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# Shape and weight grading of mangoes using visible imaging

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ABSTRACT

This paper presents the work on the use of visible imaging as a tool in grading the mangoes. A Fourier-descriptor method was applied on mango images acquired by a CCD camera, to grade the fruits by their shapes. The method was able to correctly classify 98.3% using DA and 100% using SVM. It is also possible to estimate the weight of the mangoes from their images by applying the Cylinder approximation analysis method. The scatter plot between the estimated and actual values of the weight shows high correlation, with $R^2$ equal to 94.0%. The high prediction accuracy obtained shows that this simple formula is adequate for the prediction of fruit weight and volume (measured volume using the cylinder method). The correlation formula derived based on the collected data is determined as $w = 2.256\,V - 157.7$ where $w$ is estimated weight in grams and $V$ is estimated volume. Overall result for weight grading using our proposed method yields 95% accuracy.



## 1. Introduction

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae. It is grown extensively and commercially in India, Philippines, Thailand, tropical Australia, the lowlands of South-East Africa, Hawaii and in the lowlands of Central and South America. The 'Harumanis' variety is mainly grown in the northern part of Malaysia, particularly in the State of Perlis. Harumanis is considered the "*King of Mangoes*" and is very popular in Malaysia because of its sweet and aromatic fragrance (Musa et al., 2010).

Since the 1970s, the automatic visual inspection systems have become useful tools in industrial and agricultural process. They are used to detect malfunctions during the manufacturing process and control product quality (Gonzalez and Woods, 2002). Grading is an important operation to measure size, color, shape and defect of agricultural product. Image pre-processing is an important step for agricultural product quality system. Presently, there are many methods available for analyzing 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 conceptualised by Zahn and Rookies (1972). It was based on Fourier Descriptors (FD). They provide detailed 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.

The image processing final step of agricultural external grading system is decision making which is the result of image processing steps for the sample. In the other hand it is sample classification and ranking method compared to the known samples which trained to the system before base on specific factors. Generally, there are different techniques used to train the reference samples to the grading system and then classify the new sample base on the training stage which are; statistical classification, neural network classification, fuzzy logic classification and then neural-fuzzy classification. Statistical approaches are generally characterized by having an explicit underlying probability model, which provides the probability of being in each class rather than a simple classification (Du and Sun, 2004). SVM is a supervised machine learning method that performs classification based on the statistical learning theory. Essentially, SVM is based on fitting a separating hyperplane that provides the best separation between two classes in a multidimensional feature space. This hyperplane is the decision surface on which the optimal class separation takes place. In order to represent more complex shapes than linear hyperplanes, a variety of kernels including the polynomial, the radial basis function (RBF), and the sigmoid can be used. Also, a

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penalty parameter can be introduced to the SVM classifier to allow for misclassification during the training process. Finally, SVM classifiers can be extended to more than two classes by splitting the problem into a series of binary class separations. The aim of this study is to develop vision technique to grade the mangoes by its shape and weight using visible imaging and classifying the mango using statistical classification then be applied to post-harvest handling.

## 2. Materials and methods

### 2.1. Elements of machine vision system

The procedures and methods are implemented on machine vision workstation, conveyer show in Fig. 1, which included an illumination system Philips LED lighting, 4.5–5 watt, 6500 K color temperature and a Basler acA1600-20gc GigE camera with the Sony ICX274 CCD sensor delivers 20 frames per second at 2 MP resolutions. The RFID module is used to trigger the camera and the belt speed for the conveyer is adjustable. The conveyer that use in this study is flat bed and the purple cup is use for fruit containers.

The particular image analysis and processing developed in this study consisted of three levels: low-level processing, intermediate processing and high-level processing. In summary the first level includes image acquisition and pre-processing such as image enhancement, extraction and restoration. Meanwhile the second level concerned with the image transformation such as RGB to HSI transformation, segmentation and filtering. Finally, the third level involved recognition and interpretation. All programming was implemented directly using Labview 2013 software with vision acquisition and development toolkit.

### 2.2. Grading standards

The Perlis Department of Agriculture, Malaysia has established three grades (A, B and C) for the Harumanis Mangoes, which is used in this study. The grades are determined by qualitative and quantitative criteria. Table 1 shows the Market Grading Requirement for Mangoes.

The top grade mangoes are 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 the discrimination boundaries using shape and weight information frequently require physical inspection and grading by experienced human experts.

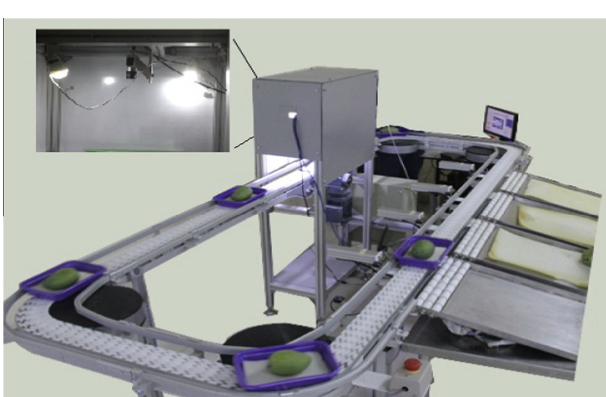

**Fig. 1.** Machine vision workstation.

**Table 1**
Market grading requirement for mango (Perlis Department of Agriculture).

| Grade | Quantitative/qualitative features | Tolerance (%) |
|---|---|---|
| A | Standardize in shape and size (weight > 400 g) | 5 |
| | Mangoes must be free of defects | 5 |
| B | Standardize in shape and size (weight 351–399 g) | 5 |
| | Mangoes must be free of defects | 5 |
| C | Standardize in shape and size (weight < 350) | 5 |
| | Mangoes may have the following defects, | 5 |
| | – Slight skin defects due to rubbing or sunburn. | 5 |
| Rejected | – Not standardize in shape and size | 5 |

### 2.3. Shape measurement

The Harumanis mangoes can be viewed adequately by two-dimensional perspectives. Hence, they are most suitable for real-time machine processing. Only one population which is Harumanis mango will use in this study. The Harumanis mangoes were grab via the camera in a random orientation. The sample will be place on the purple trays. Before this method could be implemented, several image pre-processing operations were performed on the mango image. The image was firstly binarised with an adaptive threshold, and secondly, processed via a sequence of morphological image processing. Fig. 2 shows the image processing sequence.

Finally, the object centroid was extracted using first-order geometric moments and derived using Green's theorem.

Mathematically, the two-dimensional centroid $(x_c, y_c)$ is given below;

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

and

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

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 is calculated as follows:

$$R(k) = \sqrt{(x_k - x_c)^2 + (y_k - y_c)^2} \tag{3}$$

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

$$|F(m)| = \frac{1}{N} \times \sqrt{\left[\sum_{k=0}^{N} R(k)\cos\left(\frac{2\pi mk}{N}\right)\right]^2 + \left[\sum_{k=0}^{N} R(k)\sin\left(\frac{2\pi mk}{N}\right)\right]^2} \tag{4}$$

Since the descriptors are influenced by the curve shape and by the initial point of the curve, therefore, calculating and examining each harmonic component in $|F(m)|$ provide an indication of the shape. For a given shape, the plot of Fourier descriptors produces a pattern or fingerprint which uniquely describe this shape. In theory, the order of Fourier descriptors ranges from zero to infinity (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. Therefore, only the first few components of $|F(m)|$ are