

**Automated External Skin Defect Detection System for
Mangoes Using Computational Intelligence and
Machine Learning Techniques**

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A Thesis Submitted to

Avinashilingam Institute for Home Science and Higher Education for Women,

Coimbatore - 641 043

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy in Computer Science

August 2016

CERTIFICATE

I certify that the thesis entitled “Automated External Skin Defect Detection System for Mangoes Using Computational Intelligence and Machine Learning Techniques” submitted to Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for the award of the degree of Doctor of Philosophy (Ph.D) in computer Science, is a record of original research work carried out by Deepa.P, during the period from August 2010 to August 2016 of her study in the Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore under my guidance and supervision and the thesis work has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other Titles in this University or any other University or institution of Higher Learning.



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DECLARATION

I hereby declare that the matter embodied in the thesis entitled **“Automated External Skin Defect Detection System for Mangoes Using Computational Intelligence and Machine Learning Techniques”** submitted by me for the degree of Doctor of Philosophy (Ph.D) is the record work carried out by me in the **Department of Computer Science**, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, during the period from August 2010 to August 2016 under the guidance of **Dr. S.N.Geethalakshmi, Professor**, Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and it has not been formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or similar title in any other University or other similar institution of Higher Learning.



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ACKNOWLEDGEMENT

At the outset, I would like to express my sincere thanks to the God Almighty for his constant love and grace showered on me and making my life a worthwhile to the community.

*I owe my reverential gratitude to **Late Ayya Dr.T.S. Avinashilingam Avl.,** Founder and President and First Chancellor of Avinashilingam Institute for Home Science and Higher Education for women, Coimbatore for providing the temple of learning and also for his heavenly blessings. I also owe my sincere and humble gratitude to **Late Amma Dr. Rajammal P.Devadas Avl, M.A., M.Sc., Ph.D.,** Former Chancellor, Avinashilingam Institute for Home Science and Higher Education for women, Coimbatore.*

*I am very grateful to **Dr.P.R Krishnakumar Chancellor,** Avinashilingam Institute for Home Science and Higher Education for women, Coimbatore, for his support and encouragement during the course of my study.*

*I heartily thanks **Dr.(Mrs) Premavathy Vijayan M.sc., Dip.,spl.edn., M.phil., Ph.D., Vice Chancellor,** Avinashilingam Institute for Home Science and Higher Education, Coimbatore, for her flamboyant support in carrying out this research work.*

*I take this opportunity to thank **Dr.(Mrs).Saroja Prabhakaran M.A., Dip.Ed., Ph.D., Former Vice Chancellor,** Avinashilingam Institute for Home Science and Higher Education, Coimbatore, for her zealous support and inspiration. She sparks the researchers interest in every sphere be it academic or co-curricular activities.*

*I express my humble gratitude to **Dr.(Mrs). Gowri Ramakrishnan M.Sc., M.Phil., Ph.D., Former Registrar** and **Dr. A. Venmathi, Registrar i/c** Avinashilingam Institute for Home Science and Higher Education, Coimbatore, for providing all infrastructures needed for carrying out this research work.*

*I am also thankful to **Dr.(Mrs). R. Parvatham M.Sc., Dip.Ed. M.Phil., Ph.D., Former Dean Faculty of Science**, for granting the facilities required. I am obliged to her extended support throughout my work.*

*I express my sincere thanks to **Dr. (Mrs.) A. Parvathi, M.Sc., Dip.Ed., M.Phil., Ph.D., Dean, Faculty of Science , Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore** for her spontaneous and timely help and amenities provided for the successful completion of this research work.*

*I wish to place on record my deep sense of gratitude to **Dr.(Mrs).G.Padmavathi M.Sc., M.Phil., Ph.D., Professor and Head, Department of Computer Science**, for providing all the amenities to give shape for my research. She is always ready to lend her valuable times and guidance towards the improvement in the investigator's career.*

*I feel extremely privileged and fortunate to have worked under the able supervision and professional guidance of my guide, **Dr.S.N.Geethalakshmi M.C.A., M.Phil., Ph.D., Professor, Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore**. Her constant encouragements, motivation, valuable and constructive suggestions and untiring support have guided me to gain and explore deep knowledge in the research field.*

She helped me to define my research goals and showed the way to achieve them. Her able guidance, systematic approach guided me to put my best possible efforts in completing my work and documentation. Her sympathetic friendly nature, timely counseling, willingness to help at anytime, anywhere and at any situation during the entire period of the study have molded this research into a reality.

*I am greatly indebted to beloved sir **Mr. M. Karunamoorthy, Professor, K S G College of Arts and Science, Coimbatore** for his timely guidance in drafting the final version of the thesis by offering suggestions for improvement of the research draft which is of inestimable value.*

*I express my appreciation to the members of **R&D team**, Avinashilingam Institute for Home Science and Higher Education, Coimbatore for their contribution and co operation, professionally, at Research Laboratory throughout the study.*

*I feel that I would fail in my duty if I do not thank all the **Ph.D and M.Phil Research Scholars, staff members and Members of Computer Center Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education, Coimbatore, for their cooperation and wishes.***

*In no less a measure I thank my **Husband Dr. E.Muthukumar** and my **sweetest daughter M.Vaishnavee** for their love, warmth and untiring support at each and every moment of my life.*

*I render my heartfelt thanks to my **parents Mr. C. Ponnusamy, Mrs. P.Savithiri** , and my **brother Mr. P.Vinothkumar**, who spared no pains in their efforts and raised me with a love for science and supported me in all pursuits without which I could not have scaled to these heights. I also thank all my **Friends and Relatives** for their support and encouragement.*

If by mistake, I have failed to thank anyone, who has slipped my memory, I offer my humble apologies, and render my heartfelt thanks.

Deepa.P.

CONTENTS

CHAPTER	TITLE	PAGE No.
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xvii
	ABSTRACT	xxi
1	INTRODUCTION	1
1.1	Overview to the Research Topic	1
1.2	Mango – The King of Fruits	3
1.2.1	Origin of Mango	4
1.2.2	Botanical Description	4
1.2.3	Uses of Mango	6
1.2.4	Varieties of Mangoes	7
1.3	Quality and Defects	12
1.4	Motivation and Research Objectives	18
1.5	Layout of the Chapters	20
1.6	Chapter Summary	21
2	REVIEW OF LITERATURE	22
2.1	Fruit Quality Assessment	22
2.1.1	Electronic Devices used for Fruit Quality Assessment	24
2.1.2	Computer Vision – Based Software Systems	27
2.2	Preprocessing	28
2.3	Segmentation	33
2.4	Feature Extraction	40
2.4.1	Color Features	41
2.4.2	Texture Features	44
2.5	Fruit Defect Detection and Classification	47
2.5.1	Apple	49
2.5.2	Dates	52
2.5.3	Blueberries	53

CHAPTER	TITLE	PAGE No.
2.5.4	Grapes and Citrus	53
2.5.5	Peach	54
2.5.6	Pomegranate	55
2.5.7	Watermelon	56
2.5.8	Banana	56
2.5.9	Orange	56
2.5.10	Mango	59
2.6	Chapter Summary	61
3	METHODOLOGY	62
3.1	Automated Defect Detection System (ADDS)	63
3.2	Research Methodology	66
3.2.1	Data Acquisition	67
3.2.2	Phase I : Preprocessing	69
3.2.3	Phase II : Segmentation	71
3.2.4	Phase III : Feature Extraction	73
3.2.5	Phase IV : Defect Detection	74
3.3	Research Contribution	75
3.4	Chapter Summary	76
4	PREPROCESSING ALGORITHM	77
4.1	Impulse Noise	79
4.1.1	Salt and Pepper Noise Model	82
4.2	Switching Median Filter	82
4.3	Adaptive Fuzzy Switching Filter (AFSF)	84
4.3.1	Impulse Noise Detection	84
4.3.2	Adaptive AFSF	86
4.3.3	Fuzzy Switching	87
4.4	Proposed AFSF – PSO	88
4.4.1	Particle Swarm Optimization	89
4.4.2	Optimized Fuzzy Filtering with PSO	91
4.5	Chapter Summary	94

CHAPTER	TITLE	PAGE No.
5	SEGMENTATION ALGORITHM	95
5.1	Fuzzy C – Means (FCM) Clustering Algorithm	96
5.2	Fuzzy Possibilistic C - Means Algorithm (FPCM)	98
5.3	Modified Fuzzy Possibilistic C - Means Algorithm (MFPCM)	100
5.4	Artificial Bee Colony Optimization (ABC)	102
5.5	Proposed MFPCM – ABC Algorithm	105
5.6	Chapter Summary	109
6	FEATURE EXTRACTION AND DEFECT DETECTION	110
6.1	Feature Extraction	111
6.1.1	Color Feature Extraction	112
6.1.2	Texture Feature Extraction	113
6.1.3	Feature Fusion	117
6.2	Defect Detection	120
6.2.1	Support Vector Machine (SVM)	120
6.2.2	Relevance Vector Machine (RVM)	123
6.2.3	Enhanced RVM with Simulated Annealing (SA – RVM)	126
6.3	Chapter Summary	128
7	RESULTS AND DISCUSSION	129
7.1	Dataset	129
7.2	Performance Metrics	134
7.2.1	Preprocessing	134
7.2.2	Segmentation	135
7.2.3	Feature Extraction and Defect Detection	136
7.3	Preprocessing	138
7.4	Segmentation	147
7.5	Classification	162
7.6	Chapter Summary	170

CHAPTER	TITLE	PAGE No.
8	SUMMARY AND CONCLUSION	171
	REFERENCES	176
	PUBLICATIONS RELATED TO THE RESEARCH WORK	213

LIST OF TABLES

Table No.	TITLE	Page No.
1.1	Varieties of Mangoes	9
1.2	Hybrid Varieties of Mango	11
1.3	Components of Quality for Mangoes	15
2.2	Color Spaces Used for Feature Extraction	42
2.3	Comparison of Color Extraction Methods	43
2.4	Types of Texture Features	45
7.1	Mango Dataset	130
7.2	Definition of TP, TN, FP and FN	137
7.3	Coding Scheme	138
7.4	PSNR (dB) of Alphonso Mango	139
7.5	PSNR (dB) of Banganapalli Mango	140
7.6	PSNR (dB) of Neelum Mango	141
7.7	PSNR (dB) of Sendura Mango	142
7.8	Stability Criterion (%)	153
7.9	Anti-Noise Criterion (%)	154
7.10	Sensitivity (%)	163
7.11	Specificity (%)	164
7.12	Accuracy (%)	165

LIST OF FIGURES

Table No.	TITLE	Page No.
1.1	Mango Tree (Mangifera Indica)	5
1.2	Different Colored Mangoes	5
1.3	Varieties of Mangoes	8
1.4	Hybrid Mangoes	10
1.5	Defect Categorization	15
1.6	External Defects Caused by Decay of Mango Fruit	17
1.7	Moderate Defects in Mangoes	18
3.1	General framework of ADDS	64
3.2	Research Methodology	68
3.3	Sample Images from Mango Database	69
4.1	General Noise Removal Process	80
4.2	Noise – Free and Noisy Mango Fruit Images	81
4.3	Salt & Pepper Noise Model	82
4.4	Conventional Switching Median Filter	83
4.5	Four 5×5 Laplacian Kernels (K_p)	85
4.6	Adaptive Impulse Noise Detection and Removal	87
4.7	Fuzzy Method	88
4.8	Particle Movement	89
4.9	Particle Swarm Optimization Algorithms	92
4.10	AFSF – PSO Algorithm	93
5.1	Conventional Fuzzy C – Means Algorithm	98

Table No.	TITLE	Page No.
5.2	The Neighborhood Structure of Study Pixel within (i,j)	106
5.3	The Overall Flow Chart for Proposed ABC – based Algorithm	108
6.1	Procedure to Construct Color Histogram	114
6.2	Support Vector Machine Hyperplane	122
6.3	Simulated Annealing Algorithm	127
7.1	Healthy Test Mango Fruit Images	131
7.2	Defect Test Mango Fruit Images	132
7.3	Mangoes in Six Angles	133
7.4	Average PSNR (db) of Alphonso Mango	143
7.5	Average PSNR(db) of Banganapalli Mango	143
7.6	Average PSNR(db) of Neelum Mango	144
7.7	Average PSNR(db) of Sendura Mango	144
7.8	PSNR (db) for the Six Selected Angles	146
7.9	Speed (Seconds) of the Denoising Algorithms	146
7.10	Noise Removal Visual Results of Alphonso Test Images	148
7.11	Noise Removal Visual Results of Banganapalli Test Images	149
7.12	Noise Removal Visual Results of Neelum Test Images	150
7.13	Noise Removal Visual Results of Sendura Test Images	151
7.14	Noise Removal Visual Results – Six Angles	152
7.15	Average Stability Criterion of the Segmentation Algorithm	155
7.16	Average Anti Noise Criterion of the Segmentation Algorithm	155
7.17	Average Speed (Seconds) of the Segmentation Algorithm	156
7.18	Segmentation Visual Results – Alphonso Fruits	157

Table No.	TITLE	Page No.
7.19	Segmentation Visual Results – Banganapalli Fruits	158
7.20	Segmentation Visual Results – Neelum Fruits	159
7.21	Segmentation Visual Results – Sendura Fruits	160
7.22	Segmentation Visual Results – Six Angles of Fruit	161
7.23	Overall Average Sensitivity (%)	167
7.24	Overall Average Specificity (%)	167
7.25	Overall Average Accuracy (%)	168
7.26	Overall Average Error Rate (%)	168
7.27	Average Speed (Seconds) of Defect Detection Classifiers	170

LIST OF ABBREVIATIONS

UAE	- United Arab Emirates
UK	- United Kingdom
NMR	- Nuclear Magnetic Resonance
ADDS	- Automatic Defect Detection System
AESDDM	- Automated External Skin Defect Detection System for Mangoes
CCM	- Color Co-occurrence Method
CCD	- Charge Coupled Device
2D	- Two Dimensional
3D	- Three Dimensional
PGF	- Peer Group Filter
MSM	- Multi State Median
CWM	- Centre Weighted Median
DWM	- Directional Weighted Median
SMF	- Standard Median Filter
DBMF	- Decision Based Median Filter
MDBMF	- Modified Decision Based Median Filter
HSOM	- Hierarchical Self Organization Map
AFCM	- Adaptive Fuzzy C-Mean
AFFCM	- Adaptive Fast Fuzzy C-Mean
eFFCM	- Extensible Fast Fuzzy C-Mean
IEF	- Image Enhancement Factor
PSNR	- Peak Signal to Noise Ratio
LMS	- Least Mean Square
FCM	- Fuzzy C-Mean
2DFCM	- Two Dimensional Fuzzy C-Mean

PIM	- Partition Index Maximization
FCS	- Fuzzy Compactness and Separation
NIR	- Near Infrared
SWIR	- Short Wave Infrared
PLS	- Partial Least Square
VIS-NIR	- Visible Near Infrared
H	- HUE
S	- Saturation
I	- Intensity
MTMF	- Mixture Tuned Matched Filtering
IVIA	- Instituto Valenciano de Investigaciones Agrarias
PCA	- Principal Components Analysis
CART	- Classification and Regression Tree
LMT	- Logistics Model Tree
MLP	- Multilayer Perceptron
MLP RP	- Multilayer Perceptron Resident Back Propagation
MLP SCG	- Multilayer Perceptron Scaled Conjugate Gradient
SSD	- Sum of Squared Distance
MSE	- Mean Square Error
ANN	- Artificial Neural Network
AIS	- Artificial Immune System
FD	- Fractal Dimension
PFCM	- Proposed Fuzzy C-Mean
NEM	- Neighbourhood Maximization
CM	- Color Moments
CCV	- Color Co-Occurrence Vector
DCD	- Dominant Color Method
STFEM	- Spatial Texture Feature Extraction Method

SpTFEM	- Spectral Texture Feature Extraction Method
GTDM	- Gray Tone Difference Matric
SVM	- Support Vector Machine
PC-SVM	- Principal Components Support Vector Machine
C-SVM	- Chlorophyll Fluorescence Support Vector Machine
FL	- Fuzzy Logic
PCC	- Pearson's Correlation Co-efficient
FLDA	- Fishers Linear Discriminant Analysis
ANFC-LH	- Adaptive Neuro Fuzzy Classifier with Linguistic Hedges
ANN	- Artificial Neural Network
CVS	- Computer Vision System
MLP	- Multilayer Perceptron
RBF	- Radial Basis Function
BPNN	- Back Propagation Neural Network

ABSTRACT

Detection of defects in mango fruit is a challenging problem in automatic inspection process and is heavily used by the food industries, particularly by the import/export companies worldwide. It is an important task of quality control which helps to reduce rejection of fruits and time spent on manual inspection. Fruit quality analysis is often based on its appearance using characteristics of skin or surface. Based on this fact, this research work is designed to identify skin or surface defects in mango fruit. The main objective of the research work thus is to design an automated external skin defect detection system for mango fruit using image processing and machine learning techniques in an accurate and time efficient manner.

The proposed research methodology consists of three phases. The first phase focuses on preprocessing technique, which enhances the quality of the image using impulse noise removal algorithms, for this purpose, an enhanced Adaptive Fuzzy Switching Filter (AFSF) enhanced using Particle Swarm optimization (PSO) is used. The second phase proposes a segmentation algorithm to divide the mango fruit image into similar regions, for this Modified Fuzzy Possibilistic C-Means (MFPCM) clustering algorithm is used, this algorithm obtains the initial centroids automatically estimated using Artificial Bee-Colony (ABC) optimization technique.

The third and fourth phases of the study perform feature extraction and surface defect detection in mango fruits. Two types of features, namely, color features and texture features were extracted. These two feature vectors are then combined to form a fused feature vector, in order to improve the defect detection and classification process. Three classifiers, namely, Support Vector Machine (SVM), Relevance Vector Machine (RVM) and an enhanced RVM were used. The enhanced RVM was designed using Simulated Annealing algorithm, which is used to fine tune the parameters.

Performance evaluation was performed using acquired mango fruit database having a total of 1800 images generated from 1000 defective and 800 healthy mangoes belonging to four varieties, namely, Alphonso, Banganapalli, Neelam and Sendura. Four types of skin defects were considered. They are, bruise, russet, blemish, and shrink.

Several performance metrics were used to evaluate the performance of the proposed algorithms. The noise removal algorithm was evaluated using Peak Signal to Noise Ratio (PSNR) and speed of noise removal. The segmentation algorithm was analyzed using stability criterion, anti-noise criterion and speed. The defect detection process was evaluated using specificity, sensitivity, accuracy, error rate and speed.

All the experiments proved that the proposed algorithms used in the proposed Automated External Skin Defect Detection System for Mango (AESDDSM), perform efficiently in terms of all selected performance metrics when compared to the corresponding existing algorithms. High accuracy with maximum speed efficiency was obtained while using the proposed Adaptive Fuzzy Switching Filter with Particle Swarm optimization algorithm for noise removal, Modified Fuzzy Possibilistic C-Means algorithm with Artificial Bee-Colony optimization technique, combined color and texture features and RVM enhanced with Simulated Annealing algorithm. Experimental results proved that AESDDSM model is efficient with small time complexity and high accuracy during defect detection and can therefore be used by the import/export industries to identify defects and increase consumer satisfaction.