TROPICAL FRUITS GRADING USING MAGNETIC RESONANCE IMAGING BASED INTELLIGENT TECHNIQUE

BY

WASIU ADEBAYO BALOGUN

A thesis submitted in fulfilment of the requirement for the degree of Master of Science in Mechatronics Engineering

Kulliyyah of Engineering
International Islamic University Malaysia

JANUARY 2014

ABSTRACT

Abundance of variety of fruits is produced in most parts of the tropical countries. However, facilities for effective storage of these fruit are not readily available making them appear edible on the surface but in most cases the quality of their tissue and juice indicates that they are internally defective. Present procedures for assessing fruit quality are X-ray, impedance, image analysis, laser spectroscopy, sonic, ultrasonic and reflectance spectroscopy but to date no further applications are known that have taken unique advantages of Magnetic Resonance Imaging (MRI). This study, applied Magnetic resonance imaging as an effective non-destructive technique to determine the internal quality of selected tropical fruits. In this thesis, two types of tropical fruits, namely oranges and banana are considered for their internal tissue evaluation. Collected data using MRI equipment were Fourier transformed to obtain related MR images once the K-space has been fully assembled. The MR images of fruit obtained from proposed image processing methods were used as features to recognize their internal quality. The variances determined and features obtained were applied to the Artificial Neural Network (ANN) code developed in MATLAB using fruit MRI intensity features as inputs. The obtained results have shown that the Levenberg-Marquardt algorithm (LM) with Mean Square Error (MSE) and R-value of 0.0814and 0.9379 for Orange and 0.0693 and 0.9989 for Banana fruit respectively produced the best performance fitness for the assessment of internal quality of the fruits. These support the view that a combination of ANN and MRI has the capability of identifying the defect as well as being able to perform better than other non-destructive techniques.

الملخص

ومرافق ذلك، ومع .الاستوائية البلدان أنحاء معظم في الفواكه من متنوعة مجموعة من وفرة إنتاج ويتم من كثير في ولكن السطح على للأكل صالحة تبدو يجعلها مما بسهولة متاحة ليست الفاكهة لهذه الفعال للتخزين X- هي الثمار جودة لتقييم الحالية الإجراءات .داخليا معيبة أنها إلى تشير وعصير الأنسجة نوعية الأحيان المقطعي التصوير الصوتية، فوق والموجات الصوتية، الليزر، أطياف الصور، وتحليل ومقاومة، ray، من الفريدة المزايا بعض لديها أن المعروف ومن التطبيقات من مزيد لا الآن حتى ولكن الطيفي والانعكاس كتقنية (MRI) المغناطيسي بالرنين التصوير تطبيق الدراسة، هذه .(MRI) المغناطيسي بالرنين التصوير من نوعين وتعتبر الأطروحة، هذه في .المحددة الاستوائية الفواكه من الداخلية الجودة لتحديد مدمرة غير فعالة باستخدام جمعها تم التي البيانات وكانت .الداخلية الأنسجة لتقييم والموز البرتقال وهي الاستوائية، الفواكه مرة الصلة ذات المغناطيسي الرنين صور على للحصول فورييه تتحول المغناطيسي بالرنين التصوير معدات طرق ثلاث الفواكه من عليها الحصول تم الصور MR استخدمت .كامل بشكل تجميعها تم الفضاء-K في واحدة الحصول تم التي الميزات وطبقت تحديد الفروق .الداخلية جودتها الاعتراف وملامح المقترحة الصور معالجة كثافة ميزات الفاكهة باستخدام MATLAB في المتقدمة رمز (ANN) الاصطناعية العصبية شبكة إلى عليها Levenberg- الخوارزمية أن عليها المتحصل النتائج أظهرت وقد .كمدخلات المغناطيسي بالرنين التصوير 0.0693و لأورانج 0.9379 0.0814and قيمة-Rو (MSE) يعني الخطأ مربع مع (LM) ماركوارت الرأي تؤيد هذه .ثمار من الداخلية الجودة لتقييم الأداء لياقة أفضل التوالي على تنتج الموز وللفاكهة 0.9989 على قادرة كونها عن فضلا الخلل تحديد على القدرة لديها المغناطيسي بالرنين والتصوير ANN بأن القائل .الأخرى المدمرة غير التقنيات من أفضل أداء

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Mechatronics Engineering.

……
Momoh Jimoh E. Salami
Supervisor

……
Yasir Mohd Mustafah
Co- Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Mechatronics Engineering.

……
Amir Akramin Shafie
Internal Examiner

……
Ali Yeon B. Md. Shakaff
External Examiner

This thesis was submitted to the Department of Mechatronics and is accepted as a fulfilment of the requirement for the degree of Master of Science in Mechatronics Engineering.

……
Md. Raissuddin Khan
Head, Department of
Mechatronics Engineering

This thesis was submitted to the Kulliyyah of Engineering and is accepted as a fulfillment of the requirement for the degree of Master of Science in Mechatronics Engineering.

……..……
Md Noor Bin Salleh
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Balogun Wasiu Adebayo

Signature…….....….. Date…….....……

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

TROPICAL FRUITS GRADING USING MAGNETIC RESONANCE IMAGING (MRI) BASED INTELLIGENT TECHNIQUE

Affirmed by Balogun Wasiu Adebayo

……..…… ……...……..

Signature Date

To my beloved late father, late mentor Olakunle Lawal and my entire family

ACKNOWLEDGEMENTS

Alhamdulillah, all praises are due to Allah (SWT) the Most Beneficent the Most Merciful, Who taught man what he knew not and who has been my guide and my strength from the beginning till the end of this program. May the peace and blessings of Allah be on our noble Prophet Muhammad (PBOH), his household and his righteous follower.

I would like to express my profound and most sincere gratitude to my supervisor Prof. Dr. M. J. E Salami for his support throughout my program, by allowing me maximum research freedom and by his fruitful ideas, he has created a positive atmosphere for an interesting and efficient research period regardless the time and day even during weekend. Thank you sir.

Special thanks to my co supervisor, Dr. Yasir Mohd Mustafah whose reviews, critical and timely comments, worthwhile suggestions as well as his corrections has helped bringing this thesis to its final form. I am extremely grateful to you. My appreciations are due to my former co-supervisor Dr. Musa A. Aibinu whom I bothered for almost two years with endless questions; his help made it possible for me to carryout numerous experiments.

I would also like to acknowledge the contributions of Prof. Mike Mccarthy and his wife Prof. Kathryn L. McCarthy, Dr. Mecit Halil Oztop, Dr. Lu Zhang, Mrs. Bette L. Lerol and Mrs. Erika Davis of the University of California, USA, for their support during my visit as a research scholar in the United State of America. More so, this program would be impossible without the support of my boss, the Rector of Lagos State Polytechnic, Dr. Abdulazeez Lawal.

I owe my deepest appreciation to my mother “my jewel of inestimable value” for her moral and spiritual support. Also to my mentor, my late father who was the architect of my education and could not witness the success of his investment. May Almighty Allah forgive his shortcomings and grant him Al Jannah Firdaos. My unquantifiable appreciations go to my wives and children for their perseverance, patience, moral and spiritual support throughout my stay and study in Malaysia. “I LOVE U ALL”.

Finally, my acknowledgements would be incomplete without appreciating my colleagues and friends for their help in one way or the other especially Bro. Bashir, Abass, Oluwo, Ajayi Binyameen, Abdul-Mumin. May Almighty Allah in His infinite Mercy bless these individuals and reward them abundantly.

To everybody I say “JAZAKUM LLAHU KHAIRAN”.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

ω	Frequency in radian/second
ε_τ	Dielectric constant
A	Area of the plates
ε_o	Permittivity of the vacuum
γ	Gyromagnetic ratio
v	Resonant frequencies of the spectral peak of interest
v_{ref}	Resonant frequencies of the spectral peak of the reference component
σ	Shielding constant
ω	Larmor frequency
M_z	Component of magnetization in z direction
$M_z(0)$	Magnetization at equilibrium state
t	Delay time
T_1	Longitudinal relaxation time
$M_{x,y}$	Component of magnetization on xy plane
T_2	Transverse relaxation time
M_o	Net magnetization
B_o	Magnetic field
T_R	Repetition time
T_E	Echo time.
ΔB_0	Difference in the strength of the locally varying field.
T	Tesla
P_l	Lowest pixel value
P_h	Highest pixel value
P_{gs}	Gray intensity pixel
P_r	Red intensity pixel
P_g	Green intensity pixel
P_b	Blue intensity pixel
X	*x* dimensional
y	*y* dimensional
C	Contrast
$\bar{x}$	Mean
W	Width
T	Threshold
σ	Standard deviation
L	Layer of neural network
E	Mean squared error
t	Time
hnn	hidden neuron number

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three dimensional
ANN	Artificial Neural Network
COMSPIRA	Combined Spiral Radial
DAQ	Data Acquisition
DFT	Discrete Fourier Transform
FSE	Fast Spin Echo
FAO	Food and Agricultural Organization
FT	Radio Frequency
FFT	Fast Fourier Transform
FID	Free induction decay
FOV	Field of View
MRI	Magnetic Resonance Imaging
MSE	Mean Square Error
NIR	Near-infrared reflectance Spectroscopy
PLS-DA	Partial Least Square-Discriminant Analysis
PCA	Principal Component Analysis
RF	Radio Frequency
RGB	Red, Green, Blue
ROI	Region of Interest
SNR	Signal to noise ratio

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Fruits have been one of the earliest edible materials collected in the history of mankind. They were readily available edibles that man considered as food before the discovery of other food materials which are generally processed before eating. Recent classification put fruits as roughages which contain mineral, vitamins and other essential elements for healthy growth and immunities in human body. Fruits are classified according to the climate regions where they are mostly grown; thus there are tropical and temperate fruits (Food and Agriculture Organisation of United Nations [FAO], 2012).

Fruits are now consumed as roughages along side meals or separately as refreshment. It is also presented as 'fruit juice' which is extracted juice of one or more fruits preserved in paper packs and cans. This facilitate the distributions of a particular fruit beyond its natural area and also available across seasons. The medicinal importance of fruits and its promotion by the medical experts as alternative to synthetic drugs have boosted the demand for fruits by all gender, age and race. However, quality ripe fruits are often accomplished with various challenges and such may not meet the desired medicinal value.

Traditionally, inspection techniques of fruits quality have been conducted manually, but this has been highly inconsistent in accuracy, time consuming, tedious and relatively expensive. Thus, the application of new techniques in fruit quality assessment is necessary in order to minimise wastage because most of these fruits are readily perishable. Furthermore, fruit quality grading is becoming a mandatory

condition in recent time, although quality of fresh fruits could be defined differently depending on a consumer's preference and final usage, but a standardization to identify the degree of quality in a commodity is necessary for marketing fresh and safe products. Varieties of common tropical fruits sold and consumed widely include oranges, watermelon, grapes, bananas, avocado, papaya and pineapples.

Quality is a general farming term and is determined by individual based on the grading method. Hence, this is susceptible to biases and may affect trade agreement between sellers and buyers. Major fruit's quality factors include size (weight, volume, dimension), shape (diameter, depth ratio), colour (uniformity, intensity), defects (bruise, stab, spot) which are external quality factors. The internal quality factors include defect (internal cavity, water core, frost damage, rotten, dry or granulation), texture (firmness, crispness, juiciness), flavour (sweetness, sourness, astringency, aroma) and nutrition (Carbohydrates, Protein, Vitamins, Functional property) (Barreiro et al., 2008; Du & Sun, 2004; García-Ramos, Valero, Homer, Ortiz-Cañavate, & Ruiz-Altisent, 2005; Kleynen, Leemans, & Destain, 2005; Noh & Choi, 2006; Ruiz-Altisent et al., 2010).

Grading of fruits and vegetables qualities in the recent past decade have since turned out to be well mechanised, particularly with the application of robotics and mechatronics expertise, though majority of such research work concentrated more on external quality assessment than internal Kondo (2010). Similarly, Du & Sun (2004) repeated that grading of fruit is essentially based on external quality evaluation which is commonly used and internal quality grading which is seldom applied.

The introduction of different techniques to determine the internal quality of fruits is becoming a principal challenge in recent time. Most of the techniques currently applied to assess fruit quality works in an invasive mode, hence, non-

destructive quality evaluations of fruit product is becoming necessary for agricultural and food industry (Du & Sun, 2004; Kleynen et al., 2005).

However, researchers are focusing on application of MRI for fruits and vegetables quality in recent time. MRI is an imaging technique that utilizes the magnetic properties of nuclei in relation with radio frequency and magnetic field. It is sensitive to the local environment of water and oil which are main composition of fruit (Létal, Jirak, Šuderlová, & Hajek, 2003; Lu Zhang & Michael McCarthy, 2012). Furthermore, MRI is used to acquire two and three-dimensional images of biological systems from obscured materials. It has been used to predict the tomato maturity with PLS-DA model for classification and shows that different maturity stages are embedded in MR images signal intensity (Zhang & McCarthy, 2012). Since 1973, medical expert has commonly been applying magnetic resonance imaging (MRI) for diseases diagnosis to determine internal defect.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

Demand for high quality of agricultural produce consumed is on high side. Consequently, requirement for quality of these produce in terms of appearance, colour, taste, purity, defect and freshness of the juices has increased. Large numbers of consumers of fruits and vegetables have been identified, recently, for demanding a superior quality with a better taste upon higher price. The demand for quality fruit required to conform with standards stated by international established body since consumer now have a high concerns for quality. Consequently, agricultural sectors now lay emphasis on developing a system that will detect accurately the quality of fruits so as to trace it to its original producer.

The developments of various methods of quality determinant factors have been encouraged during recent years and few of these methods are non-destructive while large percentage falls in the category of destructive methods. The level of technology awareness has increased the appetite to develop methods that are not destructive. Conventionally, tropical fruits inspection and grading is done manually in the agricultural and natural fruits juice Industries. Issues such as inconsistent, labour fatigue and slow grading of these fruits are common problems associated with the approach. The process of grading the required fruit is becoming tedious and time consuming since grading of fruits is to be done several times and yet internal defect of these fruits are very difficult to determine by human visual inspection.

The common available methods have only been able to grade fruits using external features, which are sometimes at variant with the internal structure of the fruits thus affecting the quality of the extract or process fruits. There are numerous non-destructive techniques (NDT) such as X-ray, ultrasonic, vibrated excitation, sonic, impedance, CT, near infra-red (NIR) and ultra-violet that are available for determining internal quality of fruits. Many of them have been applied to determine internal qualities of fruit and vegetables, though all these methods currently in use have their disadvantages or deficiencies. More so, with improvement in technology, the capability of obtaining cross-sectional images in any desired direction, high resolution, diffusion imaging, flow-related imaging and ability to use a variety of high tissue contrast in MRI is very possible. Therefore, a system without any of the mentioned deficiencies necessitates the usage of MRI as envisioned in this study.

1.3 RESEARCH PHILOSOPHY

Existing techniques for evaluating tropical fruits quality such as Sonic, Ultrasonic, Reflectance, Image analysis, Transmittance, Laser spectroscopy, Impedance, X-ray and Near infrared Imaging (NIR) would not always produce desirable result. Based on the prevailing technology with respect to advances in machine vision, signal and image processing, it is postulated that techniques involving Magnetic Resonance Imaging (MRI) would produce improved results as this would reveal the internal structures of the fruits under investigation.

1.4 RESEARCH OBJECTIVES

The main objective of this research work is to develop magnetic resonance imaging (MRI) based intelligent system for grading selected tropical fruits using internal quality non destructive technique. The sub-objectives are:

1. To investigate the relationship between several non-destructive technique (NDT) and the internal quality status of selected tropical fruits.
2. To formulate an intelligent algorithm capable of extracting features for the classification of selected tropical fruits based on MRI data.
3. To develop an Artificial Neural Network (ANN) based tropical fruits grading system.
4. To evaluate the performance of the developed system

1.5 RESEARCH METHODOLOGY

The steps taken over the course of this research in order to achieve the stated research objectives are summarized as follows:

1. Literature review of journal, articles as well as book chapters focusing on the concept of MRI, fruit grading systems, ANN and other non-destructive techniques were studied and reviewed in this research work so as to compare the developed work with existing works and establish the current state of the art in this area of research.
2. The developed system is based on acquiring fruit images data of healthy and defective fruit samples from 1T MRI system. The size of Magnetic Resonance Imaging coil used is small (60 X 90 mm RF coil) therefore fruit samples were trimmed to size less than 85m2m in diameter and 56mm in height in order to fit to the size of the coil. A code developed in MATLAB was utilized to display MR image data acquired from Fourier transformed of fully assembled K-space data.
3. A set of image pre-processing methods is applied to improve contrast and suppress any noise. The acquired images are further analysed using image processing techniques so as to locate the presence as well as to extract the region of interest (ROI) for the respective fruits in terms of colour intensity.
4. An intelligent fruit quality (defect or healthy) detection algorithm based on artificial intelligence techniques is implemented with the aim of recognizing the identity or grade of the fruits.
5. Performance of the proposed fruit grading system is evaluated and analysed.

The summary of the methodology for the research is illustrated in Figure 1.1. The flow chart of the research methodology shows the stepwise activities taken in completing this research, starting with literature survey and ending with performance