RUBBER PLANT DISEASE DETECTION USING HYBRID FUZZY NEURAL NETWORK TECHNIQUES

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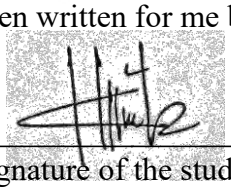

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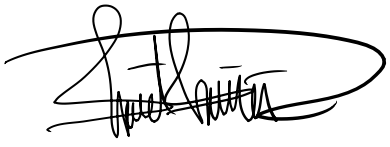

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ABSTRACT

Early disease detection in rubber plants (Hevea brasiliensis) is challenging, requiring expert knowledge and experience to confirm diseases, which is time-consuming and costly. Therefore, this study aims to develop a disease detection and prediction system using image processing techniques and artificial intelligence methods. Four types of diseases were identified: three leaf diseases (Oidium powdery mildew, Corynespora, and Collectotrichum) and one root disease (white root disease) with three stages (light, moderate, and severe). Samples were collected from rubber plantations in Tabalong, South Kalimantan, totaling 450 images. The dataset was modeled based on expert labeling. GLCM was used for texture extraction, with six selected features: contrast, correlation, energy, homogeneity, entropy, and inverse difference moment. The utilization of ANFIS and RBFNN provides a powerful and flexible approach to plant disease detection. These methods learn from training data and adjust their parameters to enhance model performance. The accuracy of detecting leaf diseases was 97.78%, with a precision of 0.98, a recall of 0.98, and an F-measure of 0.98. These results were obtained using an epoch value of 40 and value 2, with the gbell type used for the membership function. Similarly, the accuracy for detecting white root disease was 86.67%, with a precision of 0.87, a recall of 0.87, and an F-measure of 0.86. The results indicate that the choice of image processing technique significantly impacts the detection outcome. The effectiveness of the ANFIS classification technique depends on the parameter values selected, including the number of epochs and the number and type of membership functions. This capacity to generalize from training data to new, unseen data is of significant importance for real-world applications. The developed automated system greatly assists farmers in detecting rubber plant diseases, enabling prompt identification and treatment, which in turn reduces operational costs.

PENGESANAN PENYAKIT POKOK GETAH MENGGUNAKAN TEKNIK RANGKAIAN SARAF TIRUAN HIBRID

ABSTRAK

Pengesanan awal penyakit dalam pokok getah (*Hevea brasiliensis*) adalah mencabar, memerlukan pengetahuan dan pengalaman pakar untuk mengesahkan penyakit, yang memakan masa dan kos yang tinggi. Oleh itu, menggunakan teknik pemprosesan imej dan kaedah kepintaran buatan, kajian ini bertujuan untuk membangunkan sistem pengesanan dan ramalan penyakit. Empat jenis penyakit telah dikenal pasti dalam penyelidikan ini, termasuk tiga penyakit daun dan satu penyakit akar. Penyakit daun termasuk *Powdery oidium*, penyakit daun *Corynespora* dan penyakit daun *Collectotrichum*. Penyakit akar adalah penyakit akar putih dengan 3 peringkat penyakit iaitu ringan, sederhana dan teruk. Sampel diambil dari ladang pokok getah yang terletak di Tabalong, Kalimantan Selatan. Sebanyak 450 imej telah dikumpul. Set data telah dimodelkan berdasarkan pelabelan pakar. *Gray level co-occurrence matrix* digunakan untuk pengekstrakan tekstur, dengan 6 ciri dipilih iaitu *contrast, correlation, energy, homogeneity, entropy* dan *inverse difference moment*. Penggunaan ANFIS dan RBFNN menyediakan pendekatan yang berkuasa dan fleksibel untuk menangani cabaran dalam pengesanan penyakit. Kaedah ini belajar daripada data latihan dan melaraskan parameternya untuk meningkatkan ketepatan model. Ketepatan untuk mengesan penyakit daun adalah 97.78% dengan *precision* 0.98, *recall* 0.98 dan *F-measure* 0.98 menggunakan *epoch* 40, *membership function* ditetapkan kepada 2 dan jenis menggunakan Gbell. Begitu juga, ketepatan untuk mengesan penyakit akar putih ialah 86.67% dengan *precision* 0.87, *recall* 0.87 dan *F-measure* 0.86. Keputusan menunjukkan bahawa pemilihan teknik pemprosesan imej mempunyai kesan yang signifikan terhadap hasil pengesanan. Teknik klasifikasi ANFIS sangat bergantung pada nilai parameter, termasuk *epoch*, bilangan dan jenis tipe *membership function* yang dipilih. Jadi ia mempunyai kapasiti untuk membuat generalisasi daripada data latihan kepada data baharu yang tidak kelihatan, yang penting untuk aplikasi dunia sebenar. Sistem automatik yang dibangunkan sangat membantu petani mengesan penyakit pokok getah, supaya ia dapat dikendalikan dan dirawat dengan cepat serta mengurangkan kos operasi.

CONTENTS

		Page
DECLARATION OF ORIGINAL WORK		ii
DECLARATION OF THESIS		iii
ACKNOWLEDGMENT		iv
ABSTRACT		v
ABSTRAK		vi
CONTENTS		vii
LIST OF TABLES		xii
LIST OF FIGURES		xiv
LIST OF ABBREVIATIONS		xvii
LIST OF PUBLICATION		xix
APPENDIX		xx
CHAPTER 1 INTRODUCTION		
1.1	Introduction	1
1.2	Background of the Study	2
1.3	Problem Statement	6
1.4	Research Objective	8
1.5	Research Question	9
1.6	Importance of The Research	9
1.7	Scope of Research	10
1.8	Thesis Layout	11

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction 13

2.2 Image Processing Technique for Plant Diseases Detection and Prediction 14

2.2.1 Image Acquisition 16

2.2.2 Image Preprocessing 20

2.2.3 Image Segmentation 28

2.2.4 Image Feature Extraction 33

2.2.5 Machine Learning 41

2.3 Detection and Prediction of Plant Diseases with Identification of Symptoms in plants 44

2.3.1 Identification of Disease Symptoms on Leaf 44

2.3.2 Identification of Disease Symptoms on Root 51

2.3.3 Identification of Disease Symptoms on Fruit 52

2.3.4 Identification of Disease Symptoms on the Plant Parts Other than the Target Organ 55

2.4 Collection of Data Conducted by Researchers 57

2.5 Automatic Detection and Prediction of Plant Diseases 60

2.6 Rubber Tree Diseases 65

2.6.1 Powdery Mildew Oidium 66

2.6.2 Colletotrichum Leaf Disease 68

2.6.3 Corynespora Leaf Fall Disease 69

2.6.4 White Root Disease 70

2.7 Research Trend 73

2.8 Summary 74

CHAPTER 3 RESEARCH METHDOLOGY

3.1 Introduction 77

3.2 Research Framework 78

3.2.1 Population and Sample 81

3.2.2 Data Collection Method 87

3.2.3 Data Collection Techniques 90

3.2.4 Development of a Database on Rubber Related Diseases for the Tabalong State 91

3.3 Proposed Method 92

3.3.1 Process of the Image Acquisition 93

3.3.2 Image Preprocessing 94

3.3.3 Segmentation of Image 95

3.3.4 Feature Extraction of Image 97

3.3.5 Modification of the Model for Detection of Leaf Diseases 101

3.3.6 A Web-based Automatic Detection System for Rubber Related Disease in Tabalong State 112

3.4 Validation and Evaluation of a Automatic Detection System 114

3.5 Summary 116

CHAPTER 4 RESULT AND DISCUSSION

4.1 Introduction 118

4.2 Database of Rubber Plant Related Disease 119

4.2.1 Image Collected 120

4.2.2 Identification of Diseases in Rubber Plants 122

4.2.3 Database on Powdery Mildew Oidium 123

4.2.4 Database on Colletotrichum Leaf Fall Disease 128

4.2.5 Database on Corynespora Leaf Fall Disease 132

4.2.6 Database on White Root Disease 135

4.3 Automatic Detection and Prediction System for Rubber Related Disease 142

4.3.1 Application of the K-means Clustering Algorithm for the Segmentation of Images. 143

4.3.2 Application of the Gray Level Co-occurance Matrix Method 147

4.3.3 Disease Classification 154

4.3.4 System Implementation 173

4.4 Rubber Disease Information System on the Web 188

4.4.1 Design System 190

4.4.2 Validation and Evaluation 197

4.5 Discussion 206

4.6 Summary 209

CHAPTER 5 CONCLUSION AND RECOMENDATION

5.1 Introduction 210

5.2 Achievements of the project 211

5.2.1 Comparative Study of Leaf Disease Detection Methods in Rubber Plants and their Application in Automatic Detection System 211

5.2.2 Collecting Data on Diseases of the Rubber Plant in Tabalong 213

5.2.3 Quantitative Model for Automatic Detection of Rubber Plant Disease 215

5.2.4 Application of Technology for Automatic Detection Using Artificial Intelligence 217

5.3 Research Summary 218

5.4 Research Implications 221

5.5 Future Research 223

5.6 Contribution 224

5.7 Novelty 225

REFERENCES 226

APPENDIX 244

LIST OF TABLES

Table No.	Page
2.1 Step in the Image Processing Technique for the Detection of Plant Diseases	15
2.2 Image Acquisition Technique for the Detection of Plant Diseases	19
2.3 Image Segmentation Technique for the Detection of Plant Diseases	30
2.4 Image Feature Extraction Technique for Plant Disease Detection	33
3.1 Research Design Phase	78
3.2 The Parties Involved in this Study	88
4.1 GLCM Feature Extraction Results of Leaf Disease Training Data	149
4.2 Value Ranges of GLCM Texture Features for Leaf Disease	153
4.3 Value Ranges of GLCM Texture Features for Root Disease Data	153
4.4 Results of Training Data Using K-means Segmentation (K=1)	156
4.5 Results of Training Data Using K-means Segmentation (K=2)	158
4.6 Results of Training Data Using K-means Segmentation (K=3)	159
4.7 Accuracy Results of Training Data on Leaf Disease Using the ANFIS Method	161
4.8 Accuracy Results of Training Data on Root Disease Using the ANFIS Method	162
4.9 Accuracy Results of Testing Data on Leaf Disease Using the ANFIS Method	164
4.10 Accuracy Results of Testing Data on Root Disease Using the ANFIS Method	165
4.11 Accuracy and Performance Results of RBFNN Leaf Disease Training Data	168
4.12 Accuracy and Performance Results of RBFNN Root Disease Training Data	169
4.13 Accuracy and Performance Results of RBFNN Leaf Disease Testing Data	171
4.14 Accuracy and Performance Results of RBFNN Root Disease Testing Data	172
4.15 Display of Training Data Detection Process Output	176

4.16 The Results of the Training and Testing System 198

4.17 The Results of the Validation System 199

4.18 Results of the Leaf Disease Prediction on Basis of White Root Disease 204

LIST OF FIGURES

Figure No.	Page
2.1. Results of image pre-processing on diseases of the rice leaf. Adapted from Gayathri Devi & Neelamegam, 2019	22
2.2. Application of the k-means clustering technique to images of tomato leaves. Adapted from Harakannanavar et al., 2022	29
2.3. Sample images of leaf diseases on apples a) apple scab, b) apple black rot, c) apple cedar and d) healthy apple. Adapted from Al-bayati & Üstündağ, 2020	46
2.4. Processing of the wheat images to characterise the images for disease. Adapted from Al-windi et al., 2023	48
2.5. Different types of diseases that affect citrus fruit. Adopted from Palei et al.,2023	53
2.6. Prediction results using web application for fresh cotton leaves. Adapted from Islam et al., 2023	62
2.7. Results of the prediction using the web application of the diseased leaf. Adapted from Islam et al., 2023	62
2.8. Automated tool for disease detection and assessment for cacao Black Pod Rot (BPR) (a)The original photo of the image; (b)Detected infections by AuToDiDAC; (c) Infected labels annotated by the plant pathologies. Adapted from Tan et al., 2018.	63
2.9. Automatic wheat disease diagnosis using mobile capture devices (a)The leaf photo taken by the farmer is shown (b)The output result from the algorithm is visualized. Adapted from Johannes et al., 2017.	64
2.10. Image of Powdery Mildew (Oidium Hevea). Adapted from Cattlin, 2015	67
2.11. Image of Colletotrichum leaf disease. Adapted from Rokhmah, 2017	68
2.12. Image of Corynespora leaf fall disease	70
2.13. Image of White Root Disease. Adapted from Mayerni et al., 2017	71
2.14. Foliage symptoms of infected white root disease. Adapted from Yulia et al.,2017	72

2.15. Foliage symptoms of infected white root disease. Adapted from Yulia et al.,2017 72

3.1. Automatic disease detection plants 80

3.2. Plantation area in plantation cultivation by district/city in the province of South Kalimantan (ha), 2020 and 2021. Adopted from Direktorat Jenderal Perkebunan, 2019 82

3.3. Production of rubber plantations by county/city (ton), 2020 and 2021. Adopted from Direktorat Jenderal Perkebunan, 2019. 83

3.4. Total area by the district in Tabalong state (square km) 84

3.5. Planted area of estate crops by district and kind of crop in Tabalong state (hectare) 2016. Adapted from Badan Pusat Statistik Kabupaten Tabalong, 2016b 85

3.6. Plants Area And Production Estate of Rubber Plants, 2016. Adapted from Badan Pusat Statistik Kabupaten Tabalong, 2016b 86

3.7. Design Develop database 92

3.8. Image Processing Step 93

3.9. ANFIS Ilustration 103

3.10. Schema of RBFNN 109

3.11. Design Web-Based System Automatic Detection 113

4.1 Leaf diseases according to type a) Colletotrichum, b) Corynespora, c) Powdery 121

4.2. The severity of the white root disease can be divided into three categories: a) light, b) moderate, c) severe 121

4.3. Rubber trees that are infected with the white root disease. 136

4.4. Rubber plant leaves a) Original Image, b) Image Preprocessing, and c) Binary Image 143

4.5. Application view of the Kmeans segmentation with k values: a) k = 1, b) k = 2 and c) k = 3. 146

4.6. RBFNN training performance graph with leaf disease image 167

4.7. RBFNN training performance graph with root disease image 170

4.8. Home view 174

4.9. Display of the training data input process 175

4.10. Display the results of the training data process 176

4.11. The first display of the testing process 182

4.12. Home display program testing 1 183

4.13. The input program testing 184

4.14. The result program testing 1 184

4.15. Home display program testing 2 185

4.16. Figure The input program testing 2 185

4.17. The result program testing 2 186

4. 18. Home screen programme test 3 186

4.19. The input program testing 3 187

4.20. The result program testing 3 187

4.21. Flowchart system 188

4.22. Flowchart user 189

4.23. Diagram context 190

4.24. Website start page design 191

4.25. Rubber plant page design 192

4.26. Disease page design on rubber plants 193

4.27. Page design how to prevent rubber disease 194

4.28. Page design how to treat disease 194

4.29. Rubber disease detection page design 195

4.30. Leaf disease detection input page design 195

4.31. Leaf disease detection output page design 195

4.32. Root disease input detection page design 196

4.33. Root disease detection output page design 196

4.34. Contact and question page design 197

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
ANFIS	Adaptive Neuro Fuzzy Inference System
ANOVA	Analysis of variance
ASM	Angular Second Moment
AuToDiDAC	Automated Tool for Disease Detection and Assessment for Cacao Black Pod Rot
BPR	Black Pod Rot
CLA	Carnation Leaf Agar
DIC	Digital Image Correlation
ECT	Electrical Capacitance
EIS	Electrochemical Impedance Spectroscopy
FIS	Fuzzy Inference Systems
FP	False Positives
FN	False Negatives
Gbell mf	Generalised bell-shaped membershipfuncton
GDP	Gross Domestic Product
GLCM	Gray Level Co-Occurrence Matrix
GUI	Graphical User Interfaces
HSV	Hue, Saturation, Value
IDM	Inverse Difference Moment
IDR	Indonesia Rupiah

IONP	Iron Oxide Nanoparticles
MATLAB	Matrix Laboratory
MFs	Membership Functions
MySQL	Structured Query Language
NIR	Near Infrared
PCU	Prototype Console Unit
PDA	Potato Dextrose Agar
PHP	Hypertext Pre-processor
PCap	Phytophthora Capsici
RBFNN	Radial Basis Function Neural Network
RGB	Red, Green, Blue
RNA	Ribonucleic Acid
RMSE	Root Mean Squared Error
RRIM	Rubber Research Institute Malaysia
SPSS	Statistical Package for the Social Sciences
SVM	Support Vector Machine
TL	Transfer Learning
TN	True Negatives
TF	True Positives
UV-Vis	Ultraviolet-Visible Spectroscopy
WRD	White Root Disease

LIST OF PUBLICATION

1. Review article on plant disease detection methods: open challenges, and pathways for future research, International Journal of Advanced Research in Technology and Innovation, pp 21-28, Vol . 1, No. 3, e-ISSN: 2682-8324, 2019. https://myjms.mohe.gov.my/index.php/ijarti/article/view/8172
2. Detection of rubber (*Hevea brasialiensis*) leaf disease using image processing techniques, Transactions on Science and Technology, pp 48-53, Vol. 1, No. 2, e-ISSN 2289-8786, 2023. https://tost.unise.org/pdfs/vol10/no2/ToST-10x2x48-53xOA.html

APPENDIX

A	RESULT OF LITERATURE REVIEW
B	LIST OF EXPERT
C	TYPE OF LEAF DISEASE ON THE BASIS OF VISUAL OBSERVATION BY AN EXPERT
D	LETTERS OF REQUEST FOR RESEARCH PERMISSION AND EXPERT JUDGEMENT
E	APPROVAL LETTER FROM THE AGRICULTURE DEPARTMENT FOR RESEARCH PERMIT AND EXPERT JUDGEMENT

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents a clear problem statement, research objectives and research questions, and outlines the research themes and background studies. The importance and contribution of this research are also discussed. Section 1.2 presents a background summary of the research component. While Section 1.3 identifies and recognises the problem statement on which the research direction is based. Section 1.4 presents a description of the research objectives. Section 1.6 describes the significance of the research. the importance of the research. Section 1.7 discusses the research contributions. Finally, section 1.8 summarizes this chapter.

1.2 Background of the Study

Plant diseases are a challenge as long as crops are grown, especially in the plantation sector. Economic losses resulting from uncontrolled disease damage make this an increasingly pressing issue. It is important to recognise that disease emergence is a natural process in the development of crops. However, human intervention must be taken into account.

The plantation sub-sector contributes the most to the Agriculture, Livestock, Hunting and Agricultural Services sector's Gross Domestic Product, accounting for 35%. It also helps balance the national trade of agricultural commodities, provides food and industrial raw materials, generates foreign exchange through exports, creates employment opportunities, and increases state revenue from customs duties, export taxes, and export duties (Direktorat Jenderal Perkebunan, 2019). The plantation sector proved to be relatively resilient during the economic crisis. It became a strong contributor to the country's economic recovery (Sub Direktorat Statistik Tanaman Perkebunan, 2016). One of these is the rubber plantation, which plays a role in building the national economy with high incomes and is the second of the ten commodities that individual farmers are cultivating in their work.(Badan Pusat Statistik, 2023).

In the last 3-5 years, major plantation crops have experienced an average yield loss of 1.25 million hectares due to pest attacks. According to the 2014 calculation data, the estimated yield loss is around IDR 4.84 trillion (Direktorat Jenderal Perkebunan, 2016). The productivity of Indonesian rubber in 2018 remained unchanged at 1,205 kg/ha per year. However, estimates for 2019 and 2020 indicate a decrease in

productivity due to pest attacks and rubber leaf fall. This occurred because pest control measures were not comprehensive enough to address the extent of the attack. Additionally, the need to recover diseased plants for normal production and the lack of implementation of the latest technological innovations in post-harvest management have contributed to the issue (Direktorat Jenderal Perkebunan, 2019). Improved cultivation techniques are needed to achieve optimum productivity and quality in rubber plantations. Plant diseases are a major challenge in the cultivation of rubber plants, often hampering the cultivation effort more than any other problem (D. L. Zhai & Xu, 2023). This will lead to a reduction in the production of latex and can even lead to the death of the plant (Tarigan, Ramadhan, & Kustini, 2021).

Diseases are caused by fungal, pest and animal pathogens (Hendrawan, Haris, Rasywir, & Pratama, 2020). Fungal pathogens are the most common (Yulia, Istifadah, Widiantini, & Utami, 2017). During the last decade, there have been significant problems associated with rubber diseases in smallholder rubber farming (Imelda, Mulyo, Suryantini, & Masyhuri, 2023). Plant disease and pest control in plant cultivation is an activity that has to be conducted when the plant has been positively tested for disease. When the plant has been infected by a disease, it will be difficult to control it.

The area of plantations in Indonesia in 2018 was approximately 3,671,387 hectares, while the area of smallholder plantations managed by farmers was approximately 3,235,761 hectares. The area of smallholder plantations experienced a significant increase of 1.36% compared to the previous five years. South Kalimantan is among the ten largest regions with a plant population of 88.81% of all plantings

(Direktorat Jenderal Perkebunan, 2019). Rubber plants are susceptible to various diseases, such as root fungi, tapping field diseases, upas fungi, and leaf fall diseases. These diseases have resulted in significant economic losses, not only due to production losses resulting from plant damage, but also due to high control costs. This problem is one of the growing issues today. Rubber plants that are attacked by disease will be the cause of economic losses for farmers (Mayerni, Rezki, & Heriza, 2017).

Losses are not only in the form of yield loss due to plant damage but also in the form of costs to overcome the disease (Junita, Lubis, Pinem, & Dalimunthe, 2017; Sharif et al., 2018). The total maintenance cost per hectare of rubber plantation was $1,331.81, which included disease control, fertiliser application and pruning (Ansong, Acheampong, Echeruo, Afful, & Ahimah, 2021). Therefore, it is essential to implement efficient control measures, starting with the early detection of diseases that attack the leaves of rubber plants, to reduce losses and increase good rubber productivity while maintaining quality, as the characteristics of plants affected by diseases.

Farmer participation has an important role in the development of rubber cultivation, without farmer participation, rubber plant cultivation will not be implemented (Badan Pusat Statistik Kabupaten Tabalong, 2017b). Chemical pesticides are still used to control various disease attacks on rubber plants, in addition to being relatively expensive, control using this material can cause damage to the ecosystem, and farmers who cultivate rubber plants still have a low level of education, this results in the control and handling of pests and diseases still lacking in terms of expertise to determine the type of disease (Direktorat Jenderal Perkebunan, 2016).

There are many methods in artificial intelligence that can be implemented and developed to build automatic detection systems with short time and accurate disease results such as citrus disease detection referring to Greening, Anthracnose, and Downy Mildew (Ali, Lali, Nawaz, Sharif, & Saleem, 2017). Nowadays, there are a number of rapidly growing technologies, one of which is the use of websites that offer a variety of services. One of them is the development of detection cases such as pest and disease detection in web-based plants. In artificial intelligence, many methods can be implemented to develop automated detection systems accurately. One of the technologies that gain most attention recently is the use of websites with various services provided, including a web-based for plant disease detection.

The early detection and management of diseases affecting rubber plants is crucial for maintaining the productivity and quality of rubber plantations. Conventional methods relying on visual inspection by experts are often inefficient, expensive and prone to human error. Consequently, the development of an effective and efficient approach to identifying and managing diseases affecting rubber plants is required. Digital image processing technology has demonstrated considerable potential in various agricultural applications, including plant disease detection.

The application of advanced image processing algorithms and artificial intelligence has enabled the development of automated and highly accurate techniques for the analysis and detection of disease symptoms in plants. One promising approach is the use of the Adaptive Neuro-Fuzzy Inference System (ANFIS), which combines the advantages of artificial neural networks and fuzzy logic to address uncertainty and non-linearity in image data. Fuzzy ANFIS exhibits high adaptability and is capable of

processing image data to recognise complex patterns. The integration of ANFIS techniques into image processing enables the system to be trained to detect disease symptoms on leaves, stems, and other parts of rubber plants with high accuracy. This approach not only accelerates the disease detection process but also enhances the reliability of the diagnosis, which in turn facilitates the formulation of more efficacious orchard management decisions. The objective of this research is to develop a novel image processing technique that employs fuzzy ANFIS for the detection of diseases in rubber plants. The primary objective of this research is to develop a model that is capable of accurately identifying various types of rubber plant diseases from leaf images. This approach is expected to provide practical and economical solutions for farmers and rubber plantation managers in maintaining plant health and increasing rubber plantation productivity.

1.3 Problem Statement

Plants are recognised as being important because they are the most common source of energy for the people of the world. The rubber-growing season commences with land preparation, nursery, planting, maintenance, tapping, and the productive period, concluding with replanting (Arsi et al., 2022). The agricultural sector has been experiencing difficulties due to leaf diseases, which can lead to significant reduction in the quality and quantity of agricultural products (Rastogi, Arora, & Sharma, 2015; Zeng et al., 2022). The value of plantation exports in 2023 was 32.68 billion USD, representing a significant decline when compared to 2022, when the figure was 40.58 billion USD. This is due to a decrease in the value of exports of rubber, which represents

the leading commodity in foreign exchange. One contributing factor is disease, which has caused a 30.10% decrease in the volume of rubber exported (Perkebunan, 2023).

The application of image processing techniques to the detection of rubber plant disease represents a promising approach. However, several issues must be addressed in order to achieve effective and accurate results (Islam et al., 2023). The most significant challenge associated with image processing techniques is the impact of changing lighting conditions. Leaf images captured in the field frequently exhibit fluctuations in lighting, which can compromise image quality and impede the detection of disease symptoms (Afifi, Alhumam, & Abdelwahab, 2021).

The colour and texture variations of healthy and diseased leaves are often subtle, making them difficult to distinguish without precise analysis (Kaur, Randhawa, & Malhi, 2021). It is common for leaf images to be affected by environmental factors such as shadows, dirt, and other forms of physical damage, which can interfere with the detection process (Hasan, Jahan, & Islam, 2022). Classic image processing algorithms, such as basic colour segmentation and simple texture analysis, are often insufficiently accurate for the detection of complex and diverse disease symptoms (S Ramesh & Vydeki, 2020).

It has been observed that many image processing techniques require significant manual intervention, which has the effect of reducing both the efficiency with which the techniques can be applied, and the degree of consistency that can be achieved (Islam et al., 2023). Furthermore, the symptoms exhibited by certain diseases may be similar in some cases, or may overlap with those exhibited by other diseases, which makes

identification of specific diseases challenging (Arshad et al., 2023). The manifestation of symptoms associated with disease can vary over time, exhibiting a range of forms, from small, discrete lesions to more extensive necrotic areas. This presents an ongoing challenge for the development of effective detection techniques that are capable of responding adaptively and dynamically to the changing landscape of disease symptoms (Sujatha, Moy, Jhanjhi, & Nawaz, 2021).

The most critical gap in the current landscape of training data is the availability of quality data (Br.Kaban, Allwine, Alamsyah, Sianturi, & Tambunan, 2022). The development of an effective ANFIS model necessitates the availability of high-quality leaf image datasets that can be utilised for the training of the model in the context of a range of disease and environmental conditions. It is essential that the training data is correctly labelled by experts in order to ensure that the model can learn to detect disease symptoms in an appropriate manner (S. Zhang, Zhu, You, & Wu, 2017). It is essential to test and validate ANFIS models under a range of field conditions to ensure their generalisation and reliability (Kaushik et al., 2017). Models require adjustments to achieve optimal performance in real conditions (Wulansari & Chulkamdi, 2021).

1.4 Research Objective

Research objectives are:

1) To develop a database of leaf diseases in rubber plants in Tabalong State.
2) To develop new image processing techniques for the early detection of diseases.

3) To develop the Adaptive Neuro-Fuzzy Inference System (ANFIS) technique for the purpose of automating the detection and prediction of rubber leaf diseases.
4) To evaluate and validate the developed automatic disease detection system in performing accurate detection.

1.5 Research Question

The research question of the research are :

1) What are the steps to develop a database of leaf diseases on rubber plants in Tabalong State?
2) What are the steps involved in the application of new image processing techniques for the purpose of disease detection?
3) What are the steps of ANFIS technique for automatic detection and prediction system of rubber leaf diseases?
4) How to evaluate and validate the developed automatic disease detection system in accurate identification?

1.6 Importance of The Research

The important of research are:

1) The GLCM effectively reduces the impact of lighting variation and improves the reliability of disease symptom detection, given the available features.

2) This technology reduces the reliance on time-consuming and error-prone manual visual inspections.
3) Assist rubber farmers and extension workers in early detection and treatment of rubber plant diseases quickly and precisely, so as to reduce economic losses and increase the productivity of rubber plantations.
4) The ANFIS algorithm learns and adapts to new data over time , thus improving the system's performance.
5) Provide solutions for the detection of rubber plant disease through image processing techniques to the local government, which will inform the formulation of policies for the development of smallholder rubber plantations in Tabalong state.

1.7 Scope of Research

The scope of this research includes:

1) The use of a camera phone to take images of leaf samples under a variety of lighting conditions is employed in order to ensure the representation of a range of variations.
2) The leaf images were subjected to preprocessing in order to enhance their quality and reduce noise. This involved the application of colour normalisation, contrast enhancement, and shadow removal techniques.
3) A method for extracting texture features from leaf images utilising GLCM is presented. The extracted features include contrast, correlation, energy, homogeneity, entropy and IDMN.

4) Design and develop a software-based disease detection system that integrates GLCM and ANFIS techniques.
5) A dataset comprising images of diseased leaves was collected in the plantation area of Tanjung, Tabalong state, South Kalimantan, Indonesia.

1.8 Thesis Layout

There are three chapters in this thesis. The summary of these chapters is as follows:

Chapter 1 presents the research background and problem statement. The research objectives and contributions are presented.

Chapter 2 presents a literature review on plant disease detection and prediction. This is followed by an overview of available plant disease databases and the methods used. An overview of the off-line and on-line forms of detection of the disease is also presented.. In addition, this chapter also provides an overview of the diseases that affect the cultivation of rubber plants. Finally, there will be an analysis of the research problem and suggestions for the solution of the problem.

Chapter 3 presents a description of the research methodology. Each step is in accordance with the research objectives to be achieved. A detailed description of the methods to be used in disease detection and prediction as well as evaluation and validation are presented.

Chapter 4 presents the research findings from this study in response to the existing research questions. The findings have been obtained through the implementation of the research methodology for the interpretation of the results data. Results will be presented through narrative, figures and tables.

Chapter 5 presents the discussion and conclusion of the research. In the discussion, the results of the study are discussed in relation to the previous research and the theory in the literature review. The conclusions are critical. They are in line with the research questions. Suggestions for future research are also presented along with the implications and significance of the research.