Quality Monitoring of Mangoes using Infrared and Visible Imaging

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ARTICLE INFO

Article history:
Received 20 November 2013
Received in revised form 24 January 2014
Accepted 29 January 2014
Available online 5 April 2014

Key words:
mangoes; vision system; IR camera; CCD camera

ABSTRACT

The perceived quality of fruits, such as mangoes, is greatly dependent on many parameters such as ripeness, shape, size, and is influenced by other factors such as harvesting time. Unfortunately, a manual fruit grading has several drawbacks such as subjectivity, tediousness and inconsistency. By automating the procedure, as well as developing new classification technique, it may solve these problems. This paper presents the novel work on the using Infrared and visible Imaging and acoustic as a Tool in Quality Monitoring of Harumanis Mangoes. A Fourier-Descriptor method was developed from a CCD camera images to grade mango by its shape and able to correctly classify 98.3%. The histogram of infrared image was used to distinguish and classify the level of ripeness of the fruits based on the colour spectrum by week. The approach proposed was shown to be able to achieve 90.5% correct classification.

INTRODUCTION

Mango (Mangifera indica L.) belongs to the family Anacardiaceae. It is the only species grown extensively and commercially in India, Philippines, tropical Australia, the lowlands of South-East Africa, in Hawaii and in the lowlands of Central and South America (Zainon Mohd Ali, Santhi Armugam 1995). The Malayan name of mango (mangga) attests its origin outside Malaya, being the same word as the Tamil mangas (Malamasa, E. N., E. G. M. Petrakisa, et al. 2003).

In Malaysia, especially Perlis state, the popular variety is Harumanis mango and Japan shows strong interest in Harumanis that why Perlis is hoping to increase its annual yield, which currently stands at 350 tonnes for local consumption. The bigger challenge, however, lies in persuading local farmers to apply good agricultural practices. Fig 1. Show harumanis mango farm in Universiti Malaysia Perlis, Perlis Malaysia.

Fig 1: Harumanis Mango farm

Presently, the quality inspection was done manually by the workers (Fig 2) and there are difficulties in enforcing these standards, especially where it entails a large amount of mango to be evaluated, made no easier by increasing difficulty in hiring personnel who are adequately trained and willing to undertake the tedious task of inspection.

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For this reason, this paper, we present the methods and techniques of an internal and external automatic grading system inspection using infrared and visible imaging to standardize the grading scheme of mango thus promoting the quality awareness amongst the planters and producers.

2. Methodology:

A. Grading Standard.

Jabatan Pertanian Perlis, Malaysia established three grades for Harumanis Mango, which is used in this study. The grades are Grade A, Grade B and Grade C are determined by qualitative and quantitative criteria. Table 1 shows the Market Grading Requirement for Mango.

Table 1: Market Grading Requirement for Mango (Jabatan Pertanian Negeri Perlis)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Quantitative/qualitative features</th>
<th>Tolerances (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Uniform in size (weight &gt;400g)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mangoes must be free of defects</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>Uniform in size (weight 351-399g)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mangoes may have following slight defects,</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>Uniform in size (weight &lt;350g)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mangoes may have following defects,</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>- Defects in shape,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Slight skin defects due to rubbing or sunburn.</td>
<td></td>
</tr>
</tbody>
</table>

The top grade mango is allowed little variation in these quality characteristics, while the lower grade is allowed greater variation and degradation. Generally, mangoes of the same variety do not show significant variation in sizes and weights. However, establishing discrimination boundaries using color and shape information usually require an inspection and grading by experience human expert.

B. Elements of Machine Vision and conveyor System:

The procedures and methods are implemented on a machine vision workstation, which included a Personal Computer (PC), LabVIEW 2012 software, an illumination system, a charge coupled device (CCD) camera, VarioCam thermographic camera, NI CompactRIO and a conveyor system (Fig 3). NI CompactRIO was used to control the conveyor system for inspection and sorting process, both CCD camera and VarioCam thermographic camera were used for capturing the image and LabVIEW 2012 software was used for image analysis and classification process.

The particular image analysis and processing developed in this study consisted of three levels: low-level processing, intermediate level processing and high-level processing (Fig 4). In summary, the first group includes image acquisition and pre-processing such as image enhancement, extraction and restoration (Brosnan and Sun
Meanwhile the second group concerned with the image transformation such as RGB to HSI transformation, segmentation and filtering. Finally, the third group involved in recognition and interpretation.

![Diagram](image)

**Fig. 4:** Different level in the image processing

### C. Shape Analysis:

Harumanis mango can be viewed adequately by 2 Dimensional perspectives; therefore they are most suitable for real-time machine processing. Fig 5 shows Grade of Harumanis mango.

(a) Grade A

(b) Grade B

(c) Grade C

**Fig. 5:** Grade of Harumanis mango by shape

Presently, there are many methods available for analyzing the shape of an object, ranging from a simple multiple point features method to a complicated geometric features approach. The method used in this project was conceptionalised by (Heinemann, P.H., Pathare, N.P. and Morrow, C.T. 1996). It was based on Fourier Descriptors (FD). They provide details mathematical explanation of FD for object recognition, matching and registration. One unique feature of this method is that it uses global image descriptors instead of the local ones,
making it more applicable to real-world images in which simple multiple point features may be difficult to extract, and eliminating the need for feature matching between the reference and observed images.

Before this method could be implemented, several image pre-processing operations were performed on Harumanis mango image. The image was firstly binarised with an adaptive threshold, and secondly, processed via a sequence of morphological image processing. Fig 6 shows the image of Harumanis mango after image processing.

![Image](image_url)

**Fig. 6**: The image of Harumanis mango after image processing; (a) Original (b) morphological

Finally, the object centroid was extracted using first-order geometric moments and derived using Green's theorem (M.Z. Abdullah, et al 2006) shown in Fig 7.

![Image](image_url)

**Fig. 7**: Object centroid and boundary

Mathematically, the two-dimensional centroid \((x_c, y_c)\) is given,

\[
x_c = \frac{\sum_{k=0}^{N} y_k (x_k^2 - x_{k+1}^2) - x_k^2 (y_k - y_{k+1})}{2 \sum_{k=0}^{N} y_k (x_k - x_{k+1}) - x_k (y_k - y_{k+1})}
\]

(1)

and

\[
y_c = \frac{\sum_{k=0}^{N} y_k^2 (x_k - x_{k+1}) - x_k (y_k^2 - y_{k+1}^2)}{2 \sum_{k=0}^{N} y_k (x_k - x_{k+1}) - x_k (y_k - y_{k+1})}
\]

(2)

Where \(N\) is the total number of boundary pixel defined in a clockwise direction from any starting point; \((x_k, y_k)\) are the coordinates of the boundary pixel, \(k\). The distance of each boundary point to the centroid was calculated as follows:

\[
R(k) = \sqrt{(x_k - x_c)^2 + (y_k - y_c)^2}
\]

(3)
The $R(k)$ was then subjected to Discrete Fourier Transform (DFT), yielding a one-dimensional feature vector of Harumanis mango. In Fourier space, such transformation was mathematically implemented as follows:

$$F(m) = \frac{1}{N} \left[ \sum_{k=0}^{N-1} R(k) \cos \left( \frac{2\pi mk}{N} \right) \right]^2 + \left[ \sum_{k=0}^{N-1} R(k) \sin \left( \frac{2\pi mk}{N} \right) \right]^2$$

Since the descriptors are influenced by the curve shape and by the initial point of the curve, therefore, calculating and examining each harmonic component provide some clues of the shape. For a given shape, the plot of Fourier descriptors produces a pattern or fingerprint which uniquely describes this shape. In theory, the order of Fourier descriptors ranges from zero to infinity (M.Z. Abdullah, et al. 2006). However, one favourable property common to Fourier descriptors is that the high-quality boundary shape representation can be obtained using only a few lower-order coefficients. Fig 8: summarizes the overall procedure taken for shape analysis.

![Diagram](image)

**Fig 8:** overall procedure taken for shape analysis

**D. Maturity Level Determination Analysis:**

In order to classify the different internal colour of mango, histogram method was applied and performed by normalized them in histogram. The entropy method is an efficient and general optimization algorithm (Alfatni, M. Shariff, et al. 2008). Fig 9 and Fig 10 shows the image captured by the CCD camera and IR Camera.

![Image](image)

**Fig 9:** Image captured by a CCD camera
RESULTS AND DISCUSSION

A. Shape Analysis:

The experiment conducted graded the fruits to three grades, from grade A, representing the best quality grade, to grade C. The quality of each fruit was inspected by inspectors, who studied the mango one at a time and made a judgment as to fruit quality. Damaged or injured fruits and fruits infected by insects, diseases, blemishes such as scars, scabs and staining were discarded.

Approximately 300 fruits were sampled; the first 300 samples were allocated to test set, comprising of 100 samples for each grade. These samples were then imaged and later used to train machine vision system for shape inspection and recognition. The test sets were used to evaluate the machine vision accuracy for shape, weight and maturity inspection. In the same way, the inspectors looked at the mangoes one at the time and performed classification based on the quality feature of each fruit.

Fig. 10: Image captured by IR Camera

Fig. 11: shape analysis based Fourier Descriptor

The resulting image was used to calculate the moments and finally the Fourier of the object. Fig 11 shows the plot of normalised Fourier descriptors for each shape category. Clearly from Fig 11, the Grade A, B and C can be characterised by \(|F(3)|\). The method based on direct thresholding cannot be used because of the difficulty in establishing a single and effective shape threshold. A different approach is needed to solve this type of pattern recognition problem by applying discriminant analysis to establish classification.

B. Discriminant Analysis (DA) Learning for Shape Analysis:

The objective of DA learning is principally to identify a subset of dominant features that are most responsible for splitting a set of observations into two or more groups. Frequently, the successful application of shape recognition using machine vision system relies strongly upon the choice of proper spectral range and the number of variables employed in the calibration model.
The discrimination power of these principal FD can be examined by studying the Mahalanobis’ distances which are shown canonically in Fig. 12. This plot clearly demonstrates that the mango separate into three groups, corresponding to three different grades. A close inspection of Fig. 13 reveals that Grade A, B and C groups separate distinctively among themselves and the classification result for grade A, B and C are 98.3% classify.

**C. Maturity Analysis using IR Camera:**

Normally, the maturity and ripeness level of mango depends on their external skin colour whether they are ripe, unripe, mature and immature. Unfortunately, this is not the case of Harumanis mango. Alternatively, different maturity and ripeness level can be detected by using IR camera. Fig 13 shows the distribution of different maturity and ripeness level of mango samples. All images were captured using VarioCam Thermographic camera.

The mango images were captured and each image is subjected to histogram.

Fig 14 shows the average of thermal image for week 8 and 9. From the graph, data for week 8 skew to low intensity and data for week 9 skew to more high intensity. The method based on direct thresholding cannot be
used because of the difficulty in establishing a single and effective intensity threshold. A different approach is needed to solve this type of pattern recognition problem by applying discriminant analysis to establish classification. The classification result for week 8 and 9 are 90.5% classified.

Conclusions:
A Fourier description method was developed from CCD (visible) data to grade mango by its shape and the results were able to correctly classify 98.3% mango sample by its' shape. The histogram of infrared image was used to distinguish and classify the level of ripeness of the fruits based on the color spectrum by week. The approach proposed was shown to be able to achieve 90.5% correct mango classification in terms of maturity and ripeness levels by week. The results show that the entire sensors can be used to determine difference quality parameters of fruits and it was also observed that the data fusion of the CCD and IR camera data can provide a real alternative to human expert panel in non-destructive fruit quality assessment for mango.

ACKNOWLEDGMENT
This research has been supported by a Fundamental Research Grant Scheme (FRGS) Multi Modalities Sensor Fusion for Quality Assessment of Agro based product (9003-00250).

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