DUAL – MODE TELEMETRY FOR UNMANNED AERIAL VEHICLE (UAV) USING RADIO FREQUENCY AND CELLULAR NETWORK

An Undergraduate Thesis

Presented to the
Faculty of Bachelor of Science in Computer Engineering
University of Science and Technology of Southern Philippines
Cagayan de Oro City

In Partial Fulfillment
of the Requirements for the Degree of
BACHELOR OF SCIENCE IN COMPUTER ENGINEERING

JODIE REY D. FERNANDEZ
May 2017

APPROVAL SHEET

This Thesis entitled: "DUAL – MODE TELEMETRY FOR UNMANNED AERIAL VEHICLE (UAV) USING RADIO FREQUENCY AND CELLULAR NETWORK", prepared and submitted by JODIE REY D. FERNANDEZ in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN COMPUTER ENGINEERING** has been examined and approved.

Engr. Jodie Rey D. Fernandez
Adviser

PANEL OF EXAMINERS

Approved by the committee on Oral Examination with a grade of **PASSED**.

Engr. Jodie Rey D. Fernandez
Chair

Engr. Mark Lister V. Nalupa
Member

Engr. Miriam M. Bergado
Member

Approved and accepted in partial fulfillment of the requirements for the degree **BACHELOR OF SCIENCE IN COMPUTER ENGINEERING**.

Approved:

Dr. Israel A. Baguhin
Dean, College of Engineering and Architecture

ABSTRACT

This study explores the advancements and applications of telemetry systems, which are pivotal in remote data monitoring and analysis across various industries. Telemetry technology, encompassing data acquisition, transmission, and analysis, plays a crucial role in fields such as aerospace, healthcare, and environmental monitoring. The research highlights the effectiveness of telemetry systems in providing accurate and reliable real-time data, enhancing operational efficiency, and enabling predictive maintenance. Key findings include significant improvements in data transmission speeds and reliability due to advancements in wireless communication and the integration of the Internet of Things (IoT). The study also identifies challenges such as data security and transmission interruptions in remote areas. Recommendations for future research include addressing these challenges and exploring new applications in emerging fields. This work underscores the transformative impact of telemetry on modern technology and its potential for continued innovation.

Keywords: *Telemetry, GPS Location*

This piece of work is wholeheartedly dedicated

to my parents

Papang

and

Nanay

ACKNOWLEDGMENT

I would like to express my gratitude to the following people and institutions which, in one way or another, greatly contributed towards the completion of this study.

To my adviser ***Engr. Jodie Rey D. Fernandez*** for painstakingly checking every detail of this paper. I am extremely thankful and indebted to you Sir for sharing your expertise and valuable guidance. Had not of your encouragement and moral support, this endeavor would surely fall to a complete obscurity.

To my panel members, ***Engr. Mark Lister V. Nalupa*** and ***Engr. Miriam M. Bergado*** for sharing your knowledge and diligently spending your time in giving valuable insights, corrections and suggestions for the betterment of this study. I have high regards to both of you.

To the faculty and staff of the ***Department of Computer Engineering*** for your encouragement and support.

To my classmates, ***Methos***, ***Shirley***, ***Lovely***, ***Lady Lee***, ***Cris***, and ***Ma'am Bern*** for sharing your laughter and wonderful moments with me. Finally, sleepless nights and tiring days are over but they are all worth it.

To my friends, ***Ruemar***, ***Chyn***, ***Vine***, ***Abigail***, ***Rachel***, ***Long***, ***Elaine***, ***Claire***, ***Allan***, ***Xander***, ***Laiza***, ***Ate Leslie***, ***Sir Greig***, ***Jean***, ***Sir Harold***, ***Ate Josh***, ***Ma'am Amelia***, ***Jovy***, ***Leonel***, ***Jerson***, ***Sir Raymund***, ***Sir Nur P.***, ***Mama Marge***, ***Mama Belle***, ***Mama Lady***, ***Mama Hazel***, ***Brother Mark***, ***Sir Nur***, ***Sir Elmer*** and to my ***AHK Family*** for your prayers and moral support. You all made this journey worthy of remembering.

To my family, ***Nanay Angga***, ***Papang Willy***, ***Nanay Toto***, ***Ina***, ***Ate Love***, ***Ate Ging***, ***Kuya Boboy***, ***Andi***, ***Marlo*** and ***Ate Lyn*** for your unceasing love, moral and financial support. All of you are my inspirations which constantly remind me of not giving up amidst difficulties and uncertainties.

And to those people I failed to mention, who directly or indirectly, lent their hands, extended their prayers and support for the completion of this study.

Above all, to our ***Almighty God***, whose unconditional love infinitely transcends all human comprehensions, provides us with good health, divine protection and bountiful blessings.

Jodie

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

List of Equations

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Theobroma cacao, widely known as cacao, is one of the most economically influential crops in the world. It serves as the primary raw material for the multibillion-dollar chocolate industry, supporting the livelihoods of approximately six million small-scale farmers globally. Once harvested, cacao seeds are processed to produce cocoa powder and cocoa butter—essential ingredients used in a wide range of products, from confections and beverages to cosmetics and pharmaceuticals. Despite its global demand and economic importance, cacao cultivation faces persistent challenges from various biotic and abiotic stressors. In particular, fungal pathogens such as *Phytophthora palmivora* cause black pod disease, which has been documented to inflict significant annual yield losses Avila-Quezada et al. (2023).

Traditional disease management in cacao farms typically involves manual inspection and subjective classification of pods. The Philippine Cacao Industry Roadmap (2021) reported that this method is labor intensive and error prone, often failing to detect infections in their early stages—especially in regions with limited access to skilled agricultural labor and advanced diagnostics. In the Philippines, for example, cacao production has not kept pace with local consumption demands. Despite favorable growing conditions, the Davao Region has been recognized as the "Cacao Capital of the Philippines" Philippine Council for Agriculture and Fisheries (PCAF) (2021).

To address these threats, modern agriculture has increasingly turned to advanced technological solutions for early disease detection and intervention. Unmanned Aerial Vehicles (UAVs) and deep learning algorithms have emerged as powerful tools in precision agriculture, offering efficient and scalable monitoring of large plantations. UAVs, equipped with high-resolution cameras and multispectral sensors, can rapidly survey wide areas, while cutting-edge models like You Only Look Once (YOLO) provide high-accuracy plant disease identification **?**. Early detection during the pre-harvest phase, as supported by Upadhyay et al. (2025); Choudhary et al. (2024), enables timely interventions to mitigate crop losses and ensure quality harvests.

Existing technological interventions for cacao disease detection, such as mobile applications that utilize image processing and machine learning, have made strides in bridging the gap. For instance, Tan et al. (2018) developed AuToDiDAC, an app designed to detect black pod rot, while Tovurawa et al. used convolutional neural networks (CNNs) to classify cacao leaf diseases. However, these solutions are predominantly dependent on static image inputs and close-range data collection. As noted by Taesiri et al. (2023), such methods can cause models to focus only on the most discriminative regions of the plant, potentially missing early-stage infections or atypical symptoms that may be spread across the pod's surface. Additionally, mobile-based approaches require farmers to manually photograph individual pods, which is laborious and impractical for large-scale plantations, thereby limiting mobility and scalability.

With these challenges in mind, this study introduces a UAV-based cacao disease detection system that leverages aerial imagery and the YOLO object detection algorithm to overcome the constraints of static, close-range data collection. By capturing images from various angles and altitudes, this approach enables more comprehensive monitoring of cacao plantations. Integrating deep learning models with UAV technology allows for the detection of disease symptoms across the entire pod surface that traditional methods may miss.

The system will be developed and followed by field tests to evaluate its performance, functionality, and integration in real-world agricultural environments. Its potential for large-scale deployment in cacao farms will also be assessed, aiming to provide a scalable, efficient, and accurate disease detection solution for one of the world's most valuable crops.

1.2 Statement of the Problem

The Philippine cacao industry faces persistent challenges that hinder its ability to meet the demands of both the domestic and international market. Although the country has favorable climate conditions and fertile land, especially in the Davao Region, which represents 78% of national production, it continues to fall short of its annual production target of 50,000 metric tons. According to the Department of Agriculture (2021), this shortfall is largely due to cacao diseases, particularly black pod disease caused by *Phytophthora palmivora*, which leads to post-harvest losses of up to 90%.

Traditional detection methods rely on manual inspection, which is labor intensive, slow, and prone to human error, leading to delayed intervention and significant crop losses. Although existing studies explore machine learning and imaging technologies for cacao disease detection, they primarily use static imaging and mobile-based approaches, limiting monitoring and scalability. To address this gap, this study proposes the integration of an Unmanned Aerial Vehicle (UAV) with You Only Look Once (YOLO) technique for detection of cacao pod disease, particularly *Phytophthora palmivora*, without human effort. The system also includes geotagging, using QGIS to pinpoint where the affected cacaos are, which are processed and viewed in a web-based application where farmers can monitor their cacao farms.

1.3 Objectives of the Study

This study aims to design a UAV-based system that integrates YOLO for identifying *Phytophthora palmivora* disease in cacao pods, with GPS geotagging for precise location mapping. Specifically, it seeks to:

1. Design and configure a UAV capable of autonomous navigation over cacao farms while providing stable flight and imaging.
2. Develop and implement a monitoring system that tracks the UAV's flight status and detection for cacao pod disease.
3. Implement a YOLO-based object detection model for cacao pod detection and a classification model for identifying *Phytophthora palmivora* infection.
4. Test the system's detection accuracy, classification performance, geotagging precision, and overall operational efficiency.

1.4 Significance of the Study

This study holds significance for multiple sectors, starting with cacao farmers, who will benefit from a practical and accessible solution for early disease detection, enabling timely intervention to prevent further contamination. This proactive approach helps reduce crop losses, improve yield quality and quantity, and promote stable income and long-term sustainability in farming practices.

The cacao and chocolate industry will also gain from a more disease-resilient cacao supply, ensuring stability and reliability in the value chain, supporting both local and global markets, and maintaining consistent raw material availability to sustain production, control prices, and boost economic activity in cacao-dependent regions. For the agricultural sector, the system promotes the modernization of farming through precision agriculture technologies, enhancing productivity and sustainability, particularly in disease-prone areas.

The government can leverage the study's outcomes to align with national agricultural development goals, such as those in the Philippine Cacao Industry Roadmap, providing a basis for policy-making, funding assistance, and technology-based interventions, while contributing to Sustainable Development Goals (SDG 8 and SDG 15) by fostering sustainable agriculture, increasing farmer income, and encouraging innovation. Lastly, future researchers in precision agriculture and remote sensing can use this work as a valuable reference for further advancements in plant disease detection technologies.

1.5 Scope and Limitations

This study focuses on the development and testing of a UAV-based detection system for cacao farms in Claveria, Misamis Oriental. The system integrates three major components: (1) a YOLO-based model for detecting symptoms of *Phytophthora palmivora* infection in cacao pods, (2) GPS and QGIS for precise geolocation and mapping of affected areas, and (3) a web-based application for monitoring and visualization of results.

The scope of the system is limited to the detection of external symptoms of black pod disease, such as visible pod rot. Internal infections that are not outwardly visible cannot be identified by the current implementation. Furthermore, while the system can assist in identifying potentially infected pods, it does not automate subsequent farm management activities such as pruning or removal of diseased pods, which must still be performed manually by farmers.

The imaging capability of the UAV is also constrained by the use of a 720p camera, which may affect the level of detail captured and thus the accuracy of disease detection under certain conditions. Additional environmental factors such as lighting, weather conditions, and UAV flight stability may also influence detection performance. These limitations define the operational boundaries of the proposed system and provide considerations for future improvements.

1.6 Definition of Terms

For clarity and consistency, the following terms are defined as they are used in this study:

Dataset - A structured collection of related data, such as images of cacao pods, used to train and evaluate deep learning models for disease detection in this study.

Deep Learning Algorithms - A subset of machine learning algorithms, particularly neural networks, used to analyze large datasets and recognize patterns in images or other inputs, enhancing precision agriculture applications.

Disease Detection - The process of identifying and diagnosing plant diseases, often involving technology such as image analysis and machine learning algorithms for early intervention.

Field Tests - Practical trials conducted in real-world agricultural environments to assess the effectiveness and performance of the proposed UAV and deep learning-based system for detecting cacao pod diseases.

Geotagging - The process of adding geographical location data, such as latitude and longitude, to images or data collected by UAVs, enabling spatial tracking and mapping of disease occurrences in cacao farms.

Image Processing - The technique of manipulating and analyzing digital images using algorithms to extract meaningful information, often for detecting patterns such as plant diseases.

Phytophthora palmivora - A fungal pathogen responsible for causing black pod disease in cacao plants, which leads to significant yield losses in cacao production.

Pod - Refers to the fruit of the cacao tree that contains cacao beans; it is the primary site for disease detection, particularly for symptoms caused by pathogens like *Phytophthora palmivora.*

Pre-harvest Detection - The process of identifying signs of disease or stress in crops, specifically cacao pods, before they are harvested, allowing for timely intervention to prevent yield loss and improve crop quality.

QGIS - An open-source Geographic Information System software that provides tools for geospatial data processing, mapping, and analysis. In this study, it is used for automating geotagging and visualizing infected cacao trees.

Static Imaging - The process of capturing fixed, non-moving images, often used in traditional disease detection methods, which may miss early-stage infections or dispersed symptoms.

Unmanned Aerial Vehicles (UAVs) - Aerial devices, typically drones, that operate without a human pilot, often equipped with cameras and sensors, used for monitoring agricultural environments and gathering data for analysis.

You Only Look Once (YOLO) - An advanced real-time object detection model that can quickly identify and classify objects within images, used for detecting diseases on plant surfaces in this study.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Cacao Diseases and Diagnosis

Cacao (*Theobroma cacao*) is highly vulnerable to various diseases that threaten yield and production quality. One of the most aggressive fungal pathogens is *Phytophthora megakarya*, responsible for black pod disease. This disease affects all parts of the cacao plant, including pods, leaves, and stems, particularly in humid conditions.

While *P. megakarya* is a major threat in West Africa, a different variant of this species, *Phytophthora palmivora*, is the primary cause of pod rot in the Philippines, as mentioned by Solpot (2020). This pathogen was first documented in Luzon in 1918 by Reinking and remains a significant challenge for local farmers. According to Ministry of Agriculture, Land and Fisheries, *P. palmivora* can cause annual losses of 20–30%, with severe cases reaching up to 90% under high humidity.

Studies suggest that infected cacao plants can contribute to the spread of the disease to neighboring trees. Field experiments demonstrated that pod removal reduces black pod incidence, confirming the role of contaminated pods in disease transmission. However, research by Babin (2018) later revealed that insect pests, particularly *Helopeltis bakeri*, a mirid bug, also facilitate the spread of fungal pathogens. These insects feed on pods and shoots, causing severe damage and creating potential entry points for fungal infections.

Other notable diseases affecting cacao include Cacao Swollen Shoot Virus (CSSV), Vascular-Streak Dieback (VSD), Witches' Broom Disease caused by *Moniliophthora perniciosa*, and Frosty Pod Rot (*Moniliophthora roreri*). Farmers and researchers typically distinguish between healthy and diseased cacao plants by observing specific visual symptoms on leaves, pods, stems, and roots. Initial signs include small, circular brown spots on the pod surface, as described by Ministry of Agriculture, Land and Fisheries, which expand rapidly and often emit a characteristic fishy odor if untreated.

2.2 Current Approaches to Cacao Disease Detection and Quality Control

The Philippine Cacao Industry Roadmap Department of Agriculture (2021) highlighted that most cacao farms in the country are smallholdings, managed using ancestral knowledge or experience. This includes manually identifying black pod rot and separating diseased pods post-harvest. However, this is limited in effectiveness. According to Forest Phytophthoras of the World, healthy pods exposed to pathogens can develop internal infections within 15 days, making early detection and intervention crucial.

To mitigate diseases, farmers employ cultural and chemical control methods. Sanitation and pruning, as described by Merga (2022), reduce humidity and fungal inoculum sources. Similarly, frequent harvesting minimizes pathogen load. Fungicides such as copper-based compounds and metalaxyl were also developed and remain essential when combined with crop sanitation.

In cacao classification, traditional destructive methods like the cut-test are common, though labor-intensive and less precise Nguyen et al. (2022). Advanced but complex alternatives, such as chromatographic analysis, were proposed by Quelal-Vásconez et al. (2020). Non-destructive techniques have since emerged: imaging sensors, spectroscopy, and thermal imaging Alvarado et al. (2023), with promising applications in detecting root diseases and leaf infections. For instance, Silva and Almeida (2024) demonstrated edge computing with thermal imaging for real-time leaf disease classification. Hyperspectral Imaging (HSI) and Near-Infrared (NIR) spectroscopy also help assess cacao's internal attributes like moisture, fat, and fermentation.

2.3 Pre-harvest Disease Detection

Manual inspection remains the most common pre-harvest disease detection method, though it is time-consuming and prone to errors in large-scale farms. According to Tan et al. (2018), delays in detection increase the spread of diseases like *Phytophthora palmivora*. UAVs with high-resolution cameras and multispectral sensors provide a scalable solution. Choudhary et al. (2024) demonstrated UAV-based early disease detection, capturing subtle symptoms such as pod discoloration or texture changes, often missed by manual inspection. Similarly, Upadhyay et al. (2025) highlighted UAV integration with deep learning for more robust monitoring.

UAV integration in precision agriculture improves accuracy and timeliness. UAVs cover vast areas quickly, generating large-scale datasets. Taesiri et al. (2023) emphasized that advanced image processing and geotagging enhance precision, detecting even atypical or subtle symptoms. This proactive approach ensures early intervention and reduces crop loss.

2.4 Computer-aided Cacao Disease Detection Technology in Agriculture

Alam et al. (2022) developed a drone-based monitoring system using Gaussian kernel SVM to classify vegetables into rotten and non-rotten categories, achieving 97.9% true positive rate. Similarly, Mazzia et al. (2020) refined satellite-driven NDVI indices using UAV data and CNNs for vineyard vigor maps. Vardhan and Swetha (2023) further introduced CNN-based plant disease detection using drone imagery, showing scalability even under challenging imaging conditions. These studies highlight UAVs combined with deep learning as promising tools for precision agriculture.

2.5 You Only Look Once version 8 (YOLO) for Object Detection

Deep learning, especially YOLO, has enhanced UAV-based crop monitoring. UAV-YOLO, developed by Wang et al. (2023), integrates Wise-IoU v3, BiFormer, and FFNB to optimize aerial imagery detection. Likewise, custom YOLO variants improve detection accuracy at the expense of processing speed. YOLO also excels in plant disease diagnosis: several studies have achieved over 90% accuracy on benchmark datasets, outperforming traditional ML models.

2.6 Geotagging using QGIS in Agriculture

Geotagging links crop data with precise locations, aiding decision-making in precision agriculture. Rahman (2021) used QGIS to geotag durian trees in Malaysia, integrating ground data (e.g., tree height, canopy size, soil pH) with coordinates for improved monitoring. Such methods enable more organized, spatially-aware farm management.

2.7 Synthesis

Traditional cacao disease management relied on visual inspection, pruning, sanitation, and fungicides Merga (2022). While effective to some degree, these methods depend heavily on farmer expertise and are limited by risks of misdiagnosis and environmental impact. Laboratory-based methods like PCR and chromatographic analysis Nguyen et al. (2022); Quelal-Vásconez et al. (2020) improve accuracy but are impractical for large-scale field use.

Non-destructive imaging and AI-based approaches Alvarado et al. (2023); Silva and Almeida (2024) have become viable alternatives, enabling early detection via spectral, thermal, and hyperspectral methods. Meanwhile, mobile applications such as AuToDiDAC Tan et al. (2018) and UAV-based CNNs Tovurawa et al. showcase the power of deep learning in crop disease management.

Nonetheless, reliance on static images risks missing subtle pod-level symptoms. Integrating UAVs with YOLO-based real-time detection ensures scalability, precision, and efficiency, making it a promising solution for modern cacao disease detection and smart agriculture.

CHAPTER 3

METHODOLOGY

In this chapter, we detail the methodology employed to conduct the study, providing a comprehensive overview of the research design, data collection, and analytical procedures.

3.1 Research Design

Your research design.

Table 1: Sample Data Table

Item	**Quantity**	**Price ($)**
Apples	10	0.50
Bananas	5	0.30
Cherries	20	1.20
Dates	50	2.50

3.2 Formula

3.3 Tables

3.4 Images

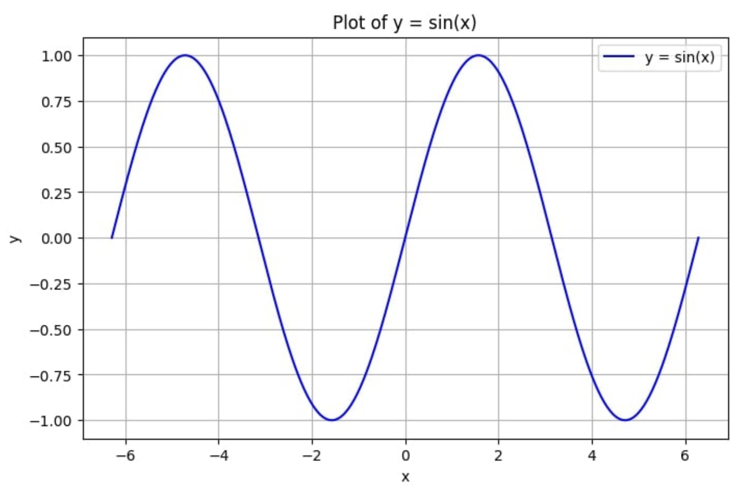

Figure 1: Sine Graph

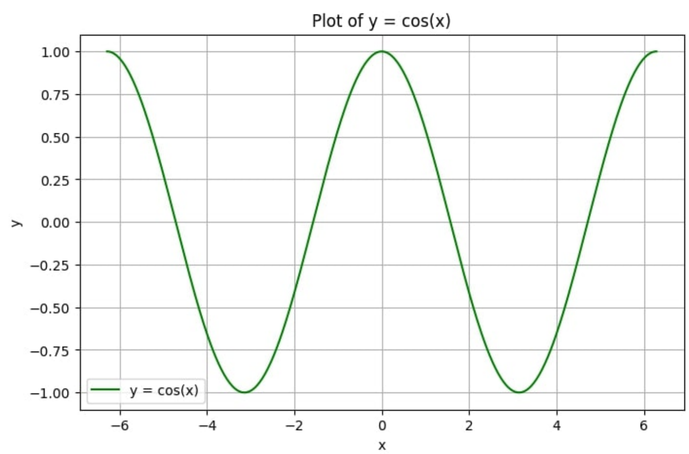

Figure 2: Cosine Graph

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the findings from the research conducted and provides a thorough analysis and interpretation of these results.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter provides the summary of the results obtained in this study and gives some recommendations for further investigation.

5.1 Summary of Findings

The study's findings address the initial research questions by confirming the effectiveness, reliability, and diverse applications of telemetry systems. The "Summary of Findings" section provides a concise overview of the key results from your research. This section should be factual and focus on presenting the data without interpretation. It should include:

Key Results:

Briefly summarize the most significant findings. Use bullet points or numbered lists for clarity if appropriate. Present the data as it was found, highlighting major patterns, relationships, or trends. Data Presentation:

Include tables, graphs, or charts that succinctly summarize the data. Make sure each visual aid is clearly labeled and includes a brief description. Coverage of Research Questions:

Address each of the research questions or hypotheses posed at the beginning of the study. Summarize the results relevant to each question.

5.2 Conclusion

The "Conclusions" section interprets the findings and discusses their implications. This section should:

Interpret Findings:

Provide an interpretation of the data summarized in the previous section. Discuss what the results mean in the context of the research questions or hypotheses. Implications:

Explain the significance of the findings. Discuss how the results contribute to the field of study or practical applications. Limitations:

Acknowledge any limitations in the study that may affect the results or their interpretation.

5.3 Recommendations

The "Recommendations" section provides actionable suggestions based on the study's findings and conclusions. This section should:

Practical Applications:

Offer specific recommendations for practitioners, policymakers, or other stakeholders based on the findings. Future Research:

Suggest areas for further investigation that could address the study's limitations or build on its findings. Implementation:

Provide guidance on how the recommendations can be implemented effectively.

APPENDICES

Type your appendix here.

References

Alam, A., Chauhan, A., Khan, M. T., and Jaffery, Z. A. (2022). Drone-based crop product quality monitoring system: An application of smart agriculture. In *Agri-food 4.0*, pages 97–110.

Alvarado, M. C., Sanchez, P. D. C., and Polongasa, S. G. N. (2023). Emerging rapid and nondestructive techniques for quality and safety evaluation of cacao: Recent advances, challenges, and future trends. *Food Production, Processing and Nutrition*, 5:40.

Avila-Quezada, G. D. et al. (2023). Novel nanotechnological approaches for managing phytophthora diseases of plants. *Trends in Plant Science*, 28(9):1070–1080.

Babin, R. (2018). Pest management in organic cacao. In Vacante, V. and Kreiter, S., editors, *Handbook of pest management in organic farming*, pages 502–518. CAB International.

Choudhary, P., Shinde, B., Yadav, A., Kumayu, A., Parmar, A., Upadhyay, A., and Joshi, A. (2024). Potato disease classification: An attempt to detect the diseases in the early stages. *International Journal of Emerging Technologies and Innovative Research*, 5(6):262–272. Received: 18-09-2024; Accepted: 21-10-2024.

Department of Agriculture (2021). Philippine cacao industry roadmap 2021–2025. `https://www.da.gov.ph/philippine-cacao-industry-roadmap/`. Accessed: 2025-09-11.

Forest Phytophthoras of the World. Disease in phytophthora palmivora. Retrieved March 4, 2025, from `https://forestphytophthoras.org/species/palmivora-0/disease`.

Mazzia, V., Comba, L., Khaliq, A., Chiaberge, M., and Gay, P. (2020). Uav and machine learning based refinement of a satellite-driven vegetation index for precision agriculture. *Sensors*, 20(9):2530.

Merga, J. (2022). Epidemiology and management strategies of cocoa black pod (phytophthora spp.). *Plant Pathology & Quarantine*, 12(1):34–39.

Ministry of Agriculture, Land and Fisheries. Black pod disease of cocoa. [n.d.].

Nguyen, D. T., Pissard, A., Fernández Pierna, J. A., Rogez, H., Souza, J., Dortu, F., Goel, S., Hernandez, Y., and Baeten, V. (2022). A method for nondestructive determination of cocoa bean fermentation levels based on terahertz hyperspectral imaging. *International Journal of Food Microbiology*, 365:109537.

Philippine Council for Agriculture and Fisheries (PCAF) (2021). Pcaf recognizes davao region as the cacao capital of the philippines. `https://pcaf.da.gov.ph`. Accessed: 2025-09-11.

Quelal-Vásconez, M. A., Lerma-García, M. J., Pérez-Esteve, E., Talens, P., and Barat, J. M. (2020). Roadmap of cocoa quality and authenticity control in the industry: A review of conventional and alternative methods. *Comprehensive Reviews in Food Science and Food Safety*, 19(2):448–478.

Rahman, M. I. (2021). Durian plantation management using aerial imagery and gis application. Unpublished. Retrieved May 19, 2025, from `https://www.researchgate.net/profile/Nur-AdibahMohidem/publication/357333940`.

Silva, P. E. C. and Almeida, J. (2024). An edge computing-based solution for real-time leaf disease classification using thermal imaging. *IEEE Geoscience and Remote Sensing Letters*, pages 1–5.

Solpot, T. (2020). Cacao (theobroma cacao) diseases: Threats to the philippine cocoa industry. *ResearchGate*, 1(1):2–4.

Taesiri, M. R., Nguyen, G., Habchi, S., Bezemer, C.-P., and Nguyen, A. (2023). Imagenet-hard: The hardest images remaining from a study of the power of zoom and spatial biases in image classification.

Tan, D. S., Leong, R. N., Laguna, A. F., Ngo, C. A., Lao, A., Amalin, D. M., and Alvindia, D. G. (2018). Autodidac: Automated tool for disease detection and assessment for cacao black pod rot. *Crop Protection*, 103:98–102.

Tovurawa, E., Dlamini, B., Moore, S. E., and Marivate, V. Cacao plant disease detection and classification.

Upadhyay, A., Chandel, N. S., Singh, K. P., et al. (2025). Deep learning and computer vision in plant disease detection: A comprehensive review of techniques, models, and trends in precision agriculture. *Artificial Intelligence Review*, 58:92.

Vardhan, J. and Swetha, K. S. (2023). Detection of healthy and diseased crops in drone captured images using deep learning.

Wang, G., Chen, Y., An, P., Hu, H., Hu, J., and Huang, T. (2023). Uav-yolov8: A small-object detection model based on improved yolov8 for uav aerial photography scenarios. *Sensors*, 23(16):7190.

CURRICULUM VITAE

Name:	**Jodie Rey D. Fernandez**
Date of Birth:	July 27, 1992
Place of Birth:	Alae, Manolo Fortich, Bukidnon
Home Address:	Zone 5, Alae, Manolo Fortich, Bukidnon
E-mail Address:	`jodierey.fernandez@ustp.edu.ph`

EDUCATIONAL BACKGROUND:

Master's Degree:	MSU-Iligan Institute of Technology Tibanga, Iligan City Master of Science in Computer Applications June 2020
Undergraduate Degree:	Mindanao University of Science and Technology Lapasan, Cagayan de Oro City Bachelor of Science in Computer Engineering April 2013
Secondary:	Alae National High School

	Alae, Manolo Fortich, Bukidnon
	March 2008
Elementary:	Alae Elementary School
	Alae, Manolo Fortich, Bukidnon
	March 2004

CERTIFICATE OF AUTHENTIC AUTHORSHIP

I hereby declare that this submission is my own work and, to the best of my knowledge, it contains no materials previously published or written by another person, nor material which, to a substantial extent, has been accepted for the award of any other degree or diploma at USTP or any other educational institution, except where due acknowledgement is made in the manuscript. Any contribution made to the research by others, with whom I have worked at USTP or elsewhere, is explicitly acknowledged in the manuscript.

I also declare that the intellectual content of this manuscript is the product of my own work, except to the extent that assistance from others in the project design and conception or in style, presentation and linguistic expression is acknowledged.

JODIE REY D. FERNANDEZ

JODIE REY D. FERNANDEZ

JODIE REY D. FERNANDEZ

Date: ”insert date signed