A Classification and Detection of Cotton Leaf Disease Using Lightweight CNN Architecture

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Abstract: The rapid and accurate detection of diseases in cotton leaves is crucial for ensuring high agricultural productivity and minimizing economic losses. Traditional methods of disease detection, relying heavily on manual inspection, are time-consuming and prone to errors. To address these challenges, we propose a lightweight Convolutional Neural Network (CNN) architecture designed specifically for the classification and detection of cotton leaf diseases. Our model focuses on optimizing computational efficiency and accuracy, making it suitable for deployment on edge devices with limited processing power. The proposed CNN architecture employs a series of convolutional layers with reduced parameters, leveraging techniques such as depth-wise separable convolutions and global average pooling to maintain high performance while minimizing computational costs. We trained and validated our model on a comprehensive dataset comprising various cotton leaf diseases, including bacterial blight, leaf spot, and mildew. Experimental results demonstrate that our lightweight CNN achieves a high classification accuracy, outperforming several existing models in terms of both speed and precision. Furthermore, our model's ability to generalize across different disease types highlights its potential for real-world applications. By enabling early and accurate detection of cotton leaf diseases, our approach promises to significantly enhance crop management practices, reduce the reliance on chemical treatments, and contribute to sustainable agricultural practices.

1 INTRODUCTION

Cotton is a critical cash crop and a staple in the textile industry worldwide. However, cotton cultivation is often threatened by various leaf diseases, which can significantly impact crop yield and quality. Timely detection and accurate classification of these diseases are essential for effective disease management and prevention. Traditional methods of disease detection rely heavily on visual inspection by experts, which is labour-intensive, time-consuming, and prone to human error (Chatfield, Simonyan et al. 2014). Recent advancements in computer vision and machine learning offer promising solutions to automate this process. Among these, CNNs have demonstrated remarkable performance in image classification tasks, including disease detection in crops.

This study focuses on employing a lightweight CNN architecture for the classification and detection of cotton leaf diseases. The term "lightweight" refers to neural networks designed to have fewer parameters and computational requirements, making them suitable for deployment on devices with limited resources, such as

smartphones or edge devices. This approach not only aims to provide accurate disease classification but also to ensure efficiency and practicality in real-world applications (Tijare, Khade, et al. 2019). The lightweight CNN architecture proposed in this study is designed to balance performance and computational efficiency, enabling real-time analysis of cotton leaf images. By leveraging transfer learning and optimization techniques, the model achieves high

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classification accuracy while maintaining a low computational footprint (Zhang, Shang, 2019). This enables rapid and scalable deployment in agricultural settings, potentially transforming the way farmers and agricultural professionals manage cotton crops.

In summary, this research aims to enhance the precision and accessibility of cotton leaf disease detection through the development of a lightweight CNN model, offering a practical solution for disease management in cotton cultivation.

2 LITERATURE SURVEY

In their paper titled (Barbedo, and Arnal, 2019), the authors delve into the realm of cotton leaf disease detection through innovative image processing techniques. This research is poised to offer insights into the application of advanced technologies for identifying and analyzing diseases affecting cotton plants. Leveraging the capabilities of image processing, the study likely explores methodologies for efficient disease detection and analysis, aiming to contribute valuable knowledge to the intersection of agriculture and technology. In the paper (Bhong, Vijay, et al. 2018), the authors introduce an innovative approach to cotton leaf disease detection. The methodology centres around a super pixel-based roughness measure, showcasing a nuanced and sophisticated method for capturing intricate details associated with diseases affecting cotton plants. By leveraging this novel approach, the research aims to enhance disease detection and classification accuracy as well as efficiency, showcasing the potential for advanced information technology applications in the agricultural domain. In the article authored by Jayme Garcia Arnal and Barbedo, titled (Barbedo, and Arnal, 2019) "A new automatic method for disease symptom segmentation in digital photographs of plant leaves," the author introduces an innovative and automated approach to segmenting disease symptoms in plant leaves from digital photographs. This method is designed to streamline and enhance the process of identifying and isolating specific symptoms associated with plant diseases, contributing to the field of plant pathology (Swetha, et al. 2021). The research likely delves into sophisticated image processing techniques to automate the segmentation process, potentially providing a more efficient and accurate means for researchers and practitioners to analyze and understand the manifestation of diseases in plant leaves.

In their collaborative work, (Schmidhuber, 2019) The authors undertake a detailed investigation, emphasizing the importance of addressing subtle yet crucial aspects in the design and implementation of CNNs. This work likely delves into specific architectural choices, optimization techniques, or challenges encountered during deep neural network training, shedding light on nuanced factors that substantially influence these models' performance. Current article (Khan, et al. 2018), the authors address the critical task of plant disease recognition using leaf images. The study likely explores methodologies and techniques for leveraging image processing along with machine learning for disease identification & classification of affected plant leaves. By focusing on plant leaf images as a key input, research contributes to field of agricultural science & technology, aiming to enhance early disease detection and ultimately improve crop management. In the collaborative work (Lumb, Sethi, et al. 2017), the authors conduct a comprehensive survey on methods and technologies employed in the identification of diseases affecting cotton leaves. In the research paper (Islam, Talukder, et al. 2023), the authors explore innovative methods for texture feature extraction from various image representations. The study likely investigates the use of diverse color spaces, including RGB, HSV, and YIQ, along with dithered images, employing techniques such as Wavelet Decomposition & GLCM(Grey Level Co-occurrence Matrix). In (Russakovsky, Deng, et al. 2020) author offers comprehensive survey along with an analysis of fundamental principles and advancements in deep learning(DL) field. The work is likely to offer insights into the historical development, key concepts, and theoretical underpinnings of deep neural networks. Given the title's emphasis on an overview, the paper may serve as an introductory guide for researchers, practitioners, and enthusiasts seeking a broad understanding of the principles that form DL basis in neural networks. In the paper (Patki, Sable, et al. 2018) authors contribute to field of computer vision by presenting ImageNet Large Scale Visual Recognition Challenge(ILSVRC). This influential challenge, documented in the paper, has performed vital function in advancing algorithm development and evaluation for large-scale image classification tasks.

3 METHODOLOGY

Proposed system processes foliage diseases' input images, expressed as three-dimensional arrays. These images undergo several steps to ensure accurate detection and classification:

Data Pre-processing: Photographs are rescaled and labelled during data pre-processing phase. These prepared images subsequently inputted into model.

Model Training: CNN is trained utilizing cotton leaves images. The training process involves multiple iterations where the model learns to identify patterns associated with various foliage diseases.

Evaluation and Adjustment: After training, the model's performance is evaluated for accuracy. Parameters are adjusted based on evaluation results, and the training process is repeated until satisfactory accuracy is achieved.

Deployment: Once training & evaluation are complete, model is deployed for use. The trained classifier labels new, unseen images of leaves, identifying and categorizing them based on learned patterns.

By accurately identifying and mapping disease-affected areas, farmers can develop targeted treatment plans. This supports the concept of precision agriculture, optimizing the use of resources such as pesticides and fertilizers.

4 SYSTEM REQUIREMENTS

Cotton leaf disease recognition, utilizing a lightweight CNN structure, represents a sophisticated yet resource-efficient approach. This system optimizing image acquisition and processing, leveraging the efficiency of a streamlined CNN for feature extraction and disease classification. A lightweight design allowing swift real-time detection, ensuring timely intervention in the field. Despite its efficiency, the system maintained high accuracy and precision, critical for reliable disease identification. The user interface tailored for simplicity, facilitating easy use, specifically in mobile applications for on-the-field diagnoses. Architecture's scalability enhances, enabling seamless integration with diversified devices and accommodating a growing user base. Moreover, the system adheres to strict security mechanisms, ensuring protection for sensitive agricultural data.

Functional requirements of the system defining the behaviour, responses, and functionality of the system, while the non-functional requirements focus on features like reliability and user-friendly design (Rothe, Kshirsagar et al. 2019).A feasibility study conducted under the non-functional requirements. The system requires a laptop with an Intel i3 or above processor with satisfactory storage and RAM. Software needs include Windows 10, Python for coding, and libraries like Kera's and TensorFlow.

4.1 System Architecture

System architecture defines the larger overall structure that covers both software hardware. This illustrating diagram demonstrating the components and their interactions. The entire architecture describing how input, processing data, and displaying the output

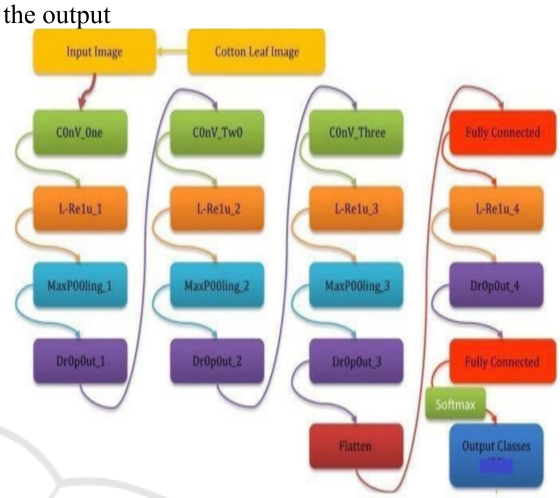

Figure 1. System Architecture

5 IMPLEMENTATION

To detect cotton leaf diseases applying CNN, follow these steps:

Collect Data: Gather many images of healthy cotton leaves and leaves with diseases like blight or curl.

Prepare Images: Resize and adjust the colors of these images to ensure consistency.

Build CNN: Create a CNN model with layers that can recognize patterns in images, differentiating between healthy and diseased leaves.

Train the Model: Show the CNN the prepared images, labelling them as healthy or diseased so it can learn to recognize these patterns.

Evaluate Performance: Test the CNN on new, unseen images to check its accuracy.

Deploy: Use the trained CNN to analyze new images of cotton leaves, identifying if they are healthy or diseased, allowing for early intervention.

Data Collection: Gather images dataset containing healthy cotton leaves & leaves infected with various diseases such as bacterial blight, leaf curl, etc. You can find datasets online or collect and label your own.

Data Pre-processing: Pre-process images by resizing them to fixed size, normalizing pixel values,

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along with augmenting data (e.g., rotating, flipping, zooming) for increasing dataset diversity & modifying model's generalization.

Model Architecture: CNN architecture designed for image classification. You can start with a simple architecture like LeNet or go for more complex architectures like VGG, ResNet, or DenseNet (Sarangdhar, Pawar, et al. 2024), depending on the size and complexity of your dataset.

Model Training: Divide your dataset into training, validation, & test sets. Train your CNN model on the training set using techniques like RMSprop, stochastic gradient descent (SGD), or Adam, & tune hyperparameters such as batch size, learning rate, along with number of epochs employing validation set.

Finally, with a trained and validated model in hand, we can deploy it for practical use in detecting cotton leaf diseases. This could involve integrating the model into a software application or system that can analyze images of cotton leaves and provide insights or recommendations based on the detected disease conditions. Ongoing monitoring and refinement may be necessary to ensure the model remains effective as new data becomes available or as environmental conditions change.

6 RESULTS

The results chapter outlines the outcomes of the project, which focused on cotton leaf disease classification & detection employing lightweight CNN architecture.

These results highlight effectiveness of using a lightweight CNN architecture for disease detection in cotton crops, showcasing its potential to advance agricultural practices and support sustainable cotton farming.

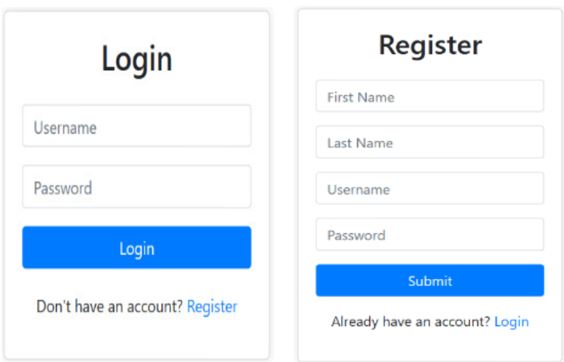

Figure 2: Login Image and Register Image

The login page for Cotton Leaf Disease Detection System serves as the secure entry point for users, including farmers, agronomists, and researchers, to access the system's functionalities. Designed with user-friendliness and security in mind, the page features fields for entering username or email & password, along with "Login" button for submitting these credentials for authentication. To accommodate new users, a sign-up link directs them to a registration page, while a "Forgot Password" link assists users in recovering their account access. Security is bolstered through HTTPS encryption, CAPTCHA verification, and an account lockout mechanism after multiple failed login attempts.

The "Register Image" page for the Cotton Leaf Disease Detection System employs CNN architecture designed to facilitate the seamless upload of cotton leaf images for disease analysis. This page provides an intuitive interface where users, including farmers and agronomists, can easily submit images for processing.

Figure 3: Disease classification.and uploading image

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The "Cotton Leaf Detecting Image" page of the Cotton Leaf Disease Detection System provides users with an efficient and user-friendly interface to upload images of cotton leaves for disease diagnosis. Upon accessing this page, users can easily select images from their devices or use drag-and-drop functionality for quick uploads. The system guides users through the upload process with clear instructions and real-time feedback, ensuring images are correctly formatted and of adequate quality for analysis.

The "Cotton Leaf Uploading Image" feature within the Cotton Leaf Disease Detection System streamlines the process of submitting images for analysis, offering users a straightforward and intuitive interface. Upon accessing this functionality, users are prompted to upload images of cotton leaves from their devices, supported by drag-and-drop functionality or traditional file selection methods. The system ensures ease of use by providing clear instructions and visual cues throughout the upload process. This step ensures that images are appropriately formatted and prepared for accurate disease detection. By simplifying the image upload process and incorporating pre-processing functionalities, the system enhances user experience and empowers users to efficiently contribute to the disease detection process, ultimately fostering more effective management strategies for cotton crop health.

6.1 Cotton Leaf Variant Identified as Below

Figure 4: Healthy Cotton and Army Worm

Healthy cotton leaves are vital indicators of a well-maintained and productive cotton crop. These leaves are essential for photosynthesis, providing the energy needed for plant growth and cotton fibre production. Healthy cotton leaves are typically a rich, vibrant green, indicating adequate chlorophyll and proper nutrient levels.

Armyworm disease, caused by the larvae of various moth species, is a major global threat to agriculture. The fall armyworm (Spodoptera frugiperda) is particularly notorious for its voracious feeding, causing extensive damage to crops such as maize, rice, cotton, and sugarcane.

Figure 5: Bacterial Blight and Powdery Mildew.

Destructive disease in plants caused by various bacterial pathogens, most notably Xanthomonas spp, is termed a Bacterial blight. It affects a wide range of crops, including rice, cotton, and soybeans, leading to significant yield losses and economic impact.

A prevalent fungal disease affecting variety of plants, encompassing cereals, vegetables, & ornamentals termed as Powdery mildew. It is caused by different species of fungi in the order Erysiphales, with each species typically specific to a particular host.

Figure 6: Target Spot and Aphids

Target spot disease is a fungal infection caused primarily by Corynespora cassiicola, affecting a variety of crops, including cotton, soybean, tomato, and cucumber. The disease is named for the characteristic concentric rings or "targets" that appear on infected plant tissues.

Aphid infestation is frequently impacting wide range of crops, consisting cotton, cereals, vegetables, & fruit trees. Aphids are small, soft-bodied insects feeding on plant sap, causing direct damage & potentially transmitting plant viruses.

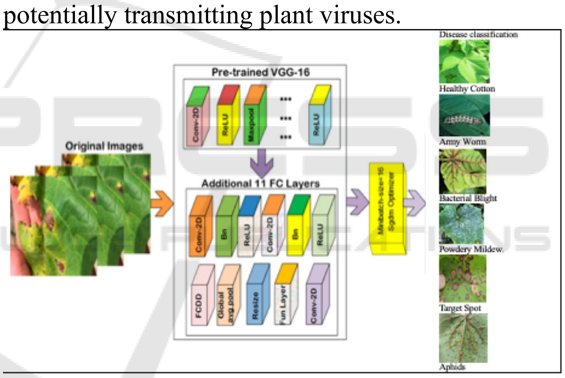

Figure 7: Cotton leaf disease classification

The results encapsulate the outcomes and achievements derived from the implementation of the project. Through a comprehensive analysis of user engagement, transaction processes, transparency measures, resource management practices, and data-driven decision-making, the project has demonstrated significant advancements in the agricultural domain. Key highlights include enhanced user engagement facilitated by a user-friendly interface, streamlined transactions leading to improved efficiency, heightened transparency through blockchain integration, optimized resource management practices, and data-driven insights empowering informed decision-making.

7 CONCLUSIONS

Our study demonstrates the efficacy of Convolutional Neural Networks (CNNs) in detecting cotton leaf diseases with remarkable accuracy and reliability. By leveraging techniques such as data augmentation and transfer learning, we achieved commendable results in distinguishing between healthy and diseased cotton leaves. The use of pre-trained CNN architectures facilitated rapid convergence during training and enabled the extraction of crucial features necessary for accurate disease identification.

Despite these promising results, several challenges persist. Notably, there is a need for larger annotated datasets and the exploration of advanced imaging techniques additional improvement in model's performance. However, the implications of our research are significant, providing farmers with the tools for early and precise disease diagnosis. This capability can lead to optimized crop management practices and reduced yield losses.

Looking ahead, further efforts are essential in expanding datasets, refining algorithms, and validating the technology in real-world agricultural settings. Such advancements will be pivotal in transitioning this technology from research to practical, widespread use in agricultural systems. Our study underscores the effectiveness of CNNs in automated cotton leaf disease detection and highlights the importance of continued research to enhance and implement these solutions in farming practices.

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