HARUMANIS MANGO QUALITY ASSESSMENTS TECHNIQUE BASED ON HIGH LEVEL FEATURES FUSION OF INFRA-RED THERMAL AND OPTICAL IMAGE

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by

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LIST OF ABBREVIATIONS

FD	Fourier Descriptor
C-CD	Contour Centroid Distances
CCD	Charge couple device
DA	Discriminant Analysis
SVM	Support Vector Machine
D-S	Dempster-Shafer
MVT	Majority voting
MANOVA	Multivariate Analysis of Variance
FI	Firmness Index
AFI	Alternative Firmness Index

Teknik Penilaian Kualiti Mangga Harumanis Berdasarkan Aras Tinggi Gabungan Ciri-ciri pengimejan Haba Infra-Merah dan pengimejan optik

ABSTRAK

Manga di import dari serata dunia, terutama Malaysia, Thailand, Mexico dan Filipina. Manga biasanya boleh didapati disepanjang tahun manakala di Perlis, Malaysia terdapat salah satu manga yang unik dan terkenal iaitu mangga Harumanis dan buah ini adalah bermusim. Setiap tahun, jumlah besar mangga dihasilkan dan perlu dinilai untuk penilaian kualiti. Pada masa ini, pemeriksaan kualiti dilakukan secara manual oleh pekerja pakar kerana tiada sistem pengredan automatik. Oleh itu, dengan mengautomasikan prosedur serta membangunkan teknik klasifikasi baru, ia boleh menyelesaikan masalah ini. Tesis ini membentangkan teknik gabungan aras tinggi ciri data pengimejan haba infra-merah dan pengimejan boleh lihat untuk penilaian kualiti manga. Analisis ciri bentuk dan analisis berat buah telah dibangunkan bagi pengimejan boleh lihat dan analisis kematangan telah dibangunkan dari pengimejan haba Infra-merah. Satu kaedah Fourier-Descriptor telah dibangunkan untuk mengred Harumanis mangga dari analisis ciri bentuk dan ciri berat buah menggunakan kaedah analisis silinder dan ianya memberikan hasil klasifikasi yang berbeza. Spektrum imej inframerah telah digunakan untuk membezakan dan mengelaskan tahap kematangan daripada buah dan ia memberikan kejituan yang rendah berbanding dengan kejituan analisis bentuk dan kejituan analisis berat buah. Untuk mendapatkan nilai kejituan yang tinggi bagi penilaian kualiti untuk Harumanis mangga, gabungan peringkat tinggi telah dicadangkan. Kaedah ini adalah menggabungkan ketiga-tiga ciri iaitu bentuk, berat buah dan kematangan dan ia didapati dapat mencapai 98% kejituan.

Harumanis Mango Quality Assessments Technique Based on High Level Features Fusion of Infra-Red Thermal and Optical Image

ABSTRACT

Mangoes imported from other parts of the world, especially Malaysia, Thailand, Mexico and the Philippines, are usually available all year round but in Perlis, Malaysia there is one unique and famous mango is Harumanis mango and this fruit is seasonal. Every year, a large amount of mangoes are produced and need to be evaluated for quality assessments. Presently, the quality inspection was done manually by the quality expert as there are no automated grading system is available. Hence, by automating the procedure as well as developing new classification technique, it may solve these problems. This thesis presents the new method on the high level features fusion of visible and IR Thermal Image features for mango quality assessment. A shape and weight analysis was developed from visible imaging and a maturity analysis was developed from IR thermal imaging. A Fourier-Descriptor method was developed to grade mango by its shape and a cylinder analysis method was used to grade Harumanis mango by its weight and it give different accuracy result of classification. The spectrum of infrared image was used to distinguish and classify the level of maturity of the fruits and it gave low accuracy compare to shape and weight classification. To get high accuracy for quality assessment for Harumanis mango, high level data fusion was proposed. This method combined all three classifier of shape, weight and maturity and it was found to be able to achieve 98% accuracy classification.

CHAPTER 1

INTRODUCTION

1.1 Introduction to Harumanis Mango

Mango is an important commercial fruit crop throughout the world, particularly in Malaysia, India, Indonesia, Sri Lanka, and Thailand and also in African countries. Mango *(Mangifera indica* L,) belongs to the family of *Anacardiaceae*. The Malayan name of mango (*mangga*) attests its origin outside Malaya, being the same word as Tamil's *mangas.*

Mango is a popular evergreen fruit tree that is natural to South-Eastern Asia. Moreover, it has been cultivated for over 4000 years during which time it has spread to other tropical and sub-tropical countries. Thus, it is universally considered as one of the finest fruits in the world.

Harumanis is considered the ''*King of Mangoes''* and is very popular in Malaysia due to its deliciousness, sweetness and aromatic fragrance. Generally, Harumanis is very suitable for the export market as it has desirable colour and sweetness and good eating quality with good aroma. For instance, the overseas demand for Harumanis has steadily increased, especially from the Japanese market.

Compared with other mango varieties, the Harumanis is somewhat temperamental. It thrives in Perlis because it needs a long dry season of with temperature range between 37 to 39 degrees Celsius to flower and fruit. Rain, even drizzles during this crucial period will spoil the yield. After the fruit is set, it needs to be wrapped in waterproof paper. About eight weeks after wrapping, the fruits must be manually harvested, washed to rinse off the residues, treated in hot water for five

minutes to eliminate fruit fly and seed weevil larvae. Hence, producing Harumanis is a labour-intensive process and there are no shortcuts.

1.2 Harumanis Mango Morphological

Harumanis mango tree is a yearly fruit bearing tree and reproductive phase of the mango trees often starts in January and ends in early Jun. Figure 1.1 shows Perlis Agricultural Department Harumanis mango farm. This type of mango is highly sensitive to the climate and known to grow well only in Perlis and part of Surabaya in Indonesia. It requires a significant dry weather period for initial flowering and the productive phase can be significantly affected by changes in weather.

Harumanis mango have a round apex and oval shape. Harumanis mango is a sweet aromatic mango with some soft fibres. Even though it has thick green-coloured skin on the outside, its flesh is ripen sweet when it reaches maturity.

Figure 1.1 Harumanis Mango Farm Located at Perlis State Department of Agricultural

1.3 Harumanis Mango Grading

Perlis Agricultural Department Malaysia established three grades for Harumanis Mango, which is used in this thesis. Generally, the grading is assessed based on:

i) Weight

ii) Shape

iii) Maturity

The grades, namely Grade A, Grade B and Grade C, are determined by qualitative and quantitative criteria. Table 1.1 shows the market grading guideline for Harumanis mango.

Table 1.1: Market Grading Guideline for Harumanis Mango [Data from Perlis State Department of Agricultural]

Grade	Features	Tolerances (%)
A	Round apex and oval shape Weight $\geq$ 400 g Maturity week 8	5 5 5
B	Round apex and oval shape Weight 351-399 g Maturity week 8	5 5 5
C	Round apex and oval shape Weight $\leq$ 350 g Maturity week 8	5 5 5

1.4 Problem Statement

Presently, the grading is mostly done manually based on the weight and stage of ripeness. The sorting is carried out by well-trained quality control inspectors only. The manual process of sorting or grading is a time consuming, laborious, less efficient and inaccurate process. The scope of automation for grading and packaging is done to reduce the labour costs and to increase the production. Moreover, mechanical graders employing firmness sorter, size graders and weight sorters are used in some countries. However, when it comes to grading/sorting based on the internal properties of mango, it is still based on destructive tests which are difficult to apply for on-line or large scale grading/sorting. In such applications, a machine vision based grading techniques employing the optical properties of fruit will be of more use for efficient and rapid grading.

In short, this research is based on the following issues: Every year, a large amount of Harumanis mango are produced and need to be evaluated for quality assessments.

- Presently, the quality inspection was done manually by the workers (Figure 1.2) and there are difficulties in enforcing the quality standards.
- Grading mostly done based on weight only
- There are no known external or visible changes in mango fruit which could be used for the accurate determination of internal quality

.

Figure 1.2 Current Inspection for Harumanis Mango

Hence, developing a fully automated grading system as shown in Figure 1.3, it may solve these problems.

Figure 1.3 Automation System for Harumanis Mango Grading

1.5 Research Objective

- To obtain the external features of Harumanis mango using an Optic camera for:
  - Shape features analysis
  - Weight features analysis
- To obtain the internal features of Harumanis mango using IR Thermal camera for:
  - Maturity features analysis
- To classify the grade of Harumanis mango using base classifier.
- To evaluate the performance of the proposed technique for grading the Harumanis Mango

1.6 Scope of the Thesis

The scope of this research is the development of a classification technique for Harumanis mango quality assessment using thermal images and optical images. Thermal images were used to ascertain the maturity and optical images were used to determine the shape and weight. The developed system will classify only the following 3 grades of Harumanis mango namely Grade A, Grade B and Grade C.

1.7 Overview of Methodology

In this thesis, an optic camera and IR Thermal camera was used to obtain the image of Harumanis mango. The image from an optic camera shows the external data and the image from IR Thermal camera can indicate the internal data of Harumanis mangoes. From the external data, the Fourier descriptor method was used to analyse the shape and cylinder method was used to analyse the weight data. Meanwhile, the IR Thermal image was used to analyse the maturity of the fruit using Hue value and Histogram method. The base classifier i.e, support vector machine and discriminant analysis are used to classify the Harumanis mango grade based on features.

The high-level fusion method was then employed to fuse the three base classifiers trained on different sources of information. The classification results of the individual classifiers were compared with those obtained from fusing the classifiers by the high-level fusion method. The overview of research methodology is given in Figure 1.4.

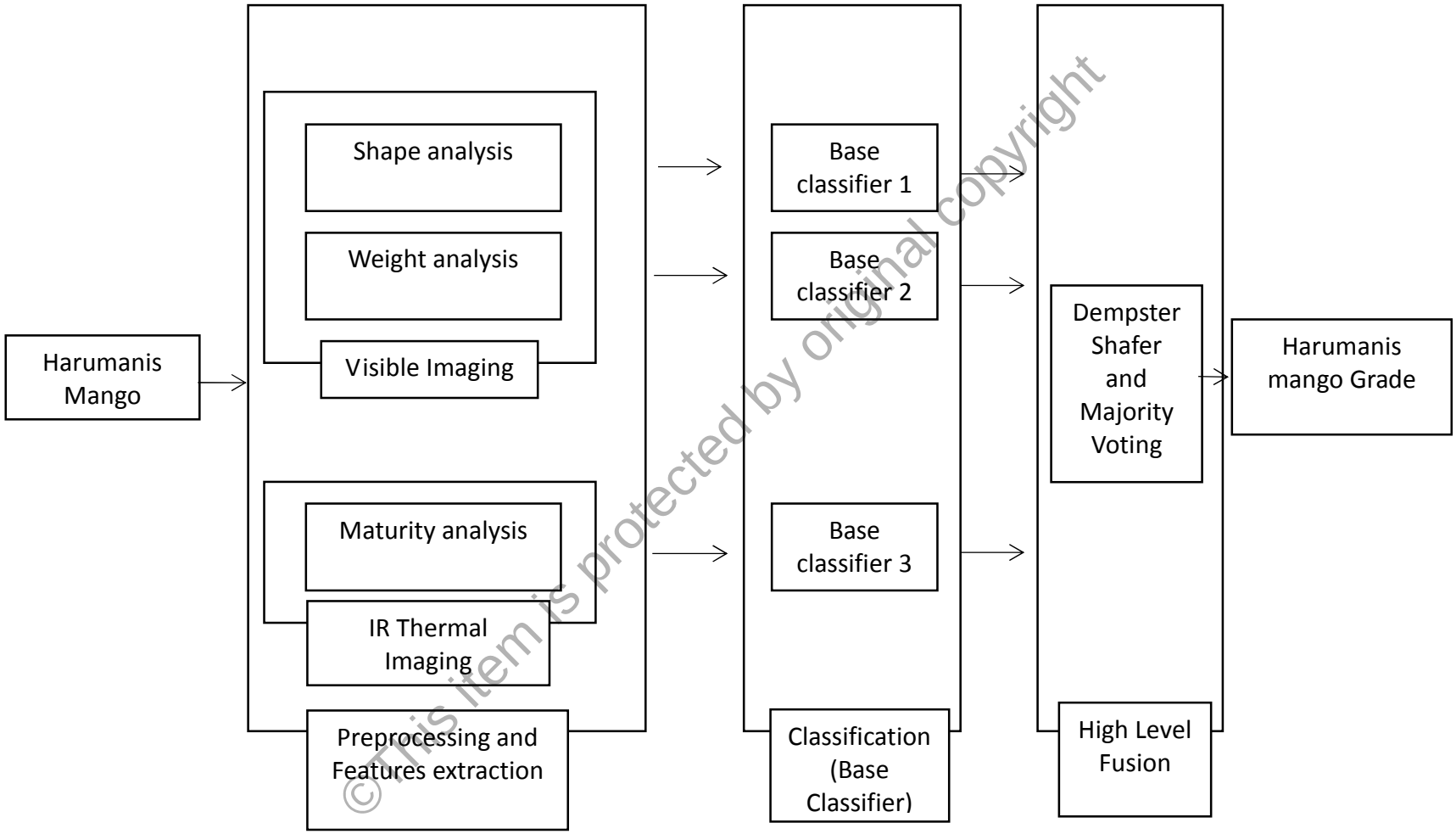

Figure 1.4 Overview of Research Methodology

1.8 Contributions of this Thesis

The principal contributions of the work reported in this thesis are:

I. The use of Fourier Descriptor for shape of Harumanis Mango

II. The use of Cylinder method for the weight of Harumanis Mango

III. The use of HIS method for maturity of Harumanis Mango

IV. Base classifier method for classifying the shape, weight and maturity of Harumanis Mango

V. High-Level data fusion method for combining shape, weight and maturity of Harumanis Mango

1.9 Organization of the Thesis

The organization of the thesis is summarized as follows:

Chapter 2 provides an overview of an Optic and IR thermal camera applications in general and application in agriculture monitoring. The chapter also discusses shape, weight and maturity analysis. The individual classifier and fusion method are also presented.

Chapter 3 describes the experimental data collection to perform the shape and weight analysis. The individual classifier based on Discriminant Analysis and Support Vector Machine for shape and weight features is also discussed.

Chapter 4 describes the experimental data collection to study the maturity analysis and the firmness correlation between IR imaging, followed by the Base classifier using DA and SVM for maturity features.

Chapter 5 presents the High-Level Fusion method for combining base classifier of shape, weight and maturity analysis.