Color Grading in Tomato Maturity Estimator using Image Processing Technique

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Abstract—**This Tomato Maturity Estimator is developed to conduct tomato color grading using machine vision to replace human labor. Existing machine has not been widely applied in Malaysia since the cost is too expensive. The major problem in tomato color grading by human vision was due to the subjectivity of human vision and error prone by visual stress and tiredness. Therefore, this system is carried out to judge the tomato maturity based on their color and to estimate the expiry date of tomato by their color. Evolutionary methodology was implemented in this system design by using several image processing techniques including image acquisition, image enhancement and feature extraction. Fifty sample data of tomatoes were collected during image acquisition phase in the format of RGB color image. The quality of the collected images were being improved in the image enhancement phase; mainly converting to color space format (L*a*b*), filtering and threshold process. In the feature extraction phase, value of red-green is being extracted. The values are then being used as information for determining the percentage of tomato maturity and to estimate expiry date of tomato. According to the testing results, this system has met its objectives whereby 90.00% of the tomato tested has not rotten yet. This indicates that the judgment of tomato maturity and the estimation of tomato's expiry date were accurate in this project.**

Keywords-color; grading; tomato; maturity; image processing

I. INTRODUCTION

Malaysia is one of the agriculture countries in Asia. There are a lot of plantation types in Malaysia such as paddy, tomato and so on. At year 2000, Malaysia exported 12295 MT of tomatoes and this only contributes 0.28% of the total of worldwide tomato exportation. The marketing plan of tomato commodity aims that by the year of 2010, Malaysia to be the top 10 worldwide tomato exporter by achieving 5% from the total of worldwide tomato exportation. Therefore, the quality of the tomato plays important role in promoting Malaysia's tomato world widely [1].

Color of the tomato is a major factor in the consumer's purchase decision. A tomato which has more color will often bring to a higher price than less mature tomatoes. The color turns lighter green, pink, and then red as they start to ripe [3]. Because of the time it takes for transportation, red tomatoes must be sold to the markets in closer distance while the green ones can travel for longer distance. Hence, color grading can determine the time to market.

In Malaysia, the process of grading and packing will then be carried out manually by human being in packing house. Tomatoes are typically separated by size using machine. Nevertheless, the color grading process was still carried out by human graders comparing the tomato color to a color classification chart according to USDA standard.

In Japan, there was a study of Judgment on Level of Maturity for Tomato Quality Using L*a*b* Color Image Processing conducted by Yoshinori Gejima, Houguo Zhang and Masateru Nagata. This study analyses tomato maturity using RGB and L*a*b* color system. The results shows that tomato maturity can be judged according to a* value which achieved 96% correctness in the study [4]. Table I shows suggestion of value a* for maturity estimation [4].

TABLE I. SUGGESTION OF VALUE A* FOR MATURITY ESTIMATION

i) 10 – 20 % of fully maturity:
$a^* < -5.8$ ·················· (1)
ii) 30 – 40 % of fully maturity:
$-5.8 \leqq a^* < 2.1$ ·········· (2)
iii) 50 – 60 % of fully maturity:
$2.1 \leqq a^* < 9.2$ ············ (3)
iv) 70 – 80 % of fully maturity:
$9.2 \leqq a^* < 21.5$ ··········· (4)
v) fully maturity:
$21.5 \leqq a^*$ ················ (5)

This study is carried out to helping the growth of Malaysia's tomato industry by enhancing the process of manpower color grading into the era of machine vision color grading in order to compete with the same industry globally

II. PROBLEM DEFINITION

Visual appearance of tomato is a major factor in the judgment of quality; visual inspection is an important part of quality control in this industry. This inspection has historically been performed by use of the only "tool" available, the human eye [5].

In current tomato industries, this manual practice of tomato color grading required a lot amount of manpower. Meanwhile, the amount of labor in this industry is not

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enough to support the appraisal growth by 2010 [1]. Thus, a vision machine for tomato color grading can solve this problem and reduce the production costs as it reduces the required manpower.

Judgment of tomato color grading by human eyes often leads to error due to visual stress, and tiredness and is therefore not accurate. A vision machine to replace human eyes can solve this weakness since a machine will not prompt errors due to stress or tiredness.

Although there is a standard classification of tomato maturity by USDA, but current tomato color grading process doesn't provide a convincing quality assurance of tomato. Human vision has limited ability in differentiating similar colors like pure green (100% green) with breaker (90% green), light red (60-90% red) with red (>90% red) [4]. Human perception towards colors is subjective and varies among different people. A same tomato may appear as pure green for first human grader but breaker for second human grader. This leads to inaccuracy of the judgment for tomato maturity.

Therefore, there is a need to develop a tomato maturity estimator using color image processing as in cooperate with Ninth Malaysia Plan for the successfully growth of tomato industry and the assurance of tomato quality.

III. METHODOLOGY

General process in image processing has been implemented in this project. It is consists of three (3) major phases as shown in Fig. 1.

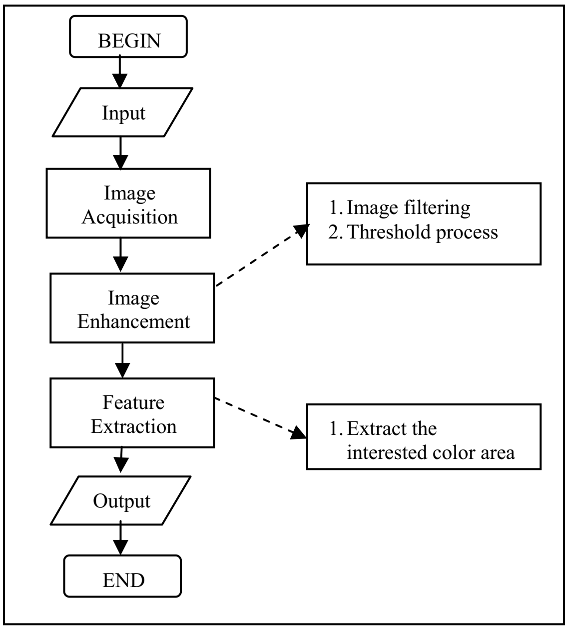


Figure 1. Overall process in Tomato Maturity Estimator

Tomato maturity can be determined by its color expression, and the color value to be taken should be the average color value of a whole tomato [6]. Meanwhile, the average color value from the bottom view of a tomato is sufficient to determine its maturity since tomato will mature as a whole, every part simultaneously.

Image acquisition is the first process in the system development. The images were captured by placing a PC camera at approximately 100mm on the top of the tomato, by using same background and same visible light condition.

Fig. 2 shows images taken as sample data. By estimation of eye, (a) is red colored tomato, (b) is light red colored tomato and (c) is turning colored tomato.

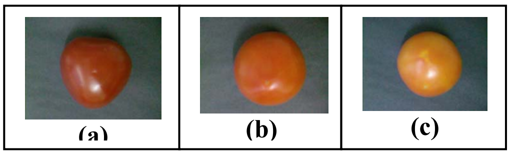


Figure 2. Tomato images estimator

Next step is Image Enhancement. The purpose of image enhancement is to highlight certain features of interest in an image. The background of the image considered as noise in this system, thus removing the influences of background is necessary. Two types of image enhancement technique in Spatial Domain methods had been implemented which are image filtering and threshold process in order to remove the influence of image background.

In this step, the original RGB image will be converted to L*a*b* image. Let function `D = makecform ('srgb2lab')` creates the color transformation structure D that defines the color space conversion specified by type `srgb2lab`. Then, `applycform(sI_rgb,D)` converts the color values in `sI_rgb` to the color space specified in the color transformation structure D which is to convert an RGB image to an L*a*b* image.

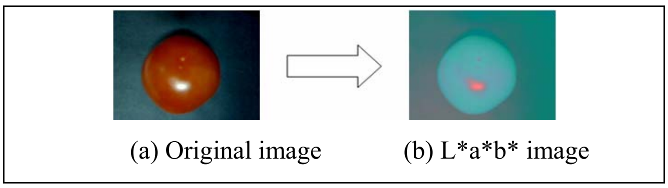


Figure 3. Converting process from (a) to (b).

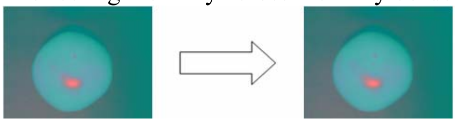
The image is then being filtered with averaging filter. The average filter computes the mean (average) of the gray-level values within a rectangular filter window surrounding each pixel. This has the effect of smoothing the image (eliminating noise). The default filter size is 3x3 as shown in Fig. 4. The filtered pixel will be calculated by (1):

$$r = (a1 + a2 + ... + a9) / 9 \qquad (1)$$

```
+---------+
|a1 a2 a3 |
|a4 a5 a6 |
|a7 a8 a9 |
+---------+
```

Figure 4. Filter window 3X3

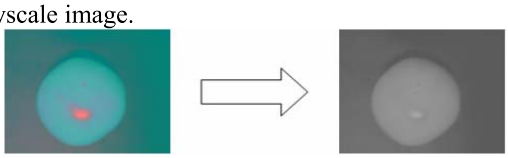
Let filter `h = fspecial('average')` is applied to the image by function `imfilter (I_lab,h,'symmetric')`. This is to smoothes image data and eliminating noise. `Symmetric` means input array values outside the bounds of the array are computed by mirror-reflecting the array across the array border.



(a) L*a*b* image (b) Filtered L*a*b* image

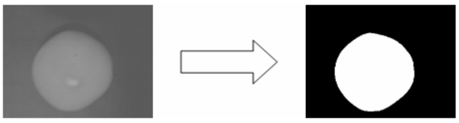
Figure 5. Image from (a) and after filtering (b)

The process is continued by converting the image into grayscale image and later into a binary image. The image is being converted to a grayscale image with function `rgb2gray(I_lab1)`. Then, the grayscale image intensity is adjusted using function `imadjust(IG,stretchlim(IG),[])` that specify lower (bottom 1% of all pixel values) and upper limits (top 1% of all pixel values) that are used for contrast stretching the grayscale image.



(a) Filtered L*a*b* image (b) Grayscale image

Figure 6. Converting process from (a) to (b)



(a) Grayscale image (b) Threshold image

Figure 7. Converting process from (a) to (b)

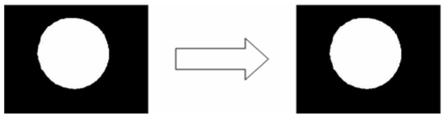
Feature Extraction is implemented after Image Enhancement. In general, the idea of features extraction is to extract the information of the interested area in the image for further usage in processing the image. a* values of the tomato color is the interested area in this process. After the influence of the image background has been removed, the total of a* values are collected and sum up. The sum of total a* values will then be used to get the mean of a* values.

In details, several processes under feature extraction are to be undergo by the image which including boundaries tracing, removing background and obtaining a* values.

For boundaries tracing, the boundary of the tomato was traced by implementing function `bwboundaries (BW,'noholes')` into the binary image. This function traces the exterior boundaries of objects where nonzero pixels belong to the tomato and 0 pixels constitute the background.

Figure 8. Filtered L*a*b* image with boundary plotted

The background of the image was then remove by function code `KM2 = imfill(KM,'holes')`. `KM` was an empty array with the size of `BW`. The cell which is located within the boundary was being assigned pixel value of 1's.



(a) Threshold image (b) Filled 1s image

Figure 9. The process of removing background

In obtaining a* values, one integer variable has been used to determine the number of cells containing pixel value of 1's in array `KM2`. Function code `rLAB = rangefilt(I_lab)` was used to return the array `rLAB`, where each output pixel contains the range value (maximum value – minimum value) of the 3-by-3 neighborhood around the corresponding pixel in the input image `I_lab`. While function code `a = rLAB(i,j,2)` was used to retrieve specifies a* value in location `(i,j)` of the image.

The a* value is then being stored in an array by function code `array(nu,1)=a`. Finally, the average of a* values that contains in `array` are being returned by function code `mean(array)`

The results of the calculation will be a* value which needed to be compared with Table I in for tomato maturity estimation. Based on the maturity percentage in Table I, expiry date of a tomato can be predicted as compared to Table II.

TABLE II. TOMATO STORAGE LIFE [2]

Storage life:
Breakers (10 – 20% of full maturity)........21 to 28 days
Turning (30 – 40% of full maturity)..........15 to 20 days
Pink (50 – 60% of full maturity)................7 to 14 days
Light red (70 – 80% of full maturity)…….5 to 6 days
Red (full maturity)....................................2 to 4 days

IV. TESTING

The test case has included hardware integration of all components in the system. There are fifty tomatoes as the testing samples at this stage. Each tomato was labeled with a expiry date tag as shown in Fig. 10. After performing tomato maturity estimation by tomato maturity estimator, the expiry date of each tomato was written to its tag. Each tomato will be checked by cut sessions on the estimated expiry date. If the tomato was found to be still in good condition as shown in Fig. 11, then the estimation considered pass. If the tomato was found to be rotten as shown in Fig. 12, then the estimation considered fail.

Figure 10. Labeled tomato

Figure 11. Good tomato at the cut session

Figure 12. Rotten tomato at the cut session

50 tomatoes were used as sample data in the testing phase of this project development. All tomato samples had gone through the phases of the prototype of this system that has produced output, mainly image acquisition, converting to L*a*b*, filtering, threshold, trace boundaries and remove background.

The 50 tomato samples that were used in this testing are in the size range from five centimeters to six centimeters. The tomatoes were all of same variety which is round tomatoes originated from Cameron Highlands. However, there were 17 tomato samples from 50% to 60% maturity category and 33 tomato samples from 70% to 80% maturity category based on Table II.

V. RESULT

The testing phase was completed with 50 tomato samples which come from several maturity categories. Table III shows the result analyzed from the testing process.

TABLE III. RESULTS FROM THE TESTING PROCESS

Tomato maturity	Not rotten tomato	Successful Rate
50% - 60%	17 / 17	100.00 %
70% - 80%	28 / 33	85.00 %
Total	45 / 50	90.00 %

From the result shows in Table III, 45 of tomatoes were not rotten out of total. That indicates 90.00 % successful rate of the Tomato Maturity Estimator in estimating tomato maturity. The results might caused by the freshness of the tomato samples for this testing purpose. The tomato samples used in this testing were obtained from the market but not directly from the field. The tomatoes samples could be several days old after post harvest process and this might affect the testing results.

There are certain constraints that lead to the results above. Three main constraints are:

- The lighting effects
- The system only can detect single image of tomato
- The resolution of PC camera
- Freshness of tomatoes

VI. CONCLUSION

There are an advantages and disadvantages in this project.

The advantages of this prototype are:

- The prototype was able to estimate the expiry date of the tomatoes which is not even available yet in the Export Market Process.
- The prototype provide a better alternative compared to using manpower in determining tomato maturity, the machine will not prone error due to tiredness or bias.

The disadvantages of this prototype are:

- The prototype can only process one tomato for each process.
- The prototype was not able to differentiate tomato with other fruits or vegetable.

The testing process which have been done shows that 90.00% of the testing result of 50 sample data of tomatoes are not rotten. This finding was contributed by 100.00% from fifty percent to sixty percent maturity category and 85.00 % from seventy percent to eighty percent maturity category. Thus, the finding proved that successful rate of the Tomato Maturity Estimator in estimating tomato maturity is 90.00%.

As a conclusion, it could be stated that this study has successfully met its objectives; mainly to develop a prototype for judging the tomato maturity base on their color and to estimate the expired date of tomato by their color. However, the usability of this prototype was being restricted due to the disadvantages and constraints as discussed earlier. Hence, further research in adapting alternative approaches in processing the image for enhancement to current prototype is very much encouraging.

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