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Development and Validation of a Tilapia Cutaneous Disease Detection System Using Machine Learning

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ABSTRACT

This study developed and validated a machine learning-based system integrated into a mobile application for detecting cutaneous diseases in tilapia. Focused on Oreochromis niloticus, the system utilized convolutional neural networks (CNN) trained with images from both local sources and online repositories. The application was tested with end users including farmers and IT experts, and evaluated using ISO 25010:2011 Software Quality Standards and the Technology Acceptance Model (TAM). Results showed high acceptability and accuracy, indicating that the system could serve as an effective early warning and disease management tool in aquaculture.

Keywords: *(machine learning, tilapia, disease detection, aquaculture, convolutional neural network, mobile application, ISO 25010, TAM)*

I. INTRODUCTION

Tilapia farming plays a vital role in global aquaculture and food security, especially in countries like the Philippines. In regions such as Cagayan Valley, it sustains rural livelihoods but remains vulnerable to disease outbreaks that cause significant fish mortality and financial loss. Disease detection methods are mostly manual and reactive, relying on farmers' visual inspections and informal resources like social media, often leading to delayed interventions.

Environmental stressors—such as fluctuating temperature and salinity—exacerbate disease outbreaks, yet local farmers lack tools like water testing kits or real-time diagnostic systems. This study addresses that gap by developing a machine learning-based mobile application that provides presumptive diagnoses of tilapia cutaneous diseases through real-time image classification using a CNN model. The app, built on .NET MAUI, is designed to be user-friendly, cross-platform, and multilingual for accessibility.

While AI and machine learning have shown potential in agriculture, their application in Philippine aquaculture remains limited. This research pioneers such integration, aiming to empower farmers with a practical and intelligent tool for early disease detection. The study also lays the groundwork for future enhancements, including sensor integration and broader species coverage, promoting a shift toward more data-driven and accessible fish health management.

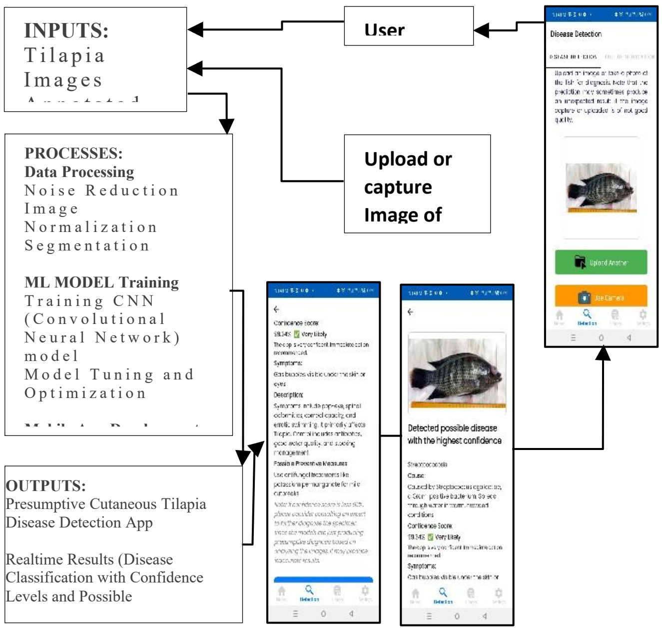
Objectives of the Study

This study aimed to develop and evaluate a mobile application powered by a machine learning model to detect cutaneous diseases in tilapia (Oreochromis niloticus). Specifically, it sought to analyze current disease detection practices, design a CNN-based image classification system, assess software quality using ISO 25010:2011, and evaluate user acceptability via the Technology Acceptance Model (TAM) to ensure effectiveness, usability, and integration into real-world aquaculture practices.

Conceptual Framework of the Study

The conceptual framework of this study was based on the integration of machine learning and image processing techniques for disease detection in tilapia. The process began with the collection of image and video data of tilapia exhibiting various health conditions. The images were preprocessed and analyzed using machine learning algorithms, such as convolutional neural networks (CNNs), to detect and classify diseases based on visual symptoms. The system's performance was then evaluated based on its accuracy, precision, and recall rates, and integrated into existing farm management practices for real-world testing and validation.

Figure 1. Input Process Output diagram



SIGNIFICANCE OF THE STUDY

The proposed system offers a transformative tool for small- and large-scale tilapia farmers by enabling early, image-based disease detection through a mobile app that is multilingual, accessible, and easy to use. It reduces mortality rates and economic losses by allowing timely intervention, especially for non-technical users in rural settings. By facilitating real-time diagnoses and simplifying workflows, it aligns with sustainable aquaculture practices and supports food security efforts.

For institutions such as CSU, government agencies, NGOs, and researchers, this system fosters innovation, supports interdisciplinary collaboration, and presents new opportunities in precision aquaculture. It demonstrates how AI can bridge the diagnostic gap in underserved communities and lays a foundation for future research in integrating environmental data and real-time monitoring into mobile-based solutions.

SCOPE AND LIMITATIONS

This study focused on developing a CNN-based mobile application to detect cutaneous diseases in Nile tilapia using image data sourced primarily from online repositories. The system was designed to perform real-time image classification and deliver presumptive diagnoses, tested within CSU-Aparri's aquaculture facilities under diverse environmental conditions.

Limitations included dependence on non-local image datasets due to the lack of archived local diseased fish images, variability in image quality, and generalizability of disease symptoms. Additionally, resource and budget constraints restricted the use of advanced imaging tools and broader field validation, which may affect the system's scalability and diagnostic depth.

II. METHODOLOGY

This study adopted a descriptive and developmental research design. The descriptive phase involved gathering data through surveys, interviews, and observations at aquaculture facilities of Cagayan State University–Aparri to understand current disease detection practices and challenges. These insights helped identify common symptoms, gaps in diagnosis, and informed the design of the system.

The developmental phase utilized the **Sprint Scrum Framework** (Figure 2), an agile methodology that structured the system's creation into iterative sprints, allowing

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continuous feedback and incremental improvements. The image dataset—primarily composed of labeled online images—was preprocessed and used to train a convolutional neural network (CNN) model. Data augmentation and transfer learning techniques enhanced the model's generalization to real-world conditions, and classification was focused on visible symptoms like lesions and discoloration.

Figure 2. Sprint-Scrum Framework

The trained model was integrated into a cross-platform mobile application designed with a user-friendly interface and multilingual support. Field trials were conducted with farmers and fisheries experts who used the app to perform real-time image-based disease detection.

The system was evaluated using ISO 25010:2011 quality metrics and the Technology Acceptance Model (TAM), focusing on accuracy, reliability, and user satisfaction.

III. Summary of Findings

The study aimed to develop and evaluate a mobile-based, machine learning-powered system for the presumptive diagnosis of cutaneous diseases in tilapia. Results showed that traditional disease detection in tilapia farming—particularly in the context of CSU-Aparri and surrounding local farms—relied heavily on manual visual inspection and anecdotal methods. Farmers and hatchery personnel commonly turned to informal sources such as social media or peer-shared practices due to the absence of formal diagnostic tools, often resulting in late interventions, high fish mortality, and limited documentation of past outbreaks. These challenges underscored the critical need for a more accessible, consistent, and technology-driven solution.

To address this need, the research introduced an intelligent image-based diagnostic system designed to support early detection through visual symptom analysis. The system underwent evaluation using two widely accepted frameworks: the **ISO 25010:2011 Software Quality Standard** and the **Technology Acceptance Model (TAM)**.

Table 1. Level of Acceptability Among Users

Dimension	Mean Score	Interpretation
Perceived Ease of Use	4.63	Excellent
Perceived Usefulness	4.20	Very Satisfactory
Self-Efficacy	4.59	Excellent
Response Efficacy	4.39	Very Satisfactory
Adoption Intentions	4.47	Very Satisfactory
Overall Mean	**4.45**	**Very Satisfactory**

Based on the Technology Acceptance Model (TAM)

The findings indicated that the system achieved high marks across all TAM dimensions, especially in **Perceived Ease of Use (4.63)** and **Self-Efficacy (4.59)**, highlighting the tool's accessibility even for users with limited technical expertise. These results reflect the app's ability to integrate smoothly into existing workflows and foster user confidence in technology use for aquaculture.

Table 2. ISO 25010 Software Quality Evaluation (IT Experts)

ISO Quality Attribute	Mean Score	Interpretation
Functional Suitability	3.38	Satisfactory – core functions are met; further feature refinement needed
Performance Efficiency	3.44	Satisfactory – performs reliably but may benefit from optimization

Compatibility	3.43	Satisfactory – integrates acceptably with other systems
Usability	3.41	Satisfactory – generally easy to use, minor UI improvements recommended
Reliability	3.43	Satisfactory – consistently operates under normal conditions
Maintainability	3.56	Very Satisfactory – system is updatable and testable
Portability	3.60	Very Satisfactory – system can be used across different platforms
Overall Mean	**3.47**	**Satisfactory** – meets standards but has room for technical enhancement

The ISO evaluation further affirmed the system's technical adequacy, particularly in **Portability (3.60)** and **Maintainability (3.56)**. While functional correctness and performance were found satisfactory, suggestions for refinement were noted to improve the system's scalability and precision.

Overall, the developed system was well-received from both a user and technical standpoint. It successfully demonstrated the potential of using machine learning to support **presumptive diagnosis** in aquaculture, particularly in resource-limited environments. The high user ratings in perceived ease of use and adoption intentions validate the app's applicability in real-world settings, while its performance across ISO attributes supports its ongoing development and deployment in support of smarter aquaculture practices.

IV. Conclusion

This study developed and validated a mobile-based application, *OreoChromDx*, that uses machine learning for presumptive diagnosis of tilapia cutaneous diseases. The findings confirmed limitations in current aquaculture disease detection methods, particularly manual inspection and the lack of diagnostic tools, especially in CSU–Aparri and nearby areas.

The mobile app, using a CNN-based image classification model, provides an efficient solution that empowers farmers with early detection capabilities. It was rated **Satisfactory** overall by IT experts based on ISO 25010:2011, with **very satisfactory marks** in Maintainability and Portability. End-users evaluated the system as **Very Satisfactory** under the Technology Acceptance Model, with particularly high marks in **Ease of Use (4.63)** and **Self-Efficacy (4.59)**.

Overall, the system demonstrated strong usability, technical reliability, and social acceptability, suggesting that it is both **technically viable and operationally valuable** for real-world tilapia health management.

V. Recommendations

Based on the findings and validation of the system, several recommendations are proposed to further enhance its applicability and impact. First, it is recommended that *OreoChromDx* be piloted within the aquaculture facilities of Cagayan State University–Aparri. This pilot deployment should include structured user training, feedback collection, and continuous monitoring to assess real-world performance and encourage adoption. Training sessions should also be conducted to help users interpret the system's outputs, with an emphasis on understanding that the system provides **presumptive diagnoses** and is not a substitute for laboratory-based confirmation.

To ensure continued relevance and effectiveness, future enhancements of the system should focus on expanding the disease image database, improving its functionality, and exploring integration with environmental monitoring tools—such as sensors for water temperature, pH, and salinity—to provide context-aware diagnostics. Notably, the application already includes **offline functionality**, which should be emphasized during training and promotion, especially in rural areas with limited internet access. This feature makes the app highly accessible and practical for small-scale farmers operating in low-connectivity environments.

Moreover, it is advisable to initiate broader **collaborative field testing** in partnership with the Bureau of Fisheries and Aquatic Resources (BFAR) and local aquaculture stakeholders. Their involvement in testing and feedback will provide valuable insights for refining the system's usability and applicability across different farming contexts. Finally, academic institutions are encouraged to integrate the system into ongoing research initiatives. Potential areas of exploration include **explainable AI (XAI)** to enhance model transparency, and hybrid systems that combine image classification with environmental and behavioral data, further enriching the diagnostic capability of the tool.

Finally, institutional support and policy backing should be explored to legitimize the role of digital, AI-assisted tools in aquaculture disease management. Establishing formal guidelines for using presumptive diagnosis systems can help bridge the gap between field realities and best practices, ultimately promoting sustainable aquaculture and better fish health outcomes.

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