A Banana Leaf Disease Detection System of an Energy-Efficient CNN-Based Framework

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Abstract: Diseases that afflict banana leaves have a substantial influence on the productivity and quality of crops, representing an important obstacle for sustainable agricultural systems and food security. Rapid and precise disease identification is crucial for sound crop management and loss minimization. The major benefit associated with leveraging machine learning and deep learning technologies within the agricultural domain lies in their capacity to facilitate fully automated diagnosis of plant disease through image-based analysis, particularly effectively complemented by detection certainty under smart agriculture systems. The paper proposes an efficient CNN-based automated framework for banana leaf disease detection. A thorough review of literature, insight into existing knowledge gaps, and a well-defined research hypothesis are elements that create a solid foundation for research. The framework here integrates preprocessing, data augmentation, and a transfer learning–based EfficientNet architecture with an emphasis on computational efficiency that is suitable for real-time deployment. This paper showcases the initial phase of a multi-phase research study aimed at conceptual design and methodological development.

Keywords: Banana Leaf Disease Detection, Convolutional Neural Networks (CNN), Transfer Learning, EfficientNet, Precision Agriculture

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Introduction

Banana has great importance among the fruit crops worldwide and is one of the most consumed fruits, contributing a lot to agro economies and food security. But banana plants are very susceptible to various diseases like Black Sigatoka, Yellow Sigatoka, Panama disease, and Fusarium wilt, which drastically decrease the yield and quality of the crop. Early identification of these diseases plays an important role in reducing crop losses and increasing productivity. Conventional methods of disease identification is primarily based on manual inspection, which is labor-intensive, time consuming and prone to human error.

With the recent development of artificial intelligence and deep learning, automated plant disease detection has become possible using image processing and convolutional neural networks.]In addition,

hybrid and ensemble learning techniques have been used to enhance crop prediction and agricultural decision-making [1]. In precision agriculture, deep learning model-based disease detection models have proven superior in terms of accuracy and robustness as compared to older methods based on image processing [2].

Related work

Many works have been conducted for banana leaf disease detection using deep learning techniques. Transfer learning–based CNN [convolutional neural network] models have gained a lot of popularity, as they improve classification performance while also simplifying the training process [13]. For banana leaf disease recognition, an approach has been proposed using YOLOv10-based object detection, and it has been shown to effectively detect banana leaf diseases with real-time performance [3]. Deep learning architectures were being used for disease classification in banana crops, with models showing promising results that CNN-based feature extraction could be a powerful technique [4].

Elastic net models have been trained for detecting banana leaf spot disease using machine learning–based approaches with feature extraction methods [4]. For example, ensemble and hybrid deep transfer learning models have been proposed in order to improve classification accuracy and robustness in banana leaf disease detection systems [6]. Moreover, the incorporation of deep learning in agricultural disease diagnosis further validates its capacity to increase detection accuracy as well as crop protection [7].

In the previous papers, they explored optimization strategies and transfer learning to improve CNN classification for banana leaf diseases, which includes a study of comparative analysis between optimization algorithms [8]. Detection of Fusarium wilt at early stages has also been explored based on hyperspectral imaging fused with deep learning [9] contributing to enhanced disease monitoring and diagnosis. Likewise, deep learning–based methods have also been suggested for the identification of the plant disease called Panama wilt in agro-based models and have led to better classifications [10].

Hybrid deep learning frameworks that use advanced architectures have been successfully implemented in precision agriculture for banana leaf disease classification [11]. In which image processing–based disease detection systems are also proposed to be related to the rapid identification of diseases by farmers and crop management [12]. It has been further shown that transfer learning-based deep CNN models can excel at detecting Fusarium wilt in banana crops which potentially illustrates the necessity of pretrained feature extraction [14].

Research Gap and Hypothesis

A framework is established that gives accurate results in banana leaf disease prediction. Literature review shows a great advancement in this area, but there are still challenges to be overcome. Current approaches are based on computationally expensive architectures, making real-world deployment not feasible. Moreover, the lack of comparison for lightweight CNN architectures and a narrow focus on real-time applicability call for efficient and deployable systems for disease detection. Utilizing transfer learning and data augmentation, a scalable and real-time deployable CNN

Proposed Framework

For the dataset, we use banana leaf images of different diseases and healthy leaves. We split the dataset into train, validation, and test sets to allow for unbiased model development. All images are resized and

normalized to the same input size limits to make the model more consistent and converge faster. We apply data augmentation techniques like rotation, flipping, zooming, and contrast adjustments to increase the diversity of the dataset and improve model generalization. We utilize a convolutional neural network-based EfficientNet with pretrained weights as our feature extractor for the proposed framework. A lightweight classification head is added to do multi-class disease classification retaining computational efficiency. This framework allows for implementation in a web-based application, which is beneficial for real-time detection of diseases on banana leaves and for deploying it practically in agriculture.

Conclusion and Future Work

In this paper, we propose the concept of a CNN-based framework for the automated detection of banana leaf diseases. Through literature review, research question identification, and hypothesis formation, a robust body of research was built. The proposed framework focuses on transfer learning, computational efficiency, and real-time deployment as a basis for experimental evaluation and optimization. Future work will include focus areas such as model training, performance evaluation, dataset augmentation, and deployment for large-scale applications in smart agriculture disease detection.

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