DESIGN AND IMPLEMENTATION OF A 2.4 GHZ EMBEDDED RFID SYSTEM FOR FRUIT MATURITY EVALUATION FOR AGRICULTURAL INDUSTRIES UTILIZING WIRELESS MESH SENSOR NETWORK

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Special dedication to my loving father Othman Bin Yusuf , my mother Siti Sareah Binti Japri, my loving husband Abd Jalil Bin Elias and my beloved daughters son Qaisara. Qayyim and Qasrina, my kind hearted supervisor Dr Farhana Binti Ahmad Poad, and my dearest friends.

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ABSTRACT

Papaya is one of the major fruits exported as well as favorite fruit among all ages. However, it is difficult for fruit sellers or consumers to identify the best quality of papaya and to detect the amount of mature papaya in a short period of time. Therefore, a simple system is proposed to determine the fruit maturity by utilizing active Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN). The main objective of this project is to determine the fruit maturity. An algorithm based on MATLAB has been developed using image processing toolbox to identify the color of the fruit. The color is analyzed by setting the average color, which must be over 400 pixels. Based on the results, the papaya can be categorized as mature when the color value exceeds 400 pixels and immature when the color value is less than 400 pixels. The accuracy of the proposed system is about 80% of which 8 of 10 papaya are able to give good prediction. To determine the amount of mature fruit within a short period of time, RFID system has been applied by using Xbee Pro S2b as a medium of transmission. Several tests have been conducted to evaluate performance of the proposed system which are the data transmission in the indoor location and outdoor location. In terms of time and distance, it is proven that when the distance exceeds 100m, the transmission is weak or no longer available. It can be concluded that, by combining image processing method with RFID technology, the maturity of fruits can be easily obtain at anywhere with reliable results.

ABSTRAK

Betik merupakan salah satu buah utama negara yang dieksport ke luar negara dan juga buah kegemaran di kalangan semua peringkat umur. Walaubagaimanapun adalah sukar untuk penjual buah-buahan atau pengguna untuk mengenalpasti kualiti betik yang terbaik serta dapat mengesan jumlah buah betik yang masak dalam tempoh masa yang singkat. Oleh itu satu kaedah yang mudah akan dihasilkan dalam projek ini bagi menentukan kemasakan buah dengan menggunakan RFID dan WSN. Persamaan telah dibangunkan dalan perisian MATLAB dengan menggunakan konsep pemprosesan imej. Pemprosesan imej yang digunakan adalah dengan mengenalpasti warna buah tersebut. Warna tersebut dianalisis dengan menetapkan purata warna iaitu mestilah melebih 400 piksel. Berdasarkan kepada keputusan, betik tersebut dapat dikategorikan masak apabila nilai warna melebihi 400 piksel dan tidak masak apabila nilai warna kurang daripada 400 piksel. Dengan menggunakan sistem ini, ketepatan sistem ini adalah kira-kira 80% dimana 8 daripada 10 betik tersebut berjaya menghasilkan keputusan yang betul. Untuk menentukan jumlah buah matang dalam masa yang singkat, sistem RFID telah digunakan dengan menggunakan Xbee Pro S2b sebagai medium penghantaran. Terdapat dua jenis pengujian yang boleh dilakukan iaitu pertama penghantaran data pada persekitaran dalaman dan persekitaran luaran. Manakala dari segi aspek masa dan jarak penghantaran, adalah terbukti mengikut spesikasi yang ditetapkan iaitu apabila jarak melebihi 100m penghantaran signal yang lemah dan tiada penghantaran signal dapat dilakukan. Dapat disimpulkan bahawa dengan menggabungkan kaedah pemprosesan imej dan teknologi RFID, kemasakan buah-buahan dapat diperolehi dengan mudah di mana saja dengan keputusan yang tepat.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Networks
GUI	-	Graphical User Interface
FUT	-	Fruit Under Test
H2H	-	Human To Human
H2M	-	Human To Machine
HF	-	High Frequency
LCD	-	Liquid Crystal Display
LF	-	Low Frequency
M2M	-	Machine To Machine
MLR	-	Multi Linear Regression
NIR	-	Near Infrared Reflectance
PCA	-	Principal Component Analysis
PLS	-	Partial Least Squares
RFID	-	Radio Frequency Identification
WMSN	-	Wireless Mesh Sensor Network
WSN	-	Wireless Sensor Network
ZC	-	Zigbee Coordinator
ZED	-	ZigBee End Device
ZR	-	ZigBee Router

CHAPTER 1

INTRODUCTION

1.1 Introduction

Agriculture is one of the contributors of the country economic policy, especially in the third world such as Malaysia, China and many parts of Asia. There are various methods to improve productivity and fruit quality such as color based grading and non-color based grading. Most farmers have less knowledge on how to manage their farm and they are unaware on how to improve their productivity of agricultural practices. Therefore, an RFID-WMSN based system is proposed to predict the maturity of fruits. In this work, papaya is selected as Fruit Under Test (FUT), since it is one of the Malaysia's local fruit with high demand request from Malaysian.

In agriculture industries, determinations of fruit maturity and quality are very important. There are two popular methods for fruit maturity prediction, which are non-destructive and noninvasive technique. These two methods allow the physical properties of the fruits is measured according to its maturity and quality indicator [1]. The papaya is said to be matured, if the flesh is soft, sugar is increased, soluble and total solids as well as increase in pigmentations. [1]. Most of researchers [1] used non-destructive testing technique to test fruits since this method is save for papaya, provide real-time measurement, low in costing, and less time consuming.

In this work, a real time remote monitoring and control system is designed and developed to predict the maturity of the fruits, which able reduce the number of labor in future of fruit industries. In addition, an algorithm is proposed to automatically identify the defect in the fruits and maturity of papaya using image processing technique. The development of RFID-WMSN based system for agriculture industries will possibly increase the efficiency, productivity and profitability, as well as decreasing unintended effects on crops and the environment in agriculture production.

1.2 Problem Statement

In fruit industries, the maturity of papaya is manually predicted by human based on color which is prone to error and inefficiency due to the human subjective nature. The effectiveness of this manual classification highly depends on the experience, expertise and high concentration of the operator. Which leads to the increment the cost of labor during maturity classification of papaya. The demand for high quality fruits by consumers has increased day by day. Fast, efficient and cost effective quality control is needed to achieve the target of production. Therefore, a system that able to predict the maturity of papaya is developed by introducing RFID-WMSN technologies on a single platform. The prediction of fruit maturity is done by MATLAB software based on consecutive algorithm.

1.3 Objectives

The objectives of this project is as follows:

i) To design a new architecture of embedded system prototype components that comprise of the RFID technology and WMSN platform.

ii) To develop fruit maturity system which can analyze, classify and identify fruits based on color.

iii) To analyze and characterize the performance of the complete proposed solution package of embedded system.

1.4 Scopes Project

There are 3 main part of the scopes.

i. Identify fruit maturity.

MATLAB Software was used to identify the fruit maturity based on image processing concept. That means can differentiate by its color.

ii. Embedded system prototype components that comprise of the RFID technology.

Used active RFID and arduino UNO as controller. RFID be able to transmit between 30 to 60 meters indoor without router and more than 200 meters outdoor as a standalone device. The data, information and number of products produced can be of real time controlled and monitored by user.

iii. Utilizing with wireless mesh network.

Field monitoring uses 2.4 GHz operating frequency nodes for the purpose of study. Used Xbee Pro S2b as a main component for data transmission.

1.5 Thesis Outline

This thesis consists of five chapters which are Chapter 1: Introduction, Chapter 2: Literature review, Chapter 3: Methodology, Chapter 4: Result and Analysis and Chapter 5: Conclusion

Chapter 1 explains on the background of the project including introduction, problem statement, objectives and scopes of the project.

Chapter 2 discusses on the method used to detect the maturity of fruit carried out by previous researchers. The method categorized into two, which are color based method and non–color based. Color based method can be categorized by 4 methods which are RGB Color Space, HSI Color Space, L*a*b* Color Space and YCbCr Color Space while non-color based method are categorized by 4 methods, which are taste, smell, size and weight. In addition to fruit maturity prediction, this chapter also highlighted on the existing technology used for data transmission as well as the network topology available.

Chapter 3 discusses on the methodology of the project suggested in order to complete the development. It can be divided into two parts namely hardware and software. The hardware part focuses on the system development including the RFID tag and reader portion. The software part refers to the development of algorithm that use image processing method using MATLAB 2009B version, while the X-CTU program is used to configure the Radio Frequency (RF) Module.

Chapter 4 focuses on the result and analysis of the fruit maturity system based on RFID-WMSN platform. From here, it can be seen the performance of this project. The performance of the develop system and algorithm are tested based on color. Algorithm 1 is developed for pre-processing of the database and algorithm-2 is proposed for identification of defects.

Finally, in Chapter 5 the conclusions and suggestions are made for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the important aspects of RFID are described and relevant background research is later explained to understand the current state of the art and a review of the previous works undertaken in designing RFID system for fruit maturity prediction is performed to suit the requirements before a complete system can be developed. Finally, this research work is put in context with the previous and current research activities.

2.2 Overview of Fruit Maturity

Nowadays, the technology used for fruit maturity prediction is growing in line with the current agricultural economic. Several research works have been done to check maturity of fruits using electronic devices [2]. However, there are several gaps regarding to the past methods on determination of the fruit maturity. On top of this, this study is to explore the most feasible methodology in determining the maturity of papaya. Papaya is one of the popular fruit in Malaysia. It also has been marked as 'Malaysia's Best Fruit' that approved by Ministry Of Agriculture [3]. Instead of papaya, other fruits such as apple, oranges, peaches, apricot also have been tested for their maturity but different methods [4]. The methods can be divided into two categories, which are first non-color based grading and color based grading. In this project, maturity color based grading is the main inspection criteria for papaya. The maturity of papaya changes from green (immature) to yellow (mature).

2.2.1 Non-color Based Grading

Preliminary, fruits in the market are inspected based on its maturity (non-color based grading). Consequently, several works have been identified on the fruit grading based on its taste, smell, weight, shape and size.

2.2.1.1 Fruit Taste

Fundamentally, the maturity of fruits can be determined through the taste of sour (immature) to sweet (mature) [4]. Therefore, by using Near Infrared Reflectance (NIR) method, the sucrose level content in various grades of mangoes maturity can be determined. [4]. In the previous research performed by A. Afhzan et al. [4], the acquired analysis indicates that there is a correlation between the absorption of infrared and the percentage of the sucrose level for each watermelon. Multi-linear regression (MLR), principal component analysis (PCA) and partial least squares (PLS) regression with respect to the reflectance and its derivative, the logarithms of the reflectance reciprocal and its second derivative are the vital components to develop NIR models [4].

On the other side, bonding of organic molecules will change their vibration energy from the peak of NIR frequency and exhibits an absorption process through the spectrum [5]. Other than papaya, the maturity and firmness for another fruits such as watermelon, peaches, and apricot are determined through this method [6]. Figure 2.1 shows the previous experiment for testing of mango fruit using NIR [7].

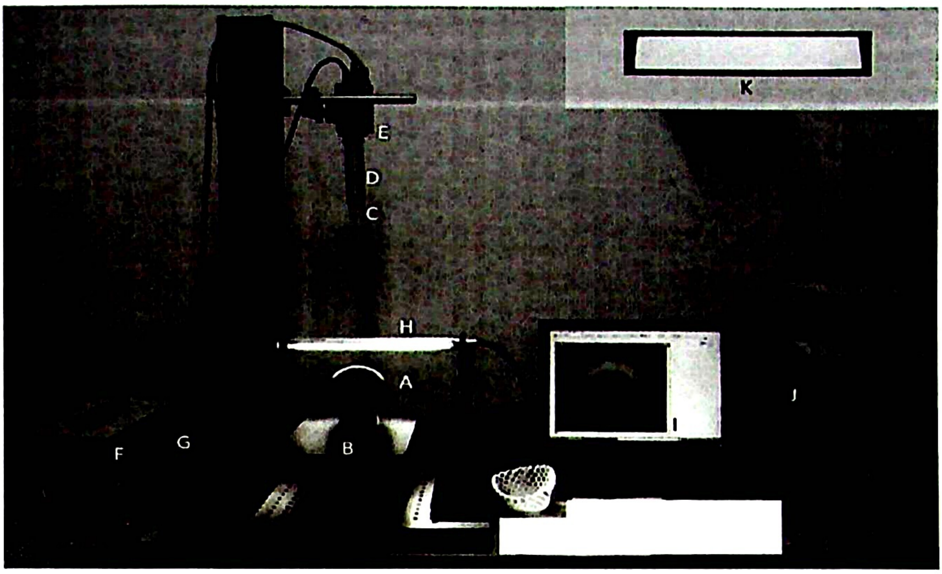

Figure 2.1 : The experimental setup for testing mango fruit using NIR [7]

In determining the sugar content of melons, sugar absorption band method via NIR was used to avoid bias caused by the color information of melons proposed by Tsuta [8]. From this related work, each of the second-derivative absorbencies at 874 nm and 902 nm had a high correlation with the sugar content of melons. Xiaobo [9] used NIR to measure sugar content inside 'Fuji' apple. Using Multiple Linear Regression (MLR), and it is observed that there is an existing correlation between content of sugar and various NIR wavelengths in this particular work. Also, sugar content of a fruit can be determined as well as it sweetness.

2.2.1.2 Fruit Smell

Durians have strong aroma which indicates that the fruit is mature. Several works have been performed to investigate the aroma of the fruits and its maturity, for example, electronic noise proposed by Brezmes [10]. In this research, an artificial olfactory system is proposed in which is used as a non-destructive instrument to measure the fruit maturity, as it was developed to follow the mammalian olfactory system within an instrument. Moroever, the system is designed to obtain measurements, identifications and categorizations of aroma mixtures. Nowadays, electronic nose technology is improved to explore the fruit ripening stage.

A. H. Gómez et al. [11] has proposed an Electronic Nose to identify the maturity of tomatoes, as the Electronic Nose device uses ten different metal oxides sensors (portable E-nose, PEN 2) with respect to the changes of volatile production [11]. Consequently, it has been proven that the Electronic Nose PEN 2 is a successful methodology in identifying the maturity of tomato other fruit such as blueberry, apple, and mandarin [12]

The Electronic Nose is an efficient process and non-destructive method in practically sensing the scent of fruits as well as expecting the uppermost crop period of time. Moreover, there is an available commercial Electronic Noses that uses an array of sensors combined with pattern recognition software [13]. Additionally, there have been several hearsays on electronic sensing in environmental control, medical diagnostics in the food industry, as a good correlation between the electronic nose signals and firmness, starch index, alongside with acidity parameters were found in this procedure and electronic noses portray the potential of becoming a reliable device to determine the fruit maturity [13]. Figure 2.2 shows that the schematic diagram of the electronic nose method potential checking mandarin maturity [14].

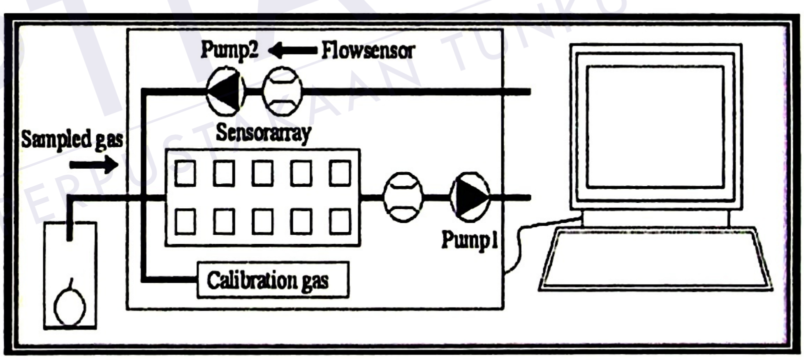

Figure 2.2 : The schematic diagram of the electronic nose to detect the mandarin [14]

2.2.1.3 Fruit Shape and Size

Fruit shapes and sizes are an important aspect to determine the fruit maturity. Mostly fruits with bigger size are much more ripped or mature in context, compare with the smaller ones. As the fruit grew more mature, its size and shape changes and reacts more toward the environment in the sense of geotropism. Furthermore, Liming and Yanchao [15] have proposed that the grading strawberry fruit is based upon its shape, size and color. Therefore, through investigated designed guidelines, strawberry contour are extracted from its shape and in eliminating the influence of the strawberry size, normalizing the line sequences eliminates its length of the shape. Also, size grading is implemented in strawberry and a similar process is desired, which is to reach the maximum horizontal diameter. Besides, from the fruit size the maturity of strawberry can be estimated by contour line sequence.

2.2.1.4 Fruit Weight

Additionally, in determining the fruit maturity by its weight, the fruit density or area of cross section of the fruit must be provided. Hsieh and Lee [16] introduced a homemade hyper-spectral imaging system to detect internal and external quality of papaya. Herein, to predict weight, the area parameter can be a linear correlation with a coefficient of 0.93, where the absolute calibration error is around 7% when area of side view cross section of the fruit was used.

2.2.2 Colour Based Grading

On the other side, from the color of the fruit, it can be determined if whether the particular fruit has matured or otherwise. This is because fruit color changes from dark green to a pale orange like color during its maturity process and thus the fruit maturity can be determined through its color observation. Besides, color space is an important factor in determining those algorithms that has to suit in the system specification. Subsequently, RGB, HSI, L*a*b* and YCbCr color spaces are the most common color space used by several researchers.

2.2.2.1 RGB Colour Space

Many researchers due to the imaging or features represented in the RGB color space broadly utilize RGB color space. The methodology works feasibly through an extract from the number of pixels of an image. Additionally, Abdul Rahman [17] used and applied RGB color space in order to monitor the ripeness of watermelon as the color space is used in extracting features from the watermelon. Also, fuzzy logic system is utilized to classified color features extracted from the three RGB components. The purpose is to determine the ripeness level of the watermelon. Herein, 95%-100% accuracy of a total of 90 samples, which contains 30 samples for each category, was achieved.

2.2.2.2 HSI Colour Space

Notwithstanding on the method employed, HSI color space was also performed by Abdullah [18] to classify starfruit maturity through its surface skin color into its maturity index based on single Hue. Therefore, in establishing the color recognition techniques, multivariate discriminant analysis and multi-layer perceptron neural network was used. This work is practicable to differentiate the maturity of the star fruit into four groups of unripe, under ripe, ripe, and overripe. Additionally, about 92% of the tested samples could be classified in this technique. Besides, Mohd Mokji has performed previous related work as well on the starfruit color maturity classification [19]. The investigation was developed based on the FAMA's old version of starfruit color maturity standard, whereby the classification if performed at six different indices and the accuracy of this work has achieved about 93.3% for starfruit color maturity.

2.2.2.3 L*a*b* Colour Space

Also, L*a*b* color space was performed by Kang [20] in 2008 based on the color changes of a mango. The investigation measured on the color value of a* and b* on a curved surface that delivers about 55% to 69% of the percentage within its range measured. Additionally, hue angle and chrominance have an average error of 2 and 2.5 respectively by using the measurement results. Syahrir [21] also uses the L*a*b* color space in investigating if whether a tomato has rotten. The image was later improved through a filter and threshold process before converting the image to L*a*b* color space format. About 90% of the tomatoes tested were not rotten according to the test outcomes and thus the judgment of tomato maturity and the estimation of tomato's expiry date were précised in this work. Besides, nine simple features of the appearance extracted from images of bananas were used for grouping purposes. The nine simple features are L*, a*, b* values; brown area percentage, number of brown spots per cm2, homogeneity, contrast, correlation, and entropy of image texture.

L* is the luminance or lightness component that goes from 0 (black) to 100 (white), and parameters a* (green to red) and b* (blue to yellow) are the 2 chromatic components, varying from – 120 to +120. The results obtained are precisely match with human observation that makes the system important to be used.

Figure 2.3 shows the computer system vision [22] for online prediction to predict the maturing phases of bananas. The computer vision system (CVS) consisted of Lighting system and Digital camera and image acquisition. The 1st critical step in displaying out banana images is by segmentation of the image from the background. A threshold of 50 in the grayscale combined with an edge detection technique based on Laplacian-of Gauss (LoG) operator is the pre-process to remove background. All banana images in their changed maturing stages were processed and segmented using the same method.

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