Starfruit Grading Based on 2-Dimensional Color Map

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Abstract

This paper present a grading technique on starfruit based on image processing. 2-dimensional color map is used in order to classify the starfruit into its ripe index. Referring to standard introduced by FAMA, there are six ripe indexes to code in. The color map is based on 8-bit RGB color space where blue component is discarded to simplify the computation process. This paper also shows that calculating the average chromaticity for the 2-dimensional color map (RG map) can determine the most concentrated color in each of the ripe index. The chromaticity value is then used to segment the starfruit image to reduce the amount of the color. From the segmented image, the starfruit is classified into its ripe index.

Keywords:

Color map, color segmentation, ripe index.

1. Introduction

Agriculture products are being more demanding in market today. To increase its productivity, automation to produce these products will be very helpful. One of the growing agriculture products is starfruit. It can be observed that the export of starfruits has been increasing steadily from 6,300 metric ton in 1988 to 18,100 metric ton in 1999. Some of the major export markets for starfruits are EEC such as United Kingdom, Holland and Germany, which takes up about 57% of the total export, Singapore 39% and with the remainder going to Middle East especially Saudi Arabia, United Arab Emirates and Kuwait, Hong Kong, China and Brunei.

Quality of the starfruit is described by its physical appearance and taste. Auspicious to have good taste of the starfruit is worthless if the physical appearance of the starfruit is ignored. However, until this paper is written, the quality inspection of the starfruit was performed manually wherein manual inspection will caused inconsistency in quality due to the human subjective of nature, slow processing and labor intensive. Currently, in the starfruit pack house, the manual grading process involves removal of the damaged starfruit and sorting the starfruit into categories (based on ripe index). Removal of the damage starfruit is done by inspecting the starfruit skin surface defects. Only starfruit with less than 5% defects will go through the next process, which is the classification of the starfruit into six indexes base on the starfruit ripeness. This shows that manual inspection is a tedious and complicated process. Automation of the process will solve the problems. With automation process, human can improve their quality of work by concentrating their works to other scopes like market planning and how to improve the effectiveness of the grading process.

Actually, automation for fruit grading has been done to apples [1], orange [2], papaya [3] and a few other fruits. However, each fruit has different criteria, which make automation for fruit grading using general machine is impossible. Hence, a specific machine for starfruit grading needs to be designed. Designing automation solution for starfruit is more difficult compared to the other fruit as it has a complicated shape. This is because the starfruit shape is unique as it has five ridges forming a star shape while the other fruit only have a flat surface. Due to this unique shape, features extraction process becomes more complicated and challenging where lighting exposure is not homogeneous to its surface. Another issue is the shiny surface on the starfruit skin. It reflects a high concentration of light and results high intensity color image, which degrades most of the chromaticity information. This means that recognizing color at this area is tough.

2. Image Acquisition

In image acquisition, a web camera is used to capture the starfruit image. Although web camera is not as good as the other sophisticated camera like a CCD camera, its low-priced wins among the other advantages. Besides, the quality of the captured image can be improved by applying good lighting system. In this work, the starfruit is placed on a conveyor that moving towards a tunnel where the image of the starfruit will be captured. In this tunnel, the normal environment lighting is blocked and a more suitable lighting source is created in the tunnel.

Captured image will be analyzed using a software develop in C language. Categorizing the starfruit into its ripe index consists of three main steps: preprocessing, color segmentation and classification. Preprocessing is to eliminate small structure in the image. This is done by filtering the image using median filter. Other filters that can be used are averaging filter and Gaussian filter. These are actually low-pass filter. Median filter is chosen because it can keep the color boundary of the image, which will alleviate the color segmentation process.

3. Color Segmentation

Color segmentation is important in many computer vision and image processing application. It is to split image into certain division, which has similarity in color information. In general, current color segmentation technique can be roughly classified based on two properties: discontinuity and similarity. Methods that are based on discontinuity property are called boundary-based method and their objective is to extract borders between regions in an image. Whereas, methods based on similarity property is called region-based method. This method will try to partition the image into a number of regions such that each region has the most similarities [4]. These methods are applied in [5], [6], [7], [8] and many others.

In this work, color in starfruit image is segmented into six regions based on chromaticity in 2-dimensional color map. Here, the 2-dimensional color map is referring to RG color map, which is used in this work to replace the typical 3-dimensional color map of RGB. Hence, less and simpler computation can be achieved as the dimension is reduced. The 2-dimensional color map was formed by discarding blue component from the RGB color map. Blue is discarded, as it does not reflect much in starfruit image. Figure 1 shows color component in a starfruit image, where most of the blue component has a small values. By ignoring the blue value (suppress the value to zero), the appearance of the original image will not differ significantly.

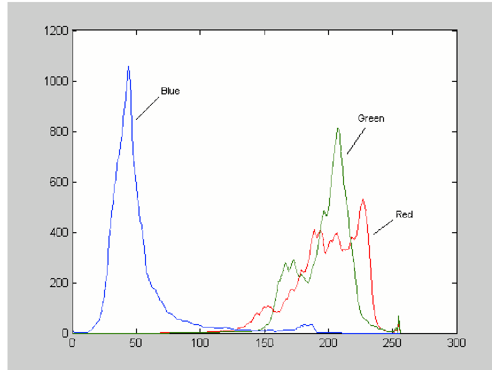

Figure 1. RGB color component.

From the 2-dimensional color map, chromaticity that represents the variation of colors can be computed as below.

$$C = \frac{R}{R+G} \tag{1}$$

Based on Equation 1, six points of chromaticity is computed to be the reference for the color segmentation process. The reason of choosing six points of chromaticity is because the starfruit will be classified into six ripe indexes. Specifically, these points is computed by taking the average chromaticity of each starfruit index in the whole database, which is denoted by

$$I_p = \frac{1}{N}\sum_{q=1}^{N} C_{pq} \tag{2}$$

In Equation 2, p and q is referring to starfruit index and starfruit number while N is referring to the total number of starfruit in the database of that starfruit index. As p is the starfruit index, it is range from 1 to 6. Having the six values of I, each starfruit image is color segmented according to Equation 3

$$f(i) = I_p \tag{3}$$

where

$$p = 1:6 \rightarrow min\{|C_i \quad I_p|\} \tag{4}$$

Here, f is the starfruit image and i is the pixel number. Thus, each pixel in the starfruit image is segmented to the nearest chromaticity distance among the six chromaticity values (I_p), which have been computed earlier by Equation 2. However, not all regions will appear in each starfruit image. For an example, starfruit of index 1 most probably will only has region 1 to 3 only and index 6 starfruit will has most of its color in region 4 to 6 only. As the color of the starfruit image has been segmented and at the same time reduced to only six colors, the next process is to classify the starfruit.

4. Classification

The strafruit is classified into six ripe indexes, which carry out a standard through a label named Malaysia's Best introduced by FAMA (Federal Agricultural Marketing Authority). Index of ripeness is used to determine whether the starfruit is suitable for export purpose or for domestic market. From Index 1 to Index 6, the ripeness of the starfruit change from an immature to mature fruit. For export purpose, only Index 2, Index 3 and Index 4 are allowed. Exporting immature starfruit is to ensure that the starfruit will only be matured at the time it arrive its destination. For domestic market, Index 5 and Index 6 are the most suitable as it can be eaten at the time the fruit is bought by consumer.

From the segmented image discussed in the previous topic, the starfruit is classified into the ripe index based on the amount of pixel in each of the segmented region. The rules are described as in the Figure 2 where R is a short form for region.

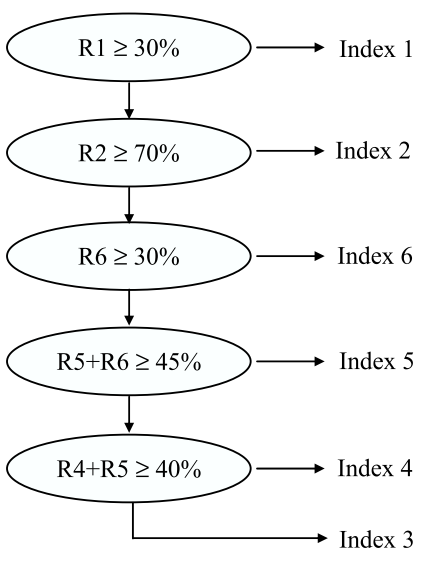

Figure 2. Classification rules

5. Experimental Results

Technique used in this work has been tested on 100 samples of starfruits. Each starfruit index contained 15 samples and there are 6 indexes all together. The other 10 samples are picked among the defected starfruit with various indexes. There are 10 types of defect on starfruit. Each and every single of the defect can be recognized by the physical appearance of the starfruit. This paper is not going to explain the detail about those defects as the main concern of the paper is on classifying the starfruit into the ripe index.

Firstly, samples are sort by human expert into its ripe index. Then it is tested using technique presented in this paper. The result produced 96% of the starfruit were correctly classified into the ripe index. Table 1 shows the results for each of the ripe index where incorrect classifications are 1% from the defected fruit and 3% from Index 6. Most of the misclassification is due to the light reflection on the starfruit shiny skin, which had degraded most of the color information. Degraded means that the skin colors of the starfruit becomes brighter toward the pure white color. This situation is less occurred on the starfruit with Index 1 to Index 4. This is the reason why they results 100% of accuracy. Thus, proper lighting condition should be applied to solve the shiny skin problem for Index 1 to Index 4.

Table 1. Classification Results

Ripe Index	Accuracy
Index 1	100%
Index 2	100%
Index 3	99%
Index 4	95%
Index 5	100%
Index 6	80%
Defected	90%
Average	94.9%

6. Conclusion

The presented work has shown that classifying the fruit into its ripe index can be accomplished using two-dimensional color map rather than the three-dimensional color map. Here starfruit is use as the subject. The technique plots magnitude of the red and green component on RG color map and calculate the cromaticity of the plot to determine the ripe index. After tested on 100 samples, it produced a result with only 5.1% of the samples are wrongly classified. Most of the misclassification is due to the high light reflection on the skin surface of the starfruit. A better lighting source should increase the classification accuracy. And it is believe that the technique will work on any fruit that has the same behavior of ripening as the starfruit does.

References

[1] Q. Yang, "Automatic detection of patch-like defects on apples", Fifth International Conference on Image Processing and its Applications, 1995, Page(s):529-533, 4-6 Jul 1995

[2] M. Recce, J. Taylor, A. Piebe, G. Tropiano, "High speed vision-based quality grading of oranges" International Workshop on Neural Networks for Identification, Control, Robotics, and Signal/Image Processing, 1996, Page(s):136-144, 21-23 Aug. 1996

[3] S. Limsiroratana, Y. Ikeda, "On image analysis for harvesting tropical fruits", Proceedings of the 41st SICE Annual Conference, Volume 2, Page(s): 1336-1341 vol.2, 5-7 Aug. 2002

[4] X. Munoz, J. Freixenet, X. Cufi, J. Marti, **"**Active regions for colour texture segmentation integrating region and boundary information"**,** 2003 International Conference on Image Processing, Volume 3, 14-17, Page(s):III - 453-6 vol.2, Sept. 2003.

[5] M, Ruzon and C. Tomasi, "Color Edge Detection with the Compass Operator", Proc. Of IEEE Conf. On CVPR, volume 2, Page(s): 160-166, June 1999

[6] W. Y. Ma and B. S. Manjunath, "Edge Flow: A Framework of Boundary Detection and Image Segmentation", Proc. Of IEEE Conf.on CVPR, Page(s): 750-755, June 1997

[7] D. Comaniciu and P. Meer, "Robust Analysis of Feature Space: Color Image Segmentation", Proc. Of IEEE Conf. On CVPR, Page(s): 750-755, June 1997

[8] J. Shi and J. Malik, "Normalized cuts and Image Segmentation", IEEE Trans. On PAMI, Vol. 22, No. 8, Aug 2000