image segmentation with watershed on colour histogram and Markov random fields",*Information , Communication and Signal Processing*, 1:527-531, 2003.

[20] V. Pratt, "Direct least-squares fitting of algebraic surfaces", computer graphics, vol-21, pp 145-152 ,1987.