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Surface colour variation of Papaya fruits with maturity

D. I. Amarasinghe and D. U. J. Sonnadara
Centre for Instrument Development, Department of Physics, University of Colombo

ABSTRACT

Surface colour considered as a quality parameter change with the maturity of fruits. Many unripe fruits initially show greenish surface colour which gradually changes to yellow colour when they mature. The change of colour patterns is similar within each fruit category. The consumer often judges the ripeness of the fruits by its colour. If the relationship between the surface colour of a fruit category and the maturity can be determined, development of electronic devices capable of sorting fruits automatically depending on the level of ripeness is a possibility. This is also useful for grading fruits when they are being harvested. In this work, by applying image processing techniques colour change with the maturity of Papaya fruits was studied. The commonly available papaya variety 'Red Lady' was selected to carry out this work because they show clear colour variation during the ripening period. RGB and OHTA colour spaces based image segmentation algorithms were developed to detect yellow colour regions in papaya fruits. A normalization technique was applied to reduce systematic bias due to the surrounding light condition in the RGB space. Results show a non-linear increase in the surface yellow colour with the age of the fruits. Preliminary results show that normalizing technique can help to reduce this systematic bias.

1. INTRODUCTION

Surface colour of fruits is an important parameter to visually identify ripeness for most fruit varieties. Rapid change in surface colour, often, from green to yellow can be seen during the maturity period of many fruits. Therefore when harvesting and marketing fruits, surface colour can be used as maturity index, quality index as well as fruit damage index. Surface colour of fruits is also a good parameter to determine the maturity of fruits from the day of harvest. Image segmentation techniques based on different colour spaces can be used to quantify the variation of surface colour from their initial stages.

A few research papers have been published on the surface colour variation of fruits focused on applications such as machine vision for harvesting and grading. However, no clear relationship has been established between the colour variation and maturity of the fruits. Past studies have been carried out in colour spaces such as RGB (red, green and blue), HSL (hue, saturation and lightness), NTSC and OHTA.

Kondou et al. [1] designed colour chart for a new variety of the grapes known as 'Aki Queen' using HSL colour space. In addition to the surface colour, they have studied the size distribution. They classified image data into six steps according to the colour of the fruit skin and typical skin colour expression of each step was determined by using the extracted colour information.

Al-Janobi [2] developed a colour vision system consisting of a microcomputer with an image frame grabber and a CCD colour camera for sorting and grading of dates using colour thresholds. In addition to the colour variation, grading was based on size, surface defects and texture of dates.

Camelo et al. [3] have compared colour indexes which are designed using different colour spaces for tomato ripening. They have compared results of colour spaces with other parameters such as temperature. As a result they were able to define colour categories which were significantly different in terms of human perception. For vine ripening, most colour indexes could be objective ripening indexes.

Fadel et al. [4] carried out a study for dates fruits to find out the colour properties of different cultivars. They have used RGB colour space to measure the colour variation. Their work shows that colour luminosity and RGB colour space can be used find out colour properties of different dates verities.

Different colour spaces can be used to detect the colour variation on the fruit surface. Several studies have been carried out successfully using OHTA colour space to detect the colour variation. This colour space was introduced by Ohta [5] which is a linear transformation of RGB colour space and its colour is defined by three orthogonal colour components.

Feng et al. [6] used OHTA colour space based image segmentation algorithms to extract strawberry from background. They introduced a fruit detachment and classification method for grading strawberries. Use of OHTA colour spaces shows above 90% accuracy in ripeness and shape quality judgement.

To reduce the effect due the background light conditions, normalizations techniques can be applied. The chromatic colour space is successfully used in normalizing, especially in skin colour detections [7].

In this work, the surface colour variation with the maturity of the Papaya fruits has been investigated. Assuming that the colour patterns are similar within the selected fruit category, image processing techniques were utilized in RGB and OHTA colour space to define the desired colour components and detect colour change with the maturity of the Papaya fruits. Papaya fruit variety 'Red Lady' was selected to carry out this initial work because they show clear colour variation during ripening period.

2. METHODOLOGY

Nikon Coolpix 2000 digital camera was used to capture the regular images of papaya fruits twice a day, morning 6.00 am and evening 6.00 pm, during the maturity period. The camera was placed in front of the papaya fruits on a tripod at a constant distance during each experiment as shown in figure 1.

Special attention had to be taken for lighting condition during the experiment because the reflections of light can be seen from the surface of the papaya fruits as bright spots (especially during early stage of ripeness) which created complications for the yellow region extraction process (image processing). Two screens were placed side ways to block the illumination lights directly falling on the fruits to reduce the reflected light falling on the camera view. It was also difficult to maintain similar background light conditions through out the experiment due to changes in the natural surrounding light from day to day. For each reading, several measurements were taken with slightly different camera views to reduce the possible errors due to viewing angle.

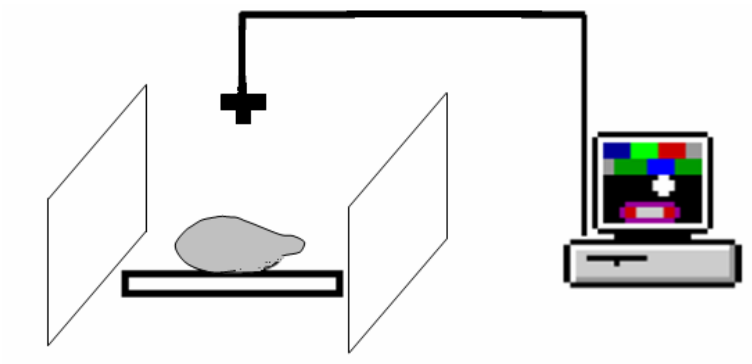

Figure 1: Experimental Setup

In the second stage, image processing techniques were used to extract the yellow regions on the surface of the digitized images of papaya fruits. In the digitized images (RGB space), the pixels colour was represented by three fragments known as R, G, and B (Red, Green and Blue). During the maturity period yellow colour variation can be seen on the papaya fruit surface. To find out the corresponding range of R, G and B values corresponding to the yellow regions, several pilot tests were carried out. Based on the results, it was found that the range of yellow colour in RGB colour space varies as shown in the table 1.

Table 1: Yellow colour range in RGB space

Red (R)	**Green (G)**	**Blue (B)**
128 – 255	100 - 255	< 76

Some studies have show that OHTA colour space has a good response to colour variation [6]. Conversion from RGB to OHTA colour space is a linear transformation. OHTA colour space has two different sets of expressions as shown in the equation (1) separating colour and intensity information. In this work, I'_2 feature was used to extract surface colour variation which represent the chromatic (colour) variation.

$$I_1 = (R + G + B) / 3 \qquad I'_2 = R - B$$
$$I_2 = (R - B) / 2 \quad , \quad I'_3 = (2G - R - B) / 2$$
$$I_3 = (2G - R - B) / 4$$

To overcome the drawbacks due to the variation in the background light conditions, normalization corrections were applied. A correction based on RGB colour space was applied in this work to normalize the images. That is converting RGB values to chromatic colour format. Normalized RGB values are easily obtained from the real RGB values by simple normalization as shown in equations (2).

$$r = \frac{R}{R+G+B},\ g = \frac{G}{R+G+B},\ b = \frac{B}{R+G+B} \qquad (2)$$

Here 'r,' 'g' and 'b' represent the red, green and blue ratios of each colour pixel of the image respectively. The mean colour ratios and standard deviations (σ) for the yellow colour range of papaya fruit surface (see Table 2) were calculated using an image set captured at the final stage of maturity. A range based on ±3σ around the mean values was used to extract yellow colour region from the images.

Table 2: Mean and σ for each colour ratios

	Red Ratio	Green Ratio	Blue Ratio
Mean	0.0199	0.027	0.0246
σ	0.4769	0.3698	0.1533

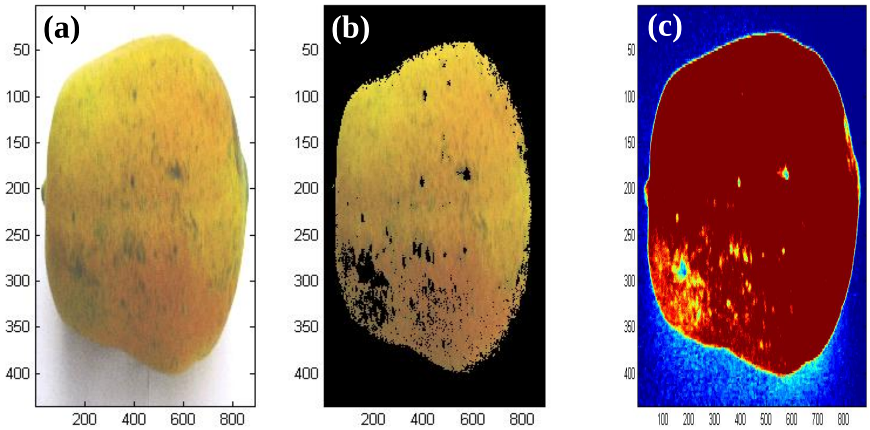

Figure 2: (a) Original Image, Calculated yellow colour region using (b) RGB colour space, (c) OHTA colour space

A computer programs were designed by using selected yellow colour region in RGB space and OHTA colour space to calculate the number of pixels represent the yellow colour regions on papaya fruit surface for each digitized image. Figure 2 shows test sample of the digitized image and extracted yellow colour regions after executing the designed computer programs for RGB and OHTA colour spaces.

3. RESULTS AND DISCUSSION

The series of images taken under each experiment were used in the analysis to study the variation of yellow area with maturity using RGB colour space and OHTA colour space. The variation of yellow colour area which is captured using RGB colour space for one of the image sets is shown in Figure 3. Consecutive pair of images represents a 24 hour period since images were captured only twice a day. Between images, fluctuations in the development of yellow regions can be clearly seen. This is due to the change in the background light conditions.

Size of a fruit is a quality parameter when fruit sorting and grading. In general, the size of the fruit remains constant through out the maturity period. The accuracy of colour segmentation algorithm can be tested by studying the variation in the detected area while the fruits undergo colour changes. In figure 4, variation of the total area of the fruits with the maturity is shown for 3 separate data sets. The number of points varies depending on the number of days the fruit has taken to fully mature. Horizontal lines are drawn to guide the eye. The data sets show less than 2.5% variation in calculating the area of fruits based on colour segmentation.

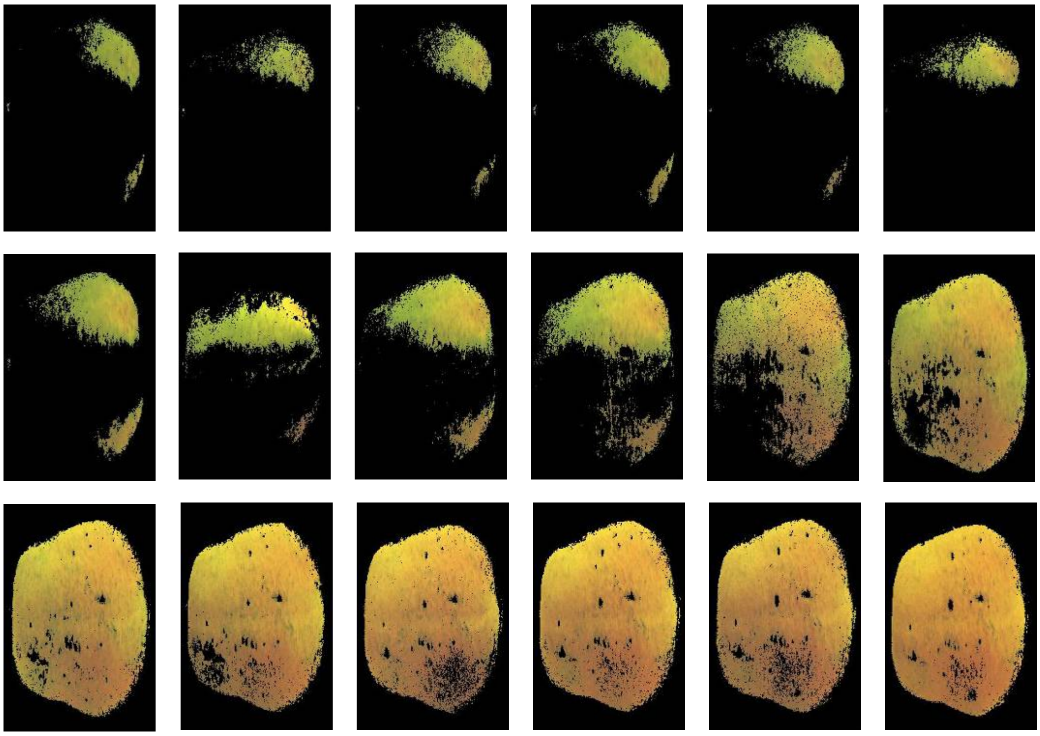

Figure 3: Development of the yellow colour regions with the maturity of the fruit

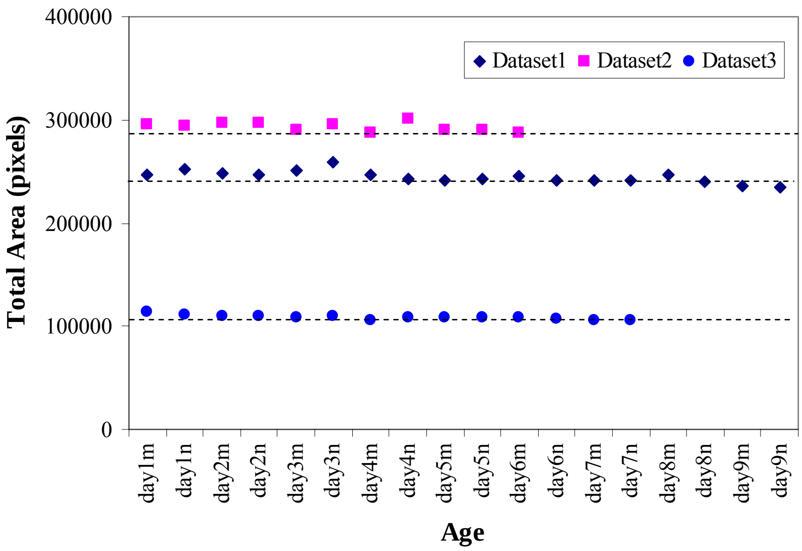

Figure 4: Variation of fruit size with the maturity.

As expected increase in yellow colour of papaya fruits with maturity are seen for all cases. Figure 5 shows the variation of surface yellow colour (ratio between yellow colour areas to the total area of the fruit) with maturity for original image set for RGB colour space and OHTA colour space. Data show deviations especially between morning and evening due to different light conditions. When the background was dark, detection of yellow regions based on colour threshold did not perform well.

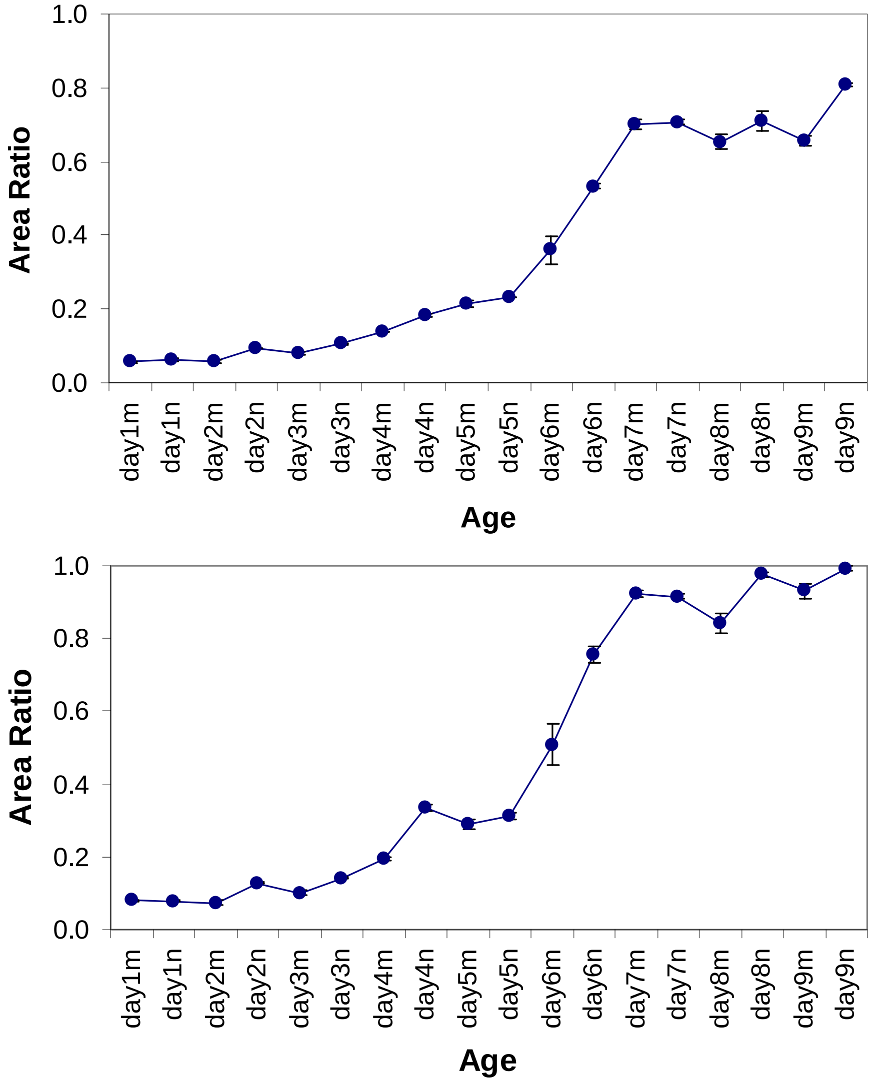

Figure 5: Ratio of yellow colour against maturity of fruits (a) RGB colour space (b) OHTA colour space

To overcome the drawbacks due to the variation in the background light conditions, normalization correction was applied using chromatic colour space. Figures 6 shows the variation of surface yellow colour (ratio between yellow colour to the total area of the fruit) with maturity for normalized image set under chromatic colour space technique.

Although the variation of colour increased with maturity, due to the variation in the background light condition of the surrounding area it was difficult to maintain smooth variation between data points. When normalization technique was applied, a significant reduction was seen on the fluctuations that were seen due to the variation in the background light condition of the surrounding area. This is a good normalizing technique to reduce luminosity effect due to light conditions. Preliminary estimates showed that normalizing techniques can enhance the sensitivity of the technique.

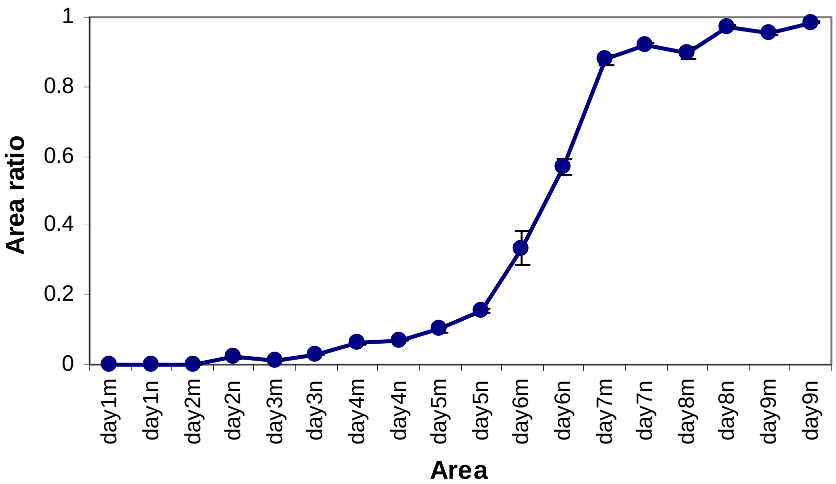

Figure 6: Ratio of yellow colour against age in chromatic colour space.

4. CONCLUSIONS

Change of surface colour of a fruit with the maturity can be used as a parameter to measure the ripeness. Often, unripe fruits show greenish surface colour which changes to yellowish colour when they ripen gradually. These colour patterns are similar within fruit categories.

In this work, by applying image segmentation under RGB colour space and OHTA colour space, change of surface colour with the maturity of Papaya fruits were studies. Papaya fruit (Golden Lady) was selected to carry out this work especially because they show clear colour variation during ripping period. Although the variation of colour with maturity was clear, due to the variation in the background light which affect the condition of the surrounding area, from one measurement to the next (especially during morning hours and evening hours), fluctuations were observed in the extracted yellow regions. This can easily effect real-time detection of maturity using colour techniques. Chromatic colour space is used as normalization technique to overcome the effect due to the light conditions and it shows a significant improvement in the results. Initial work showed that normalizing techniques can help to reduce the systematic bias created by different illuminations.

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REFERENCES

1. Kondou H., Itou H., Ishikawa H., Motonaga Y., Hashimoto A., and Kameoka T., *Colour Chart for Fruits of Grape 'Aki Queen' by Digital Image Processing,* Agricultural Information Technology in Asia and Oceania, (1998), 197-2002.
2. Al-Janobi A. A., *Date inspection by colour machine vision*, Journal of King Saud University, 12, (2000), 69-79.
3. Camelo A. F. L. and Gomez P. A., *Comparison of colour indexes for tomato ripening*, Horticultura Brasileira, Brasilia, 22, (2004), 534-537.
4. Fadel M., Kurmestegy M., Rashed M. and Rashed Z., *Fruit Colour Properties of Different Cultivars of Dates*, Agricultural Engineering International, VIII, (2006).
5. Tu-Ichi O. and Takeo K., *Colour information for region segmentation*, Computer Graphic and Image Processing, 13, (1980), 222-241.
6. Feng G., Qixin C. and Masateru N., *Fruit Detachment and Classification Method for Srawberry Harvesting Robot*, International Journal of Advanced Robotic Systems, 1, (2008), 41-48.
7. Hassanpour R., Shahbahrami A. and Wong S., *Adaptive Gaussian Mixture Model for Skin Colour Segmentation*, Proc. of World Academy of Science, Engineering and Technology, 31 (2008), 1-6.