Digital Object Identifier

Tomato Disease Detection Using CNN Algorithm

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ABSTRACT The development of a country heavily relies on the growth of its agricultural sector. However, agriculture today confronts numerous challenges such as labor shortages, the impacts of climate change, unpredictable rainfall patterns, proliferation of diseases affecting plants and crops, fluctuating market prices, among others. Thus, the agricultural domain faces an array of formidable threats. Researchers have developed applications capable of accurately identifying various diseases affecting tomato plants based on leaf images captured through smartphones or cameras. Farmers face the critical challenge of timely and accurate detection of diseases in their tomato plants, which directly affects crop yield and livelihoods. Deep learning techniques, particularly convolutional neural networks (CNNs), have gained prominence for their ability to accurately classify diseases based on image data. We Used CNN algorithm with ResNet18 architecture.Our CNN model gave an accuracy of 90 which is highest among all.The research aims to help farmers grow more food and earn more money by using better methods to detect and manage diseases in crops. These improvements make farming easier and more profitable, encouraging farmers to continue their work and produce more food for everyone.

I. INTRODUCTION

AI plays a pivotal role in tomato disease detection through its advanced capabilities in image recognition, data analysis, and decision support. By employing techniques such as deep learning and computer vision, AI algorithms can analyze images of tomato plants to identify symptoms of diseases like leaf spots, blight, and viruses with high accuracy. [4]

Additionally, AI processes vast datasets containing information on disease symptoms, causes, and treatments to uncover patterns and correlations that aid in more precise diagnosis. This enables early detection of diseases, empowering farmers to take proactive measures to mitigate crop damage. Integrated into precision agriculture systems, AI monitors plants in real-time, providing timely interventions based on data from sensors and drones. By automating the detection and diagnosis process, AI streamlines operations, saving time and resources for farmers while ensuring the health and productivity of tomato crops. [5]

Tomato Care is a complete agricultural solution which is designed to solve the problems of farmers. This advanced platform, which is available for Android, leverages cutting-edge technology to revolutionize the way farmers detect and manage diseases in their tomato crops. [7] With current methods falling short in addressing the complexities of tomato crop health, Tomato Care aims to provide an efficient and innovative solution to empower farmers. [9] By seamlessly integrating image-based disease detection, treatment recommendations, and real-time updates, Tomato Care ensures a holistic approach to crop health management. [15]

Detecting diseases in tomato plants is crucial for ensuring healthy yields and preventing crop loss. There are various diseases that can affect tomato plants, such as early blight, late blight, bacterial spot, and more. [6] Traditional methods of disease detection often rely on visual inspection by experienced people, which can be time consuming and subjective. However, advancements in technology, particularly in the field of machine learning have made way for more efficient and accurate methods of disease detection in tomatoes. [8]

This user-friendly platform not only enhances the accuracy of disease identification but also encourages a collaborative environment where farmers can make informed decisions for optimal yields. [9] The old ways of finding diseases in tomato plants are not always good enough, and it is hard to find and fix problems quickly. But Tomato Care is here to help. It uses advanced technology to make sure we find and understand the diseases in tomato crops better and faster. [10]

Farmers face the critical challenge of timely and accurate detection of diseases in their tomato plants, which directly affects crop yield and livelihoods. Traditional methods of disease identification rely on visual inspection, which can be time-consuming. Farmers need an accessible and reliable solution that leverages technology to identify diseases quickly and effectively in tomato plants, enabling them to take proactive measures for disease management and protect their agricultural investments. [14]

The project aims to create a user-friendly mobile application tailored for farmers, facilitating the identification of tomato plant diseases through image capture. By leveraging advanced technologies like machine learning, the app will enable precise disease recognition. [13] Beyond mere identification, it will offer valuable recommendations for treatment, empowering farmers to take proactive measures against potential threats to their crops. Ensuring the app remains updated with the latest information on plant diseases is integral to its functionality. Ultimately, the project seeks to support farmers in safeguarding their crops, ultimately contributing to enhanced harvests and bolstered food production on a larger scale. [12]

II. LITERATURE REVIEW

The literature reviews highlight a burgeoning interest in employing deep learning techniques, particularly convolutional neural networks (CNNs), for the detection and classification of diseases in tomato plants. Studies by Durmuş et al., Ashqar and Abu-Naser, and Gadade and Kirange emphasize the potential of advanced machine learning algorithms in addressing agricultural challenges, although specific tools or frameworks are not explicitly detailed. [6] Similarly, Chowdhury et al. and Ullah et al. underscore the importance of integrating computer vision and machine learning methodologies for plant disease detection, showcasing the interdisciplinary nature of agricultural research. Efforts by Parvez et al. and others focus on leveraging CNNs for the detection and classification of tomato crop diseases, aligning with the broader trend of utilizing deep learning methodologies in agriculture. [1] Additionally, innovative approaches such as LightMixer and hybrid optimization-enabled deep learning demonstrate strides towards developing efficient and accurate disease detection systems tailored for resource-constrained environments. Furthermore, studies exploring hyperspectral imaging technology and spectrum Transformer networks offer novel methods for identifying disease severity in tomato plants. Overall, these literature reviews collectively advocate for the adoption of deep learning and machine learning techniques to enhance disease management strategies and ensure healthy tomato cultivation. [13]

A. SURVEY TEHNIQUES

The applications related to tomato cultivation and plant diagnosis encompass a range of techniques tailored to enhance agricultural practices. Detailed tomato cultivation applications often integrate traditional farming methods with modern technologies such as precision agriculture, sensor-based monitoring, and data analytics to optimize crop growth and yield. [2] Techniques such as soil analysis, crop rotation, irrigation management, and pest control strategies are commonly employed to ensure optimal plant health and productivity. Tomato cultivation tips typically leverage expert knowledge and best practices, focusing on aspects like selecting disease-resistant varieties, proper spacing and pruning techniques, soil amendment recommendations, and seasonal cultivation advice. [3]

Durmuş, Halil et al., 2017: In their paper titled "Disease detection on the leaves of the tomato plants by using deep learning," presented at the 2017 6th International Conference on Agro-Geoinformatics, the authors explore the application of deep learning techniques to address the challenge of detecting diseases on tomato leaves. They aim to develop robust algorithms capable of accurately identifying various diseases commonly affecting tomato plants, with the ultimate goal of enhancing the efficiency and precision of disease detection in agricultural settings.

Saeed, Alaa et al., 2023: Published in Agriculture in 2023, "Smart detection of tomato leaf diseases using transfer learning-based convolutional neural networks" introduces a novel approach for identifying tomato leaf diseases. The authors propose a smart detection system leveraging transfer learning-based convolutional neural networks. This method utilizes pre-trained models to enhance the accuracy and efficiency of disease detection, contributing to improved agricultural productivity.

Ashqar, Belal AM and Abu-Naser, Samy S, 2018: In their work published in IJARW in 2018, the authors present "Image-based tomato leaves diseases detection using deep learning." This study focuses on utilizing deep learning methodologies for detecting diseases in tomato leaves based on image data. The research explores advanced techniques to automatically identify and classify various diseases affecting tomato plants, aiming to aid farmers in early disease detection and intervention.

Kumar, Yogesh et al., 2023: Published in the Archives of Computational Methods in Engineering in 2023, "A systematic review of different categories of plant disease detection using deep learning-based approaches" provides an extensive overview of various approaches employed for plant disease detection using deep learning techniques. The paper analyzes different categories of plant diseases and evaluates the effectiveness of deep learning-based methods in accurately diagnosing these ailments. This systematic review offers valuable insights into the current state-of-the-art in plant disease detection and suggests potential directions for future research and development

Tm, Prajwala et al., 2018: In the paper "Tomato leaf disease detection using convolutional neural networks," presented at the 2018 Eleventh International Conference on Contemporary Computing (IC3), the authors delve into the application of convolutional neural networks (CNNs) for detecting diseases on tomato leaves. Through their research, they aim to develop a robust system capable of accurately identifying various diseases that commonly affect tomato plants. By leveraging CNNs, they seek to enhance the efficiency and precision of disease detection in agricultural contexts.

Chowdhury, ME et al., 2021: Published in Technology in Agriculture in 2021, "Tomato leaf diseases detection using deep learning technique" explores the utilization of deep learning techniques for the detection of tomato leaf diseases. The authors employ advanced deep learning methods to develop a system capable of accurately identifying and classifying diseases affecting tomato plants. This research contributes to the advancement of agricultural technology by providing efficient tools for disease diagnosis and management in tomato cultivation.

Harakannanavar, Sunil S et al., 2022: In the paper titled "Plant leaf disease detection using computer vision and machine learning algorithms," published in Global Transitions Proceedings in 2022, the authors investigate the application of computer vision and machine learning algorithms for detecting diseases in plant leaves. Through their research, they aim to develop automated systems capable of efficiently identifying and diagnosing diseases affecting various plant species. This work contributes to the development of technology-driven solutions for enhancing crop health and productivity.

Gadade, Haridas D et al., 2021: Presented at the 2021 5th International Conference on Computing Methodologies and Communication (ICCMC), "Machine learning based identification of tomato leaf diseases at various stages of development" focuses on utilizing machine learning techniques for the identification of tomato leaf diseases at different stages of development. The authors aim to develop a comprehensive system capable of accurately diagnosing diseases across various growth stages of tomato plants. This research contributes to the advancement of agricultural practices by providing timely and accurate disease detection methods for tomato cultivation.

Ullah, Zahid et al., 2023: Published in Agriculture in 2023, "EffiMob-Net: A deep learning-based hybrid model for detection and identification of tomato diseases using leaf images" introduces a novel hybrid model for detecting and identifying tomato diseases from leaf images. The authors present EffiMob-Net, a deep learning-based approach that combines multiple techniques to enhance the accuracy and efficiency of disease detection. This research contributes to the development of advanced tools for disease management in tomato cultivation.

Paul, Showmick Guha et al., 2023: In the paper "A real-time application-based convolutional neural network approach for tomato leaf disease classification," published in Array in 2023, the authors propose a real-time application-based approach for classifying tomato leaf diseases using convolutional neural networks (CNNs). Their method aims to provide efficient and accurate classification of various diseases affecting tomato plants, facilitating timely intervention and management strategies.

Parvez, Shamima et al., 2023: The authors present "Tomato leaf disease detection using convolutional neural network" in 2023. While specific publication details are not provided, this research likely explores the application of convolutional neural networks (CNNs) for detecting diseases on tomato leaves. The study aims to develop a CNN-based system capable of accurately identifying and classifying tomato leaf diseases, contributing to the advancement of disease diagnosis in tomato cultivation.

Sakkarvarthi, Gnanavel et al., 2022: Published in Electronics in 2022, "Detection and classification of tomato crop disease using convolutional neural network" investigates the use of convolutional neural networks (CNNs) for detecting and classifying diseases in tomato crops. The authors develop a CNN-based approach to efficiently identify and classify various diseases affecting tomato plants, thereby aiding farmers in timely disease management and enhancing crop yield.

Aishwarya, N et al., 2023: In "Smart farming for detection and identification of tomato plant diseases using lightweight deep neural network," published in Multimedia Tools and Applications in 2023, the authors introduce a smart farming approach for detecting and identifying diseases in tomato plants. They propose a lightweight deep neural network model tailored for efficient disease detection and identification, aiming to enhance agricultural productivity through timely disease management.

Anim-Ayeko, Alberta Odamea et al., 2023: Published in Smart Agricultural Technology in 2023, "Automatic blight disease detection in potato (Solanum tuberosum L.) and tomato (Solanum lycopersicum, L. 1753) plants using deep learning" presents a study on automatic detection of blight disease in potato and tomato plants. The authors utilize deep learning techniques to develop a system capable of automatically detecting blight disease, contributing to the automation of disease detection processes in agriculture.

Bakır, Halit, 2024: In "Evaluating the impact of tuned pre-trained architectures' feature maps on deep learning model performance for tomato disease detection," published in Multimedia Tools and Applications in 2024, the author evaluates the impact of tuned pre-trained architectures' feature maps on the performance of deep learning models for tomato disease detection. The study aims to optimize deep learning model performance by tuning pre-trained architectures' feature maps, thereby improving the accuracy and efficiency of tomato disease detection systems.

B. STRENGTHS AND WEAKNESSES

Tomato disease detection applications present a promising solution for farmers by offering early detection of diseases, thereby enabling timely interventions to mitigate crop damage. These applications leverage advanced technologies such as machine learning and image processing to analyze images of tomato plants, accurately identifying symptoms of various diseases. [8] Their ability to detect diseases at an early stage not only minimizes yield losses but also reduces the need for extensive pesticide use, contributing to sustainable agricultural practices. Moreover, these applications can be cost-effective in the long run, potentially saving farmers significant expenses associated with manual inspections and crop losses. [9]

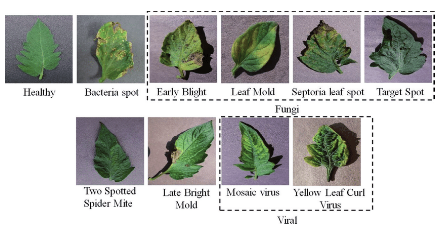
However, tomato disease detection applications are not without their limitations. They often require robust technological infrastructure, including smartphones, cameras, and internet connectivity, which may not be readily available in all agricultural regions. Additionally, the accuracy of these applications can be influenced by environmental factors such as lighting conditions and weather variability, posing challenges to consistent performance. [10] Furthermore, the diversity of tomato diseases and variations in plant morphology can limit the effectiveness of detection algorithms, necessitating ongoing refinement and adaptation. Addressing these challenges will be crucial for realizing the full potential of tomato disease detection applications in supporting sustainable and efficient tomato cultivation practices. [11]

III. PROPOSED METHODOLOGY

The methodology for tomato disease detection typically involves several key steps, beginning with data collection and preprocessing. High-resolution images of tomato plants exhibiting symptoms of various diseases are captured using digital cameras or smartphones. These images are then preprocessed to enhance their quality, remove noise, and standardize features to facilitate effective analysis. Subsequently, feature extraction techniques are employed to identify relevant patterns and characteristics within the images. [12]

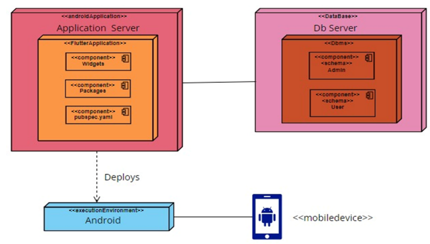
Following feature extraction, machine learning algorithms are trained using labeled datasets to classify images into different disease categories. Supervised learning techniques such as support vector machines (SVM), convolutional neural networks (CNN), or decision trees are commonly utilized for this purpose. During the training phase, the algorithm learns to distinguish between healthy and diseased tomato plants based on the extracted features. Once trained, the model is tested using separate validation datasets to evaluate its performance metrics such as accuracy, precision, recall, and F1-score. [13]

A. DISEASES

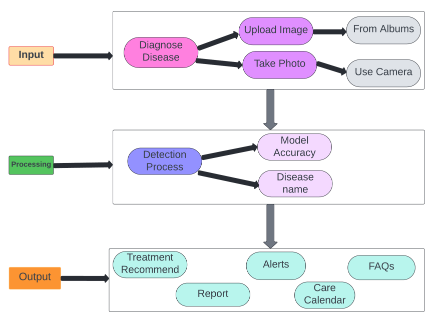


Tomato plants are susceptible to a variety of diseases that affect their leaves, potentially leading to significant yield losses if left unchecked. Among the most common leaf diseases are early blight and late blight, both characterized by dark lesions that can rapidly spread throughout the plant. [6] Septoria leaf spot presents with small, circular lesions and yellow halos, while bacterial spot manifests as dark, water-soaked lesions surrounded by yellow halos. [9] Tomato yellow leaf curl virus causes leaf curling, yellowing, and stunted growth, while powdery mildew forms white, powdery growth on leaves, hindering photosynthesis. Fusarium wilt results in yellowing and wilting of leaves, often leading to plant death. Other notable diseases include bacterial canker, gray leaf spot, leaf mold, and viral diseases like tomato mosaic virus. [11] Effective management strategies, including crop rotation, sanitation, and use of resistant varieties, are crucial for mitigating the impact of these diseases on tomato production. [15]

B. DESIGN



Tomato disease detection is crucial in precision agriculture, offering early intervention to reduce crop losses. Traditional methods are labor-intensive and error-prone, leading researchers to explore image processing and machine learning solutions. [14] Data collection involves image acquisition, preprocessing, and feature extraction, while model training includes dataset preparation and algorithm selection. Disease detection involves image classification and identification. [15]



This is a methodology diagram of our tomato disease detection application named as Tomato Care, designed to revolutionize how farmers manage the health of their tomato plants. Divided into three meticulously crafted segments, the interface begins with the Input phase, providing farmers with two convenient methods for diagnosing diseases. Within this section, the user is presented with the option to either upload an image or capture one using their device's camera. By offering such flexibility, Tomato Care ensures accessibility for users, enabling them to effortlessly select images from their albums or snap new ones in real-time.

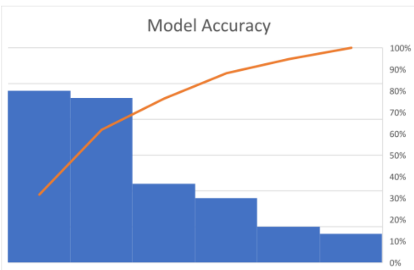
Transitioning into the Processing phase, the application showcases the intricate detection process. Here, users are provided with crucial insights into model accuracy and precise disease identification. This segment serves as the heart of Tomato Care, leveraging advanced algorithms to analyze uploaded images and deliver accurate diagnoses. Through this comprehensive processing phase, farmers can gain valuable information about the health status of their tomato plants, empowering them to make informed decisions regarding treatment and management.

Finally, the Output segment of Tomato Care serves as a comprehensive resource hub for farmers, presenting treatment recommendations and detailed disease reports. This section doesn't stop at diagnosis; it goes above and beyond by offering practical tools to aid in plant care. The inclusion of an alert system ensures timely treatment administration, while a customizable care calendar helps farmers stay organized and informed about treatment schedules. Moreover, the FAQ section provides answers to common queries about tomato diseases, fostering greater understanding and confidence among users.

Connected seamlessly, these three components—Input, Processing, and Output—form the backbone of Tomato Care, offering a holistic approach to tomato plant health management. By integrating cutting-edge technology with practical tools and comprehensive insights, Tomato Care empowers farmers to effectively safeguard their crops and maximize their yields.

IV. EXPERIMENTS AND RESULTS

A. MODEL ACCURACY



The graph shows that the accuracy of our model is achieving higher with the changing of datasets. It depends on the dataset on which we have trained our model. It achieves a final accuracy of 90 and still we are aiming to produce more further.

Our dataset comprises an extensive collection of 24 thousand leaf images meticulously curated to facilitate the training of our model. Through a rigorous training process, we subjected the model to three iterations on this dataset, aiming to optimize its ability to accurately detect diseases afflicting the leaves. It was imperative to refine the model's performance, ensuring robust accuracy in disease identification. After the fourth attempt, our efforts culminated in achieving an impressive accuracy rate of approximately 90, a testament to the efficacy of our training methodology. To further enhance the model's capabilities, we employed epoch runs, meticulously fine-tuning its parameters to maximize performance.

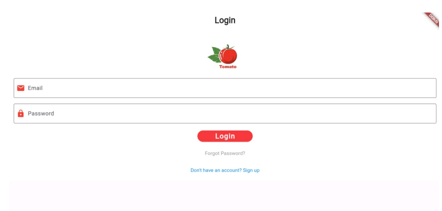
The training process was conducted utilizing a batch size of 32, a strategically chosen parameter to balance computational efficiency with training effectiveness. Leveraging the ResNet 18 architecture, renowned for its depth and efficiency, we endeavored to harness state-of-the-art technology to empower our model with the capacity to discern and classify leaf diseases with unparalleled precision and reliability. Through meticulous experimentation and optimization, we have laid the foundation for a robust and dependable tool poised to revolutionize disease diagnosis and management in agricultural settings, offering invaluable support to farmers and researchers alike in safeguarding crop health and ensuring global food security

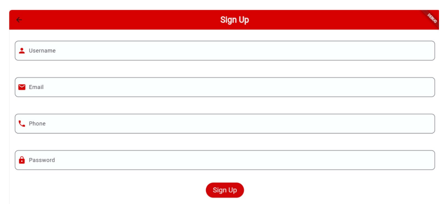
B. LIMITATIONS

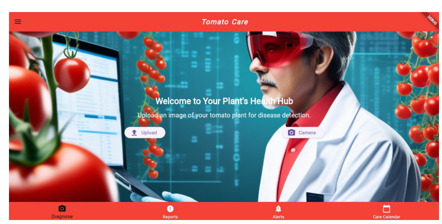
Although our CNN model, based on ResNet18, effectively detects diseases in tomato leaves, it has some limitations. It tends to identify any green-colored object, leading to false positives for objects with similar hues. This reduces its ability to specifically identify tomato leaves. Additionally, it may struggle to differentiate between different types of leaves if they appear similar. [10] The model's reliance on color features can result in inaccuracies in varying lighting conditions or with different shades of green in tomato leaves. Moreover, it may not perform well with backgrounds or textures resembling tomato leaves, limiting its generalization capabilities. Despite these challenges, the model achieves good accuracy in detecting tomato leaf diseases. [13]

V. TOOLS AND SUPPORT

A. PROTOTYPE







The hardware and software requirements outlined for tomato disease detection encompass essential components for both data collection and algorithm development. The hardware requirements include a phone for image capture in the field, a server for data storage and processing, and sufficient storage capacity to store the collected images and processed data. [12] On the software side, a database is needed for organizing and managing the collected data, while programming languages such as Python or R are essential for algorithm development. Frameworks like TensorFlow or PyTorch provide the necessary tools for building and training machine learning models for disease classification. [11]

Development tools and version control systems help streamline the software development process and ensure collaborative and iterative improvements to the detection system over time. By meeting these hardware and software requirements, researchers and practitioners can effectively develop and deploy tomato disease detection systems for agricultural management. [10]

VI. CONCLUSION

The tomato disease detection project aims to streamline the process of identifying and managing diseases affecting tomato plants to improve crop yields and agricultural sustainability. [9] The proposed solution involves a user-friendly mobile app interface where farmers can capture photos of their tomato plants using smartphones. [5] These images are then analyzed using image processing and machine learning algorithms to identify diseases and assess their severity. Based on the analysis results, the app provides farmers with tailored treatment recommendations for the detected diseases. [2]

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