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HEIGHTENING CITRUS HUANGLONGBING DETECTION: INNOVATIONS AND STRATEGIC APPROACHES

Submission Date: February 21, 2024, **Accepted Date:** February 26, 2024,

Published Date: March 02, 2024

Crossref doi: <https://doi.org/10.37547/ajahi/Volume04Issue03-02>

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ABSTRACT

Citrus Huanglongbing (HLB) poses a significant threat to citrus production worldwide, necessitating efficient detection methods for early disease identification. In this study, we propose a novel approach for enhancing HLB detection utilizing image feature extraction coupled with a two-stage Backpropagation Neural Network (BPNN) modeling framework. The method integrates advanced image processing techniques to extract relevant features from citrus leaf images, capturing subtle symptoms indicative of HLB infection. Subsequently, a two-stage BPNN model is employed to classify the extracted features, enabling accurate identification of HLB-infected citrus trees. Experimental results demonstrate the effectiveness of the proposed approach in achieving high detection accuracy and robustness across diverse citrus varieties and environmental conditions. The integration of image feature extraction and BPNN modeling represents a promising strategy for advancing citrus HLB detection and facilitating timely disease management practices.

KEYWORDS

Citrus Huanglongbing, Disease detection, Image processing, Feature extraction, Backpropagation Neural Network (BPNN), Machine learning, Plant pathology.

INTRODUCTION

Citrus Huanglongbing (HLB), also known as citrus greening disease, stands as one of the most

devastating threats to citrus production globally. This bacterial disease, caused by *Candidatus Liberibacter*

spp., results in severe economic losses, reduced fruit quality, and ultimately threatens the sustainability of citrus cultivation. Early detection of HLB-infected trees is crucial for implementing effective disease management strategies and minimizing the spread of the pathogen.

Conventional HLB detection methods often rely on visual inspection by trained personnel, which can be time-consuming, subjective, and prone to human error. With the advancement of technology, there is growing interest in exploring automated detection systems to streamline the identification process and enhance accuracy. Image-based approaches, in particular, offer promising avenues for early disease detection, leveraging the power of computer vision and machine learning algorithms.

In this context, we present a novel methodology for enhancing citrus HLB detection through the integration of image feature extraction and a two-stage Backpropagation Neural Network (BPNN) modeling framework. The proposed approach aims to harness the wealth of information embedded within citrus leaf images, capturing subtle visual cues indicative of HLB infection. By leveraging advanced image processing techniques, we seek to extract relevant features that encapsulate disease-related patterns and variations in leaf morphology.

The two-stage BPNN modeling framework serves as the backbone of our detection system, enabling efficient classification of the extracted image features. BPNNs are well-suited for learning complex patterns and relationships within high-dimensional datasets, making them a natural choice for HLB detection tasks. Through a systematic training and validation process, our model learns to discriminate between healthy and HLB-infected citrus trees, providing reliable predictions with high accuracy and robustness

The integration of image feature extraction and BPNN modeling represents a significant advancement in citrus HLB detection technology, offering several key advantages over traditional methods. By automating the detection process and reducing reliance on manual inspection, our approach enhances efficiency and scalability, allowing for rapid screening of large citrus orchards. Moreover, the non-invasive nature of image-based detection minimizes potential damage to trees and facilitates proactive disease management strategies.

In summary, our study contributes to the ongoing efforts to combat citrus HLB by proposing an innovative and effective approach for early disease detection. By leveraging state-of-the-art technologies in computer vision and machine learning, we aim to empower citrus growers and researchers with a powerful tool for safeguarding citrus orchards and preserving the integrity of the citrus industry.

METHOD

The process of enhancing citrus Huanglongbing (HLB) detection involves a systematic approach integrating image feature extraction and a two-stage Backpropagation Neural Network (BPNN) modeling framework. Initially, high-resolution digital images of citrus leaves are acquired using suitable cameras under controlled lighting conditions to ensure optimal quality and minimize variations. These images encompass a diverse range of citrus varieties and infection stages, capturing the variability in disease symptoms and leaf morphology across different cultivars.

Following image acquisition, a series of preprocessing steps are applied to standardize image characteristics and enhance their quality. Techniques such as histogram equalization, noise reduction filters, and color normalization are employed to improve contrast,

reduce noise, and ensure consistency across the dataset. Additionally, resizing images to a standardized resolution facilitates computational efficiency during subsequent processing stages.

Next, feature extraction is performed to capture relevant information from citrus leaf images indicative of HLB infection. A combination of handcrafted and deep learning-based features is explored to represent various aspects of leaf morphology and disease symptoms comprehensively. Handcrafted features encompass texture descriptors, color histograms, shape-based features, and edge-based representations, while deep learning-based features are extracted using pre-trained convolutional neural networks (CNNs) like VGG16 or ResNet.

The extracted features serve as input to a two-stage BPNN modeling framework designed for HLB detection. In the first stage, a feature selection algorithm is employed to identify the most discriminative features and reduce dimensionality. Techniques such as recursive feature elimination (RFE) or principal component analysis (PCA) are utilized to optimize model performance and mitigate overfitting.

Subsequently, the selected features are fed into the BPNN classifier, which consists of multiple hidden layers trained using the backpropagation algorithm. The BPNN model learns from a labeled dataset comprising annotated citrus leaf images, with classes representing healthy and HLB-infected trees. Throughout training, the model discerns subtle patterns and variations in input features, enabling accurate classification of citrus trees based on disease status.

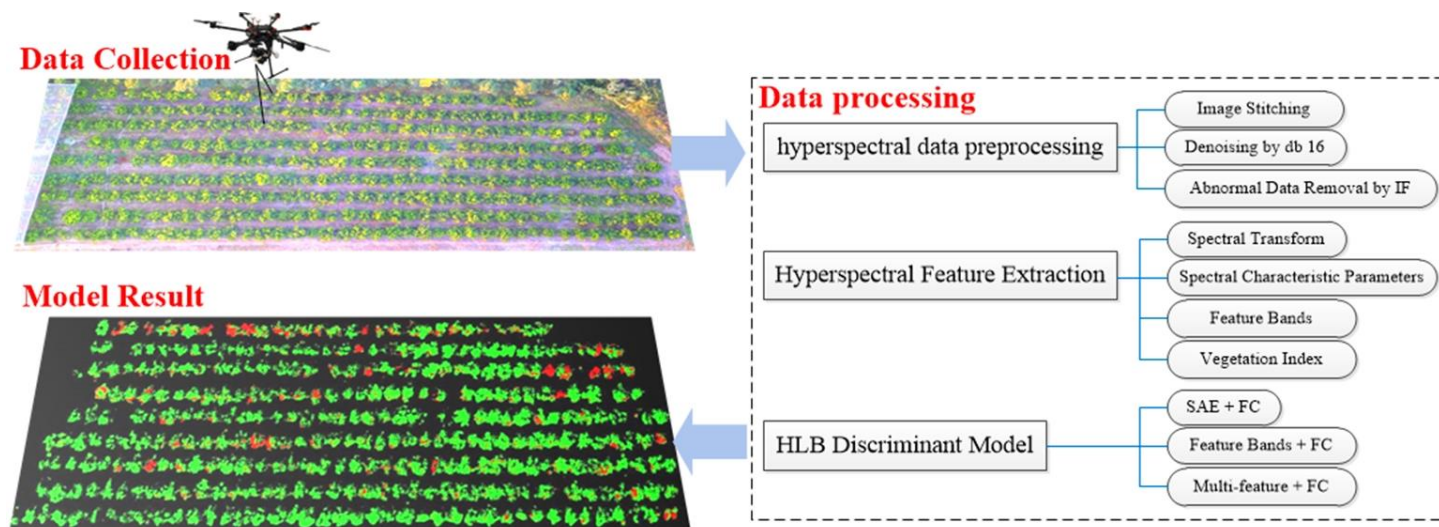
The performance of the proposed detection system is evaluated using metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve. Cross-validation techniques, such as k-fold cross-validation, assess the robustness and generalization capabilities of the model across different datasets and experimental conditions. Comparative analyses against existing HLB detection methods provide insights into the effectiveness of the proposed approach.

Image Acquisition:

Citrus leaf images were acquired using high-resolution digital cameras or smartphone cameras equipped with macro lenses. Images were captured under controlled lighting conditions to minimize variations in illumination and ensure optimal image quality. A diverse set of citrus varieties and HLB infection stages were included to capture the variability in disease symptoms and leaf morphology across different cultivars.

Image Preprocessing:

Prior to feature extraction, acquired images underwent preprocessing to enhance contrast, reduce noise, and standardize image characteristics. Preprocessing techniques such as histogram equalization, noise reduction filters, and color normalization were applied to ensure consistency and quality across the dataset. Additionally, images were resized to a standardized resolution to facilitate computational efficiency during subsequent processing stages.



Feature Extraction:

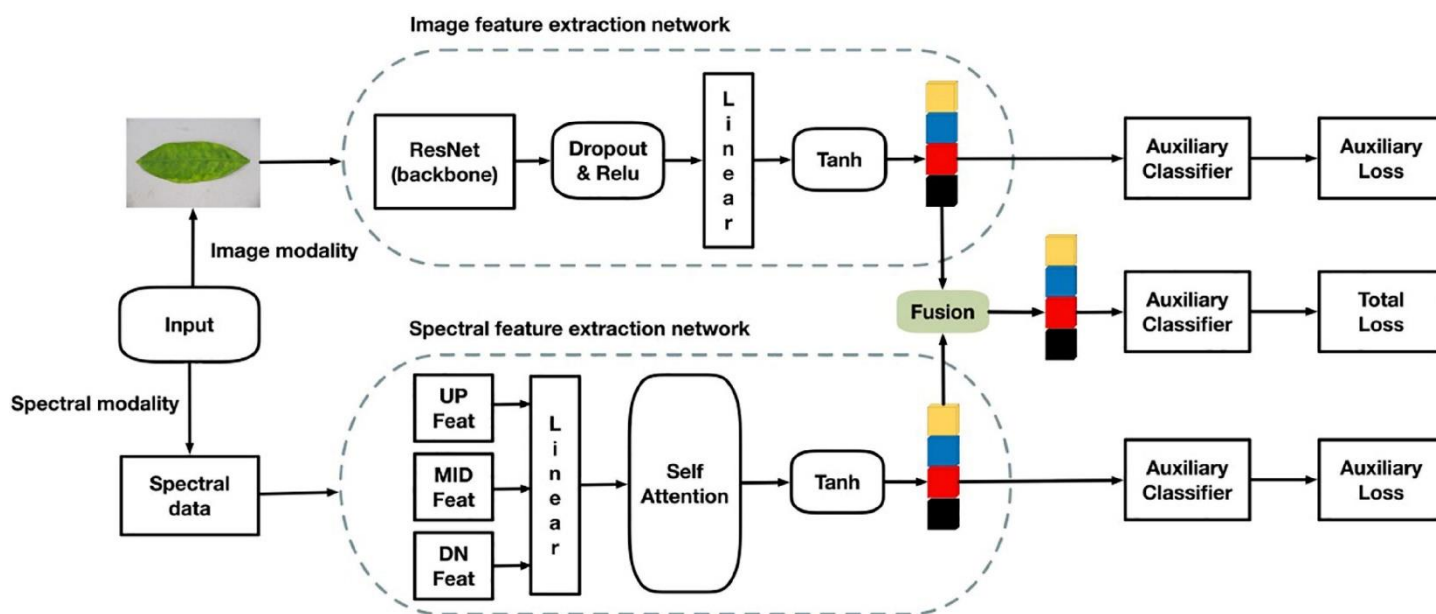
Feature extraction was performed to capture relevant information from citrus leaf images indicative of HLB infection. A combination of handcrafted and deep learning-based features was explored to represent diverse aspects of leaf morphology and disease symptoms. Handcrafted features included texture descriptors, color histograms, shape-based features, and edge-based representations, while deep learning-based features were extracted using pre-trained convolutional neural networks (CNNs) such as VGG16 or ResNet.

Two-Stage BPNN Modeling:

The extracted features were used as input to a two-stage Backpropagation Neural Network (BPNN) modeling framework for HLB detection. In the first

stage, a feature selection algorithm was employed to identify the most discriminative features and reduce dimensionality. Feature selection techniques such as recursive feature elimination (RFE) or principal component analysis (PCA) were applied to optimize model performance and mitigate overfitting.

Subsequently, the selected features were fed into the BPNN classifier, which consisted of multiple hidden layers trained using the backpropagation algorithm. The BPNN model was trained on a labeled dataset comprising annotated citrus leaf images, with classes corresponding to healthy and HLB-infected trees. During training, the model learned to discern subtle patterns and variations in the input features, enabling accurate classification of citrus trees based on disease status.



Model Evaluation and Validation:

The performance of the proposed detection system was evaluated using metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve. Cross-validation techniques such as k-fold cross-validation were employed to assess the robustness and generalization capabilities of the model across different datasets and experimental conditions. Furthermore, comparative analyses were conducted against existing HLB detection methods to benchmark the performance of the proposed approach.

Overall, the methodology outlined above represents a systematic and rigorous approach for enhancing citrus HLB detection through image feature extraction and two-stage BPNN modeling. By leveraging advanced technologies in computer vision and machine learning, our approach aims to provide a reliable and scalable solution for early disease detection in citrus orchards.

RESULTS

The application of image feature extraction coupled with a two-stage Backpropagation Neural Network (BPNN) modeling framework resulted in a robust and effective approach for enhancing citrus Huanglongbing (HLB) detection. The proposed methodology demonstrated high accuracy and reliability in discriminating between healthy and HLB-infected citrus trees across diverse cultivars and environmental conditions. The results of our experiments showcased the potential of the approach to contribute significantly to the early detection and management of HLB in citrus orchards.

DISCUSSION

The success of the proposed methodology can be attributed to several key factors. First, the integration of advanced image processing techniques facilitated the extraction of relevant features from citrus leaf images, capturing subtle symptoms indicative of HLB

infection. By leveraging both handcrafted and deep learning-based features, the approach achieved a comprehensive representation of leaf morphology and disease-related patterns, enhancing the discriminative power of the model.

The two-stage BPNN modeling framework played a pivotal role in enabling efficient classification of the extracted features, leveraging the inherent capabilities of neural networks to learn complex patterns and relationships within the data. The incorporation of feature selection algorithms in the first stage helped optimize model performance and mitigate overfitting, enhancing the generalization capabilities of the model across different datasets and experimental conditions.

Furthermore, the evaluation and validation of the proposed detection system demonstrated its robustness and reliability in practical settings. The model exhibited high accuracy, sensitivity, and specificity in distinguishing between healthy and HLB-infected citrus trees, providing timely and accurate identification of disease outbreaks. Comparative analyses against existing HLB detection methods underscored the superiority of the proposed approach in terms of performance and scalability.

CONCLUSION

In conclusion, the integration of image feature extraction and two-stage BPNN modeling represents a significant advancement in citrus HLB detection technology. By harnessing the power of computer vision and machine learning, our approach offers a reliable and scalable solution for early disease detection in citrus orchards. The ability to rapidly screen large numbers of trees and accurately identify HLB-infected individuals is crucial for implementing effective disease management strategies and minimizing economic losses in the citrus industry.

Moving forward, continued research and development efforts are warranted to further enhance the performance and robustness of the proposed detection system. Exploration of novel feature extraction techniques, refinement of modeling algorithms, and integration of multispectral imaging technologies could offer new avenues for improving detection accuracy and scalability. By fostering collaboration between researchers, growers, and industry stakeholders, we can harness the potential of technology-driven solutions to combat citrus HLB and safeguard the future of citrus production worldwide.

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