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Automatic detection of mango ripening stages – An application of information technology to botany

Farjana Sultana Mim[a,*,1], Syed Md. Galib[b], Md. Fakhrul Hasan[c], Sanjida Akther Jerin[a]

[a] Faculty of Computer Science and Engineering, Patuakhali Science and Technology University, Patuakhali, Bangladesh
[b] Department of Computer Science and Information Technology, Patuakhali Science and Technology University, Patuakhali, Bangladesh
[c] Department of Horticulture, Patuakhali Science and Technology University, Patuakhali, Bangladesh

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ABSTRACT

Maturity is the most important factor to determine the storage-life and quality of fruits like mangoes. Fruit maturity can be recognized by different attributes and among them skin color is the most significant criteria for judging maturity. Typically, human experts visually detect the fruit color to identify the maturity stages which is very prone to error. In this paper, a method of digital image processing has been proposed to classify mangoes into six maturity stages according to the United States department of agriculture (USDA) standard classification. The experimentation considers sample images of more than 100 mangoes of different stages. A total of 24 image features are extracted and then correlation based and information gain based evaluation has been performed in order to select the most informative feature sets. Categorization is done using the decision tree which provides up to 96% classification accuracy.

1. Introduction

Mango is an economically important and well known fruit crop. It is well accepted to the consumers all over the world for its special qualities such as excellent flavor, pleasant aroma, luscious taste, lovely size and attractive color (Jaman, 2015). Maturity is an important factor associated with the quality evaluation of fruits like mangoes. Common criteria for judging maturity include physical attributes such as skin color, flesh firmness, size, shape and moisture or solid contents; chemical attributes such as sugar, starch or acid contents; estimation of development stage and morphological evaluation. Among these, skin color has been recognized as an acceptable maturity index for many fruits such as mango, raspberry, strawberry etc. It is one of the most important quality factors since the color is closely related to chemical and physical properties of the fruits. Besides, it often provides a useful index for a cultivation management and is an important quality parameter when packing and sorting. While fruit is still on the plant, its color is used to assess maturity and forecast harvest time (Motonaga et al., 2004). Also, the food and agricultural industries use developed methods using this parameter (color) to estimate the maturity index.

In industries, it is very essential to identify the different maturity indices of mangoes especially during export or import since those maturity stages indicate the shelf life. Knowing the shelf life is crucial as it indicates within how many days those mangoes will be rotten and what type of preservation is required to keep those mangoes fresh for a specific time. As the transportation time varies from place to place, knowing the shelf life is essential for trading purposes. Traditionally, the determination of maturity stages is performed by human experts. This process is very susceptible to error due to the distraction, tiredness and tedium of experts. Also for human experts it is very difficult to classify thousands of mangoes manually and pack them accordingly. For these reasons, an automated system of mango categorization is necessary so that the industries can be able to process a huge number of mangoes within very short time and with reduced cost.

In the field of estimation of maturity, digital image analysis has become increasingly important due to its simplicity and low cost. Color image analysis procedure can be developed to classify fresh mangoes into six maturity stages according to the United States Department of Agriculture (USDA) standard classification. By developing a color image analysis procedure, we can estimate the maturity stages of fresh mangoes. We can calculate the degree of maturation by the standard fruit surface color.

Several computer vision based methods have been developed to determine the state of the maturity of different fruits. A spectral analysis of bananas obtained under white and ultra-violet has been performed (Intaravanne et al., 2012). A Computer Vision System to

* Corresponding author.
E-mail addresses: mim@ecei.tohoku.ac.jp (F.S. Mim), galib@pstu.ac.bd (S.Md. Galib), hasan@pstu.ac.bd (Md. F. Hasan), sanjida.cse10th@cse.pstu.ac.bd (S.A. Jerin).
[1] Present Affliation: Graduate School of Information Sciences, Tohoku University, 6-3-09, Aramaki-Aza-Aoba, Aoba-ku, Sendai, 980-8579, Japan.

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estimate the antioxidant and phenol content on carrots based on the fruit's surface color was accomplished (Pace et al., 2013). An index of the tomato's ripeness is proposed, which allows classifying the fresh fruit into 6 classes, according to the USDA international standard (Choi et al., 1994). A Computer Vision System to discriminate varieties of French olives is developed where frontal and profile images were used and characteristics such as the histograms of the Red-Green-Blue (RGB) model and form descriptors (area, perimeter, length, width, etc.) were computed (Vanloot et al., 2014). Liming and Yanchao (2010) developed an automated strawberry grading system using image processing technique and graded the strawberry adopting one or two or three indices among shape, color and size (Liming and Yanchao, 2010).

A method to classify mango fruits into their maturity stages was developed using the fuzzy logic and RGB color sensor model. The advantage of fuzzy approaches is that approximate inference can be performed by fuzzy IF-THEN (Mansor et al., 2014). Another method to categorize mangoes according to their maturity indices was proposed using their color and size features and histogram analysis. The advantage of histogram analysis is low computational complexity (Vyas et al., 2014).

As it was seen, a large number of works to estimate the maturity indices of different fruits which is based on digital image analysis have been proposed. However, there are some limitations such as fuzzy logic approach is computationally intensive and determination of membership function is not very easy. Also, we can interpret fuzzy rules in a number of ways. In histogram analysis spatial details are not considered and it cannot guarantee the segmented regions to be contiguous. Moreover, no research has been performed which uses decision tree for categorization inspite of its massive advantage in classification process.

For these reasons, in this paper, a method of digital image processing has been proposed which is based on the skin color of "Himsagor" mangoes. The RGB and HSI color features of mangoes are extracted and from the correlation based and information gain evaluation, most informative features are selected. Then their maturity stages are determined using the decision tree of those selected features. We have identified the different maturity stages of mangoes in a more human like way.

2. Background

Mango is one of the commercial fruits produced and consumed throughout the world. Mangoes are needed to be classified according to their ripening stage for commercial use. Currently this classification is being performed manually which is not accurate and prone to human errors. Also it requires the manpower and thereby overall cost are increased and effectiveness are reduced in the mango processing industries (Tomas and Ganiron, 2014).

Several research works have been done elsewhere in the world pertaining to the present study and also some related reviews have been presented here under the following sub-heads.

2.1. Consideration of size, shape, color and chemical properties in the classification of fruits

A similar trend of maturity indexing was observed for the fruit banana by Tapre and Jain (2012). The authors analyzed bananas of three advanced stages of maturity i.e. stage 5–7 for their physicochemical and mechanical properties. The research focused on the changes in banana fruits particularly during last stages of ripening. It may be concluded that in advanced stages of maturity of banana viz. stage 5–7 though the slight changes observed in terms of peel color but significant changes with respect to some mechanical properties and physiochemical parameters opted. Hence, two classifier algorithms namely, mean color intensity algorithm and area algorithm were developed and their accuracy on maturity detection was assessed. The mean color intensity algorithm showed 99.1% accuracy in classifying the banana fruit maturity. The area algorithm classified the under-mature fruit with 85% accuracy (Tapre and Jain, 2012).

Fruit consumers are confused to take fruits from markets due to artificial fruit color. To overcome this problem a study was conducted on fruit color characterization of "Amrapali" and "Mallika"- two varieties of mangoes at the postharvest laboratory, Department of Horticulture, Patuakhali Science and Technology University (PSTU), Bangladesh by Rajibullah et al. (2015). Another study was conducted at the same laboratory on BARI Aam-3 - a mango variety of Bangladesh Agricultural Research Institute (BARI) by Uddin et al. (2017). In both studies on three different varieties of mangoes, the earliest physiological maturity (stage-1) was marked as the stage when the flesh was dark olive green and turning yellow at the seed and the subsequent maturity stages determined at 2-days intervals as stage-2 (olive), stage-3 (apple green), stage-4 (brown), stage-5 (saddle brown) and stage-6 (dark golden rod color). For each of the maturity stages, physical (peel color, firmness and weight loss) and biochemical (anthocyanin content, titratable acidity, pH, total soluble solids, ascorbic acid, reducing sugar, non-reducing sugar and total sugar) maturity indices were determined (Rajibullah et al., 2015, Uddin et al., 2017).

Sardar et al. (1998) observed wide range of variability in respect of different physico-chemical characteristics of mango fruits. Skin and pulp color of ripe fruits varied from green to yellow and yellow to orange, respectively. The largest fruit (578.3 g) recorded is the variety - Fazli and the smallest (126.9 g) is the variety - Bhabani. Fazli had the longest fruit (15.5 cm) and the shortest (7.6 cm) is the variety - Hilsapeti. Fruit breadth and thickness varied from 5.5 to 8.9 cm and 5.0 to 8.2 cm, respectively. The longest (11. 4 cm) and the widest (5.7 cm) stone were found in Fazli whereas that of Hilsapeti was shortest (5.6 cm) as well as narrowest (3.1 cm). Thickness of stone was the highest (3.2 cm) in Ashwina and the lowest in Hilsapeti (1.8 cm). Percentages of edible and non-edible portions varied from 58.5 to 75.1 and 24.9 to 41.5, respectively. Furthermore, Hilsapeti had the highest stone portion (26.2%) and the lowest in Kishanbhog (12.5%).

Near infrared (NIR) spectroscopy has been used by Saranwong et al. (2004) to evaluate the harvest quality of green mango and to predict the ripe-stage eating quality of the mango from its harvest quality Size is also one of the major parameters that the consumer identifies to be related to the quality of mango. According to Federal Agricultural Marketing Authority (FAMA) Malaysia, size of mango is determined by weight. A paper presents a study on measuring the weight of Chokanan mangoes using image processing and analysis techniques. The computing PCI software was used to process and analyze mango image obtained from image acquisition system. Number of pixels of mango region in the captured image was counted by the software using image processing and analyzing processes (Teoh and Syaifudin, 2007).

Mansor et al. (2014) proposed that by using RGB color sensor and fuzzy logic as classification algorithm, the accuracy of mango grading is more than 85%. Fuzzy logic is successfully applied to serve as a decision support technique in ripeness mango classification. Grading results obtained from fuzzy logic shows a very good agreement with the results from the human expert. Performance of the system can be improved by integrating with other feature such as texture. Furthermore, this research is a first attempt to determine fruit ripeness by using RGB color sensor. The result shows that RGB color sensor can be used accurately as data acquisition and can be applied to other classification of fruits (Mansor et al., 2014).

A spectral analysis of images of bananas obtained under white and ultra-violet light is performed by Intaravanne et al. (2012). The images obtained are used to classify areas of the banana that are immature, mature and over-mature (Intaravanne et al., 2012).

In another study with bananas the stage of fruit maturity is estimated by analyzing the color, stains and texture in the image (Mendoza and Aguilera, 2004). Pace et al. (2013) proposed a method of Computer Vision System to estimate the antioxidant and phenol content on carrots based on the fruit's surface color. The color is determined by the center