

Contents

Table of Contents

Declaration by Research Scholar	I
Certificate of Supervisor	II
Thesis Approval Form	III
Declaration by Research Scholar Submission of Thesis.....	IV
Acknowledgement.....	V
Contents..	VI
List of Figures.....	XI
List of Tables.....	XV
List of Acronym.....	XVII
ABSTRACT	XVIII
Chapter 1	
Introduction to Plant Disease Detection System.....	1
1.1 Introduction.....	1
1.1.1. Application areas of Agricultural Image Processing	1
1.2 Crop/Plant Disease Detection	2
1.2.1 Legume Leaf Diseases.....	3
1.3 Introduction to Image processing	4
1.3.1 Digital Images and Image processing techniques.....	5
1.3.2 Application Area of Image Processing	6
1.4 Plant Disease Detection using Image Processing	6
1.4.1 Image Acquisition	8
1.4.2 Image Pre-processing	9
1.4.3 Image Segmentation.....	9
1.4.4 Feature Extraction	9
1.4.5 Classification.....	10
1.5 Challenges and Issues.....	10
1.6 Statement of the problem.....	11
1.7 Need of the proposed research.....	11
1.8 Objective of the study	12
1.9 Advantage of the study	13
1.10 Disease of Mung bean plant leaf.....	13

1.10.1	Mung bean Yellow Mosaic Virus (MYMV).....	13
1.10.2	Cercospora Leaf Spot (CLS)	14
1.10.3	Powdery Mildew	15
1.10.4	Healthy	17
1.11	Experimental Images.....	17
1.12	Outcome of study.....	20
1.13	Scope of the Study	20
1.14	Limitations of the Study	21
1.15	Organization of the Thesis	21
	References.....	23
Chapter 25		
	Literature Review	25
2.1	Introduction	25
2.2	Literature Review based on SVM	26
2.3	Literature Review based on ANN/CNN	28
2.4	Literature Review based on PCA/ K-means clustering and Neural Networks	31
2.5	Literature Review based on Common classifiers	32
2.6	Conclusion	38
	References.....	40
Chapter 3		
	Plant Foliar Disease Identification Model (PFDIM)	50
3.1	Introduction	50
3.1.1.	Selection of crop	50
3.1.2.	Plant Organ.....	51
3.2	PLANT FOLIAR DISEASES IDENTIFICATION MODEL - (PFDIM)	51
3.3	Hypothesis.....	60
	References.....	61
Chapter 4		
	Development of Plant Foliar Disease Identification Model (PFDIM)	62
4.1	Introduction	62
4.2	Mung Leaf Data Collection.....	63
4.3	Designing and Developing Mung Leaf disease Recognition Interface	65
4.3.1	Features of Leaf Disease Classification Interface.....	65
4.4	Developing Leaf Diseases Recognition System Engine	69
4.4.1	Pre-processing.....	69

4.4.1.1	Resizing an image	70
4.4.1.2	Augmentation	73
4.4.1.3	Edge Detection	78
4.4.2	Feature Extraction and Segmentation.....	79
4.4.2.1	HSV color map method.....	79
4.4.2.2	grabCut() color map method	82
4.4.2.3	Applying HOG	85
4.4.2.3.1	RGB to Grayscale conversion.....	85
4.4.3	Training Process.....	89
4.5	Training Process of Classifiers	90
4.5.1	Classification in Machine Learning	90
4.5.2	Support Vector Machines (SVM)	91
4.5.2.1	Training process for SVM.....	92
4.5.2.1.1	Training process for SVM in controlled environment	92
4.5.2.1.2	Training process for SVM in uncontrolled environment	94
4.5.2.1.3	Training process for SVM in combined environment.....	97
4.5.3	K-Nearest Neighbor (KNN).....	99
4.5.3.1	Training process for KNN	100
4.5.3.1.1	Training process for KNN in controlled environment.....	100
4.5.3.1.2	Training process for KNN in uncontrolled environment	102
4.5.3.1.3	Training process for KNN in combined environment	103
4.5.4	Adaptive Boosting (AdaBoost).....	104
4.5.3.3	Training process for AdaBoost.....	105
4.5.3.3.1	Training process for AdaBoost in controlled environment	105
4.5.3.3.2	Training process for AdaBoost in uncontrolled environment	106
4.5.3.3.3	Training process for AdaBoost in combined environment.....	108
4.2.5	Gaussian Naive Bayes (GaussianNB).....	109
4.5.3.4	Training process for GaussianNB	109
4.5.3.4.1	Training process for GaussianNB in controlled environment.....	109
4.5.3.4.2	Training process for GaussianNB in uncontrolled environment	111
4.5.3.4.3	Training process for GaussianNB in combined environment.....	112
4.2.6	DTC.....	113
4.5.3.5	Training process for DTC.....	114
4.5.3.5.1	Training process for DTC in controlled environment	114
4.5.3.5.2	Training process for DTC in uncontrolled environment	115

4.5.3.5.3	Training process for DTC in combined environment	116
4.2.7	LogisticRegression	118
4.5.3.6	Training process for LogisticRegression	118
4.5.3.6.1	Training process for LogisticRegression in controlled environment.....	119
4.5.3.6.2	Training process for LogisticRegression in uncontrolled environment.....	120
4.5.3.6.3	Training process for LogisticRegression in combined environment	121
4.2.8	Deep Neural Networks.....	122
4.2.9	Convolutional Neural Networks (CNN)	123
4.5.3.7	Training process for Custom CNN	123
4.5.3.7.1	Training process for CNN in controlled environment	126
4.5.3.7.2	Training process for CNN in uncontrolled environment.....	129
4.5.3.7.3	Training process for CNN in combined environment.....	132
4.5.3.8	Other changes tried with SVM	134
4.5.3.8.1	Changes tried with SVM in controlled environment.....	134
4.5.3.8.2	Changes tried with SVM in uncontrolled environment	135
4.5.3.8.3	Changes tried with SVM in combined environment	135
4.5.3.9	Other changes tried with Custom CNN	136
4.5.3.9.1	Changes tried with Custom CNN in controlled environment	136
4.5.3.9.2	Changes tried with Custom CNN in uncontrolled environment	138
4.5.3.9.3	Changes tried with Custom CNN in combined environment.....	141
4.6	Visualization of Mung Leaf Network Feature Map	144
4.7	Scope of Experimental work for Mung Leaf disease detection	146
4.8	Performance evaluation measurement	147
4.8.1	Accuracy	148
4.8.2	Precision.....	148
4.8.3	Recall	148
4.8.4	F1-score.....	149
4.9	CHAPTER SUMMARY	149
	Reference:.....	150
Chapter 5		
	Results and Conclusion	151
5.1	Overall Performance of Accuracy Classifier wise.....	151
5.2	Dataset Environment wise Comparison.....	154
5.2.1	Controlled Environment.....	154
5.2.2	Uncontrolled Environment.....	155

5.2.3	Combined Environment.....	156
5.3	Disease wise Comparison of machine learning algorithms.....	158
5.3.1	Cercospora Leaf Spot Disease.....	158
5.3.2	Healthy Leaf.....	159
5.3.3	Powdery Mildew disease.....	160
5.3.4	Yellow Mosaic Virus disease.....	161
5.4	Machine learning (ML) algorithm Vs. Deep Learning (DL) Algorithm	162
5.5	Comparison with previously done work.....	163
5.6	Conclusion	165
	References.....	167
	Bibliography.....	169
	Appendix A	171
	Plagiarism Report	171
	Appendix B.....	172
	Publications.....	172
	Summary.....	222

List of Figures

Figure 1.1: Image Processing in Agriculture	1
Figure 1.2: Crop Classification	2
Figure 1.3: Plant Organ Selection	3
Figure 1.4: A brief methodology for identification of symptoms using image analysis techniques.....	7
Figure 1.5: Leaf disease classification steps	8
Figure 1.6: Leaf with yellow mosaic virus in (a) controlled and (b) uncontrolled environment	14
Figure 1.7: Leaf with Cercospora Leaf Spot in (a) controlled and (b) uncontrolled environment	15
Figure 1.8: Leaf with Powdery Mildew in (a) controlled and (b) uncontrolled environment.....	16
Figure 1.9: Healthy Leaf in controlled and uncontrolled environment.....	17
Figure 1.10: Study Site of Mung bean Plants	18
Figure 1.11: Sample images of mung bean leaf (Controlled Environment and Uncontrolled Environment)	20
Figure 3.1: Classification of Crop.....	50
Figure 3.2: Plant Organs	51
Figure 3.3: Plant Foliar Diseases Identification Model - (PFDIM)	52
Figure 3.4: Images of the healthy and diseased leaves in (a) controlled and (b) uncontrolled environment	55
Figure 3.5: Leaf Diseases Recognition System Engine	56
Figure 3.6: Stages involved in Pre-Processing.....	57
Figure 3.7: Branching Pattern for analysis of images	60
Figure 4.1: Schematic Diagram of Mung Leaf Disease Detection System	62
Figure 4. 2: Sample Mung leaf (a) Cercospora Leaf Spot (b) Healthy (c) Powdery Mildew (d) Yellow Mosaic Virus	64
Figure 4. 3: Leaf Disease Detection Interface	66
Figure 4.4: Select an image of mung leaf to test.....	67
Figure 4. 5: Open dialog box to browse mung leaf image.....	68
Figure 4. 6: Displaying selected leaf image in interface.....	68
Figure 4.7: Final Result.....	69
Figure 4.8: (a) Original image, (b) Resized image in controlled environment.....	70
Figure 4.9: (a) Original image, (b) Resized image in uncontrolled environment.....	71

Figure 4.10: Original image and resized image from each category in controlled and uncontrolled environment	73
Figure 4.11: (a) Original Image, (b) Augmented Images in controlled environment	75
Figure 4.12: (a) Original Image, (b) Augmented Images in uncontrolled environment	75
Figure 4.13: Original and augmented images in controlled environment and uncontrolled environments	77
Figure 4.14: (a) Original Image, (b) Edges Detected from images using Canny()	78
Figure 4.15: Edges Detected from images using Canny() in uncontrolled environment.	79
Figure 4.16: Steps for HSV color map method.....	80
Figure 4. 17: Segmented Images after performing HSV Color map method in controlled environment: (a) Original Images, (b) Segmented Images	81
Figure 4.18: Uncontrolled environment Leaf images after applying HSV on them	82
Figure 4. 19: Steps for performing grabCut()	83
Figure 4.20: Original and Segmented Images after performing grabCut() method	84
Figure 4.21: Original and Segmented Images after performing grabCut method on uncontrolled data	85
Figure 4.22: Original leaf and gray scale leaf	86
Figure 4.23: leaves after applying HOG in controlled environment.....	87
Figure 4. 24: leaves after applying HOG in uncontrolled environment.....	89
Figure 4.25: Graphic representation of the SVM method.....	91
Figure 4.26: Confusion Matrix (Controlled environment).....	93
Figure 4. 27: Confusion Matrix (Uncontrolled environment).....	95
Figure 4.28: Confusion Matrix (Combined environment)	97
Figure 4. 29: K-NN classifier.....	99
Figure 4.30: Confusion matrix KNN [controlled environment]	101
Figure 4.31: Confusion matrix for KNN in uncontrolled environment.	102
Figure 4.32: Confusion Matrix for KNN in combined environment	103
Figure 4.33: AdaBoost Classifier	104
Figure 4.34: Confusion Matrix for AdaBoost in controlled environment.....	105
Figure 4.35: Confusion Matrix for AdaBoost in uncontrolled environment.....	107
Figure 4.36: Confusion Matrix for AdaBoost in combined environment	108
Figure 4.37: Confusion Matrix for GaussianNB in controlled environment	110
Figure 4.38: Confusion Matrix for GaussianNB in uncontrolled environment	111

Figure 4.39: Confusion Matrix for GaussianNB in combined environment	112
Figure 4.40: Decision Tree Classification	113
Figure 4.41: Confusion Matrix for DTC in controlled environment	114
Figure 4.42: Confusion Matrix for DTC in uncontrolled environment	115
Figure 4.43: Confusion Matrix for DTC in combined environment.....	117
Figure 4.44: Logistic Regression	118
Figure 4.45: Confusion Matrix for LogisticRegression in controlled environment	119
Figure 4.46: Confusion Matrix for LogisticRegression in uncontrolled environment	120
Figure 4.47: Confusion Matrix for LogisticRegression in combined environment.....	121
Figure 4.48: CNN Architecture.....	124
Figure 4.49: Accuracy and Loss graph For Custom CNN, VGG16, and MobileNet2	127
Figure 4.50: Keras Tuner Results (controlled – CNN).....	128
Figure 4.51: Accuracy and Loss graph for CustomCNN after hyperparameter tuning.	129
Figure 4.52: Accuracy and Loss graph of CustomCNN before tuning.....	130
Figure 4.53: Accuracy and Loss graph for CustomCNN after hyperparameter tuning in uncontrolled environment	131
Figure 4.54: Accuracy and Loss graph of Custom CNN before tuning of combined environment	132
Figure 4.55: Accuracy and Loss graph for CustomCNN after hyperparameter tuning in combined environment.....	133
Figure 4.56: Accuracy and Loss graphs before and after tuning in controlled environment.	137
Figure 4.57: Accuracy and Loss graphs before and after tuning in controlled environment with new epochs and new batch size.	138
Figure 4.58: Accuracy and Loss graphs before and after tuning in uncontrolled environment	139
Figure 4.59: Accuracy and Loss graphs before and after tuning in uncontrolled environment with new epochs and new batch size.	141
Figure 4.60: Accuracy and Loss graphs before and after tuning in controlled environment.	142
Figure 4.61: Accuracy and Loss graphs before and after tuning in combined environment with new epochs and new batch size.	143
Figure 4.62: Visualization of mung leaf network feature map in controlled environment....	145
Figure 4.63: Visualization of mung leaf network feature map in uncontrolled environment	146

Figure 5.1: Classifier and environment wise accuracy achieved	153
Figure 5.2: Accuracy achieved in Controlled Environment.....	155
Figure 5.3: Accuracy achieved in Uncontrolled Environment.....	156
Figure 5.4: Accuracy achieved in Combined Environment	157
Figure 5.5: Accuracy achieved for Cercospora Leaf Spot disease.....	159
Figure 5.6: Accuracy achieved for Healthy Leaf Category	160
Figure 5.7: Accuracy achieved for Powdery Mildew	161
Figure 5.8: Accuracy achieved for Yellow Mosaic Virus.....	162
Figure 5.9: Comparison of ML Vs. DL Algorithm	163

List of Tables

Table 1.1: Diseases of Mung bean plant.....	4
Table 3.1: Category wise number of images	55
Table 4.1: Directory wise number of image files	65
Table 4.2: Data Augmentation Property	74
Table 4.3: Classification report for SVM in controlled environment.....	94
Table 4.4: Parameter Grid (Controlled – SVC)	94
Table 4.5: Classification report for SVM in uncontrolled environment.....	96
Table 4.6: Parameter Grid (Uncontrolled – SVC)	96
Table 4.7: Classification report for SVM in combined environment	98
Table 4.8: Parameter Grid (Combined – SVC).....	98
Table 4.9: Classification report for KNN [controlled environment]	101
Table 4.10: Classification report for KNN in uncontrolled environment.....	102
Table 4.11: Classification report for KNN in combined environment	104
Table 4.12: Classification report for AdaBoost in controlled environment.....	106
Table 4.13: Classification report for AdaBoost in uncontrolled environment.....	107
Table 4.14: Classification report for AdaBoost in combined environment	108
Table 4.15: Classification report for GaussianNB in controlled environment	110
Table 4.16: Classification report for GaussianNB in uncontrolled environment	112
Table 4.17: Classification report for GaussianNB in combined environment.....	113
Table 4.18: Classification report for DTC in controlled environment.....	115
Table 4.19: Classification report for DTC in uncontrolled environment.....	116
Table 4.20: Classification report for DTC in combined environment	117
Table 4.21: Classification report for LogisticRegression in controlled environment.....	119
Table 4.22: Classification report for LogisticRegression in uncontrolled environment.....	121
Table 4.23: Classification report for LogisticRegression in combined environment	122
Table 4.24: Model architecture of custom CNN.....	125
Table 4.25: Parameter setup for CustomCNN	125
Table 4.26: Accuracy and Loss Metrics in the first round.....	127
Table 4.27: Parameter grid (controlled – CNN)	128
Table 4.28: Parameter Grid (CNN – Uncontrolled).....	130
Table 4.29: Accuracy Achieved in uncontrolled environment	132

Table 4.30: Parameter Grid (CNN - Comined).....	133
Table 4.31: Accuracy Achieved in combined environment.....	134
Table 4.32: Changes tried with SVM in controlled environment	134
Table 4.33: Changes tried with SVM in uncontrolled environment	135
Table 4.34: Changes tried with SVM in combined environment.....	135
Table 4.35: Changes tried (i) with Custom CNN in controlled environment	136
Table 4.36: Changes tried (ii) with Custom CNN in controlled environment	138
Table 4.37: Changes tried (i) with Custom CNN in uncontrolled environment	139
Table 4.38: Changes tried (ii) with Custom CNN in uncontrolled environment	140
Table 4.39: Changes tried (i) with Custom CNN in combined environment.....	141
Table 4.40: Changes tried (ii) with Custom CNN in combined environment.....	142
Table 4.41: Confusion Matrix for Two Class Problem.....	147
Table 5. 1: Summary of accuracy achieved by classifiers	152
Table 5.2: Accuracy achieved in Controlled Environment	154
Table 5.3: Accuracy achieved in Controlled Environment	155
Table 5.4: Accuracy achieved in Combined Environment	157
Table 5.5: Accuracy achieved for Cercospora Leaf Spot disease	158
Table 5.6: Accuracy achieved for Healthy Leaf category.....	159
Table 5.7: Accuracy achieved for Powdery Mildew.....	160
Table 5.8: Accuracy achieved for Yellow Mosaic Virus	161
Table 5.9: Comparison of ML Vs. DL Algorithm	163
Table 5.10: Summary of previous work.....	165

List of Acronym

AdaBoost	Adaptive Boosting
ANN	Artificial Neural Network
CLS	Cercospora Leaf Spot
CNN	Convolutional Neural Network
DTC	Decision Tree Classifier
GaussianNB	Gaussian Naive Bayes
HOG	Histogram of Oriented Gradients
KNN	K-Nearest Neighbor
LDRSE	Leaf Disease Recognition System Engine
MYMV	Mungbean Yellow Mosaic Virus
PFDIM	Plant Foliar Disease Identification Model
ReLU	Rectified Linear Unit
ROI	Region Of Interest
SVM	Support Vector Machine
HSV	Hue Saturation Value