Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7766137

TOMATO LEAF DISEASE RECOGNITION-A CRITICAL REVIEW

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Abstract: Among the most important and widely used crops in the globe is the tomato. The volume of tomatoes varies based on the method of fertilization. The main element affecting crop output in terms of both quality and quantity is leaf disease. Therefore, it is crucial to correctly identify and categorize these afflictions. Early intervention of these infections would lessen their impact on tomato plants and ensure optimum productivity. The various strategies used in plant disease identification are thoroughly reviewed using Machine Learning (ML) and deep learning, both of which are centered on artificial intelligence (AI). Similarly, deep learning has grown significantly in importance for providing improved performance results for identifying plant diseases in the computer vision field. In order to demonstrate the superiority of the deep learning model over the ML model, a comparison of the two techniques' performances and applications in different scientific articles has been made. The deep learning method has the potential to identify leaf diseases from data obtained in order to avoid significant yield reductions.
Keywords: Agriculture, Plant diseases detection, Machine-learning methods, Deep learning.

1. INTRODUCTION

Agricultural production has long been linked with the farming of fundamental plants that are thought to be crucial to our survival and our diet. The vast majority of the people in India rely on agriculture and livestock for their livelihoods. Contaminated plants and harvests, both qualitatively and quantitatively, cause a decrease in yield. Consequently, it is difficult to correctly recognize plant leaf maladies. It is extremely challenging to quantify illnesses with the naked eye. Therefore, it is important to comprehend precise and specific image patterns these days. In the field of biological research, numerous images are produced by a particular investigation and can then be classified. Therefore, for any further classification, experts must examine and extricate the particular elements. In addition, in this situation, visual analysis is crucial. Infections are brought on by climatic variation, and they significantly reduce agricultural output. Fungal, bacterium, and viruses as well as unfavorable ecological factors are the main causes of prevalent afflictions. Consequently, the most important job in the early stages of a disease is its identification. The farmer must continuously use a specialist method to examine the harvest. Therefore, it is essential in cultivation to use computerized and effective disease detection methods. Bacteria, viruses, and fungi infect the majority of tomato leaves. As a result, the study concentrated on gathering information about plant diseases and developing a specific model for disease detection. Deep learning methods, aid in the identification, classification, and detection of leaves on plants for disease detection.

Recently, a number of deep-learning methods have been used to identify plant illnesses, CNN is one of the most popular methods. Deep learning is a novel method in machine learning (ML), with cutting-edge results in many areas of study, such as computer vision, pharmacy, and bioinformatics. Deep learning benefits from being able to use raw data without the need for human processing. For two primary reasons, deep learning has produced notable successes in both academia and business. First, huge data is generated every day. Consequently, these details could be used to create a thorough strategy. Second, because of the computing power of the Graphics Processing Unit, deep models may be taught and applied to improve computational and storage efficiency. Although many studies on tomato leaf diseases have been conducted, it is still challenging to distinguish them in the early stages due to the significant chrominance similarity between the affected and unaffected plant areas. The different plant leaf sizes, variations in light and energy, the presence of noise, and blurring in the suspected images have all made the detection technique more challenging. Therefore, there is still room for possible advancement in the accuracy and speed of plant disease identification. The remainder of the essay is structured as follows: Section 3 discusses related research in relation to the various techniques used to identify tomato diseases. Section 2 reviews the various symptoms and kinds of leaf diseases. The conclusion follows.

2. SYMPTOMS & DISEASE OF TOMATO LEAF

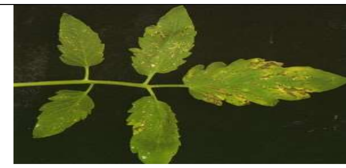
A specific alteration in the plant's color, form, or functionality as a result of the infection can be one of the symptoms. Here we address the signs of these illnesses that need to be taken into consideration if plant growth appears to be slow. The secret to preventing crop decline is the precise categorization and disease identification. Various species of leaves carry various illnesses with varying signs and symptoms. The following is the brief explanation of various diseases that affect tomato plants.

Disease Name	Infected Leaf Image
Alternaria Canker: On stalks, leaves, and fruit, Alternaria canker symptoms can be seen. The lamina of the leave between the veins is severely damaged, which causes leaf twisting and ultimately results in the death of the complete leaf.	
Early Blight (Alternaria): Alternaria, a different fungus that causes tomato plant diseases, also produces leaf spot or early blight. Lower leaves have dark-edged brown or black patches that resemble targets. Fruit stem ends may be harmed, displaying significant sunken, black regions with concentric circles. Typically after plants produce fruit, this tomato plant disease fungus manifests itself.	
Tomato Bacterial Diseases: Numerous bacterial illnesses of tomato plants, such as bacterial spot, bacterial speck, and bacterial canker, can affect tomatoes. The patches they deposit on leaves and fruits are all subtly different from one another.	

Bacterial Speck: The presence of bacterial particles is widespread. Any portion of the plant can exhibit signs. Tiny, lumpy, dark-brown spots of necrotic tissue with yellow haloes cover the leaves of infected plants.

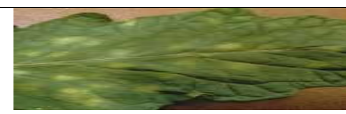
Bacterial Spot: On the leaves, water-soaked spots that start out as dark brown ultimately turn black and finally the afflicted tissue dies, leaving a hole. Fruit begins to develop at the same time with black, raised specks that later turn into scab-like patches.

Gray Leaf Spot: At first, tiny brownish-black, flecks can be seen on the lower leaf surface. These eventually grow into bigger necrotic areas, and the tissue frequently separates, giving the area a shot-hole look. Patterns could have a golden halo surrounding them. In extreme stages, yellowing, leaf drop, and defoliation may happen.



Late Blight: The fungus Phytophthora causes the tomato plant disease late blight, which can appear at the conclusion of a vegetative stage throughout cold, rainy seasons. The uneven green-black speckles on the foliage resemble frost damage. Huge, atypically curved brown spots on fruit that rapidly spoil the produce.

Leaf Mold: Light green streaks on the top surfaces of older leaves are the symptoms. In these places, a purplish or olive-green patch of mold development can be seen under the leaves. Yellowed, diseased leaves fall off the shrub.

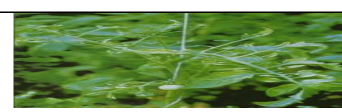


Powdery Mildew: On mature leaves, powdery mildew initially appears as yellow spots that, upon careful observation, reveal a whitish-gray powder on the surface. Even though the leaves will ultimately fall off, they usually hang on to the stem. Humid and dry weather is worse for the illness.

Septoria Leaf Spot: One of the most prevalent illnesses of tomato plant leaves is this type. This fungus first shows itself as a tiny, circular spot with a grayish-white centre and dark borders. There might be a few tiny dark spots in the middle. The leaves of tomato plants that are impacted change yellow, wilt, and drop off.

Verticillium Wilt: Affected leaves on plants with Verticillium wilt start to wilt at the leaf margins and change yellow before turning brown. Plants become stunted, and watering does not stop withering. In cross-section, the stem exhibits a light tan discoloration; illness progresses more quickly in chilly climates.

Cucumber Mosaic Virus: Stunted plants with virus infections frequently have underdeveloped foliage. Plants look to be bushy. The look of leaves is frequently "shoestring," and they may be mottled. Fruit is distorted and tiny.



Tomato Spotted Wilt Virus: Fruit is deformed, with raised bull's-eye bands in yellow, red, and green. Fruit-bearing plants have stunted growth and older foliage that is going yellow. The petiole of the leaves has dark streaks running along it and golden speckling. The leaf's growing ends could perish.

Salt Damage: The older foliage of the tomato plant gather extra salt. Yellowing leaves will ultimately fall off. Although the plant is weak and stunted, other signs might not be present.

Phosphorus Deficiency: The most typical symptom is purpling of the foliage, especially the veins. In extreme circumstances, the entire plant may develop a purple color. Poor phosphorus uptake occurs in tomato roots developing in cold soil, whether in a greenhouse or a field. Plants with deficiencies become weaker and produce less.

Beet Armyworm: Larvae have teeth for eating. The lips of adults are siphoning. Young larval stages frequently graze on the outer (epidermal) layer of cells on the underside of leaves as they eat in close proximity. They could create a thin web like the one in the image over the foliage. Larger caterpillars graze by themselves and eat leaf tissue, which can completely defoliate the host plant.

Leaf Miner: The larvae are consuming the chlorophyll-rich mesophyll cells as they move through the tomato leaf lamina. As a result, an uneven trail of infected tissue is left behind, ultimately leading to the leaf's demise. Vegetable crops with high levels of damage have stunted development and lower yields.

3. RELATED WORK

3.1. Disease Detection Using Various CNN Architectures

The approaches taken by the different authors who have detailed various ways to use CNN for disease detection are described below. They built a CNN model to identify pests and diseases in tomato crops using images of diseased tomato crop leaves [4]. The deep learning framework was used to train the detection model, which had an average classification success of 89%. In order to identify and prevent tea leaf diseases effectively, CNN was used to realize the image recognition of tea disease leaves. Firstly, image segmentation and data enhancement are used to preprocess the images, and then these images were input into the network for training. Secondly, to reach a higher recognition accuracy of CNN, the learning rate and iteration numbers were adjusted frequently and the dropout was added properly in the case of over-fitting. Finally, the experimental results show that the recognition accuracy of CNN is 71%, while the accuracy of SVM and BP neural network is 69% and 67% respectively. Therefore, the recognition algorithm based on CNN is better in classification and can improve the recognition efficiency of tea leaf diseases effectively [17].

The authors attempted to identify diseases that affect plants in greenhouses or tomato farms. Deep learning was applied to this task in order to identify the different diseases present on tomato plant leaves. Sensors installed in manufactured conservatories were used to identify diseases from up-close photos of plants [3]. In this work, researchers have been inspired by the success of deep learning in computer vision to improve the performance of detection systems for plant diseases. Most of these studies are based essentially on AlexNet, GoogleNet or similar architectures. The research did not take advantage of deep learning visualization. In this paper, they have tested multiple state-of-the-art Convolutional Neural Network (CNN) architectures using three learning strategies on a public dataset for plant disease classification. These new architectures outperform the state-of-the-art results of plant disease classification with an accuracy reaching 96%. Furthermore, they have proposed the use of saliency maps as a visualization method [3]. To detect the disease a deep learning-based approach is discussed in this paper. For disease detection and classification, a Convolution Neural Network based approach is applied. In this model, there are 3 convolution and 3 max-pooling layers followed by 2 fully connected layers. The experimental results show the efficiency of the proposed model over the pre-trained model i.e. VGG16, InceptionV3 and MobileNet. The classification accuracy varies from 76% to 100% with respect to classes and average the accuracy of the proposed model is 91%.

3.2. Disease Detection Using Machine Learning Algorithms

The approaches taken by different authors are described below as ways to use machine learning algorithms for disease detection. The thresholding algorithm was employed by the authors [5] to identify the illness. They identified the illness by calculating threshold values and comparing them to predetermined default values. These two characteristics color and shape are used to identify diseases. When performing a K-means cluster analysis, objects are grouped so that those in the same group (cluster) are more comparable to those in other groups. With this method, the authors were able to identify diseases with an accuracy of 89% without the need for additional hardware. In this method, determining the number of k was problematic. The threshold values and segmentation of the picture were calculated using the Traditional thresholding algorithm by the authors [6]. Authors processed images after segmenting the tomato image from the backdrop. Natural picture segmentation based on thresholding was employed. Since it used an older methodology than, it only provided an accuracy of 85%. With this method, segmentation was a challenge for pictures with unevenly lit backgrounds.

This paper focuses on supervised machine learning techniques such as Naive Bayes (NB), Decision Tree (DT), K-Nearest Neighbor (KNN), Support Vector Machine (SVM), and Random Forest (RF) for maize plant disease detection with the help of the images of the plant. The aforesaid classification techniques are analyzed and compared in order to select the best suitable model with the highest accuracy for plant disease prediction. The RF algorithm results with the highest accuracy of 69% as compared to the rest of the classification techniques [7]. In this paper, their main objective is to create an end-to-end system for detecting tomato disease using the machine learning algorithms like logistic regression, support vector machine, and random forest algorithms. To extract the features from the image Histogram of Oriented gradients is used, and for evaluating the model, classification metrics are used like precision, recall, and f1 score. Out of all these algorithms, the support vector machine performed best by using HOG as a feature descriptor and at the last step, image classification is deployed with the help of the Stream light application [8].

3.3. Disease Detection Using Acoustic Emission

Acoustic emission was employed by the authors [9] to identify diseases. In order to provide a theoretical foundation for condition-based and precise disease prevention and treatment, acoustic emission signals were sent out when the crop was under disease stress and was acquired by acoustic emission sensors and an automatic detecting system of acoustic emission information for crop disease stress that used a PC computer. A contrast experiment study using a healthy tomato crop and a disease-stressed tomato crop was conducted in a greenhouse as part of the research and development of a system for identifying the conditions of crop disease stress by acoustic emission technology [10]. The findings indicate that there are specific physiological cycle laws in the acoustic emission of healthy crops, generally the "double peak area" can appear; distortion occurs in the acoustic emission of disease-stressed crops, and a sharp increase in the acoustic emission frequency can take place at some point, implying the crop is starting to show disease symptoms; and acoustic emission of healthy crops, generally the "double peak area" can appear.

A real-time acquisition and detecting system for the information between acoustic emission and disease was built by the authors [11] using a PCI-2 acoustic emission board and R15 acoustic emission sensor probes as the hardware detecting system. The software system was built using AEWIN software and virtual instrument technology. Virtual Instrument (VI) Technology created the system's foundation, establishing conversations between people and crops to provide a theoretical foundation for condition-based, accurate disease prevention and treatment. The acquired data were plotted into charts using the cumulative number of times an acoustic emission happened in an hour as the measure of frequency.

The data acquisition system and the upper machine software were used by the authors [12] in their article to obtain and analyse acoustic emission signals from tomato plants with disease and water stress. Using statistical analysis of the parameters of acoustic emission patterns, a mathematical model was put forth, and its validity was established. Ultrasonic acoustic emission signals are concerned with the impact of noise, and the model is used to extract high-frequency signals. This can be utilized as a guide for acoustic source position or irrigation control. In this study, a mathematical model for the acoustic emission signals of tomato crops under water stress is built using the waveform analysis technique. The average counts of acoustic emission signals of tomato crops under diseases and water stress, according to statistical analysis, are between 4 and 10 times; however, real observation data revealed that, under normal conditions, each will generate an acoustic emission event about 30 times.

3.4 Artificial intelligence and deep learning based plant disease detection

They [22] demonstrated a method for using deep learning to identify plant diseases that could harm harvests and agricultural production and reduce crop output. The current deep learning methods expansion discovered their utility for identifying plant diseases, which contributed to the significant tool having better precision findings. The current flaws and restrictions of models for identifying plant diseases are examined and displayed. The authors of this article provided examples to support their claims, including the fact that agriculture and related industries make up the majority of the Indian economy and account for 60 to 70% of the country's economic growth. The challenge of crop leaf disease detection is the primary concern raised in this article. Although there are various categorization logics used in the research, all of them are stuck at a certain degree of complexity [26]. In order to achieve high accuracy levels in results, a well-known SVM model is used in this method. They [25] proposed a fresh extract strategy for the improved sub-set function. Depending on the forms, cultivation should be monitored for algorithmic items based on the categorization assistance provided by vector machines. The technologies' success can be best evaluated with a total precision of around 89%.

They [27] proposed that the concept be centered on fuzzy sets. The luminance quantity must be taken into account in-pixel in the images for the calculated degree whenever the instability may appear. Only when a fuzzy package properly handles image uncertainty, IFSs are handled. When the satellite can compute the segmentation's activation, the number of unknown capture images can be reduced. Then, since it relies on the spacing between the intuitionist fuzzy set, the segmentation of the deficit of the crops for the clustering method will fuse an image. The development of an automatic process that evaluates infected paddy images and gives farmers recommendations. Simplifying the identification and categorization of rice diseases is the main goal of developing a system for classifying rice diseases, which includes vector supports and artificial neural networks. The crop forecast considers variables like the amount of precipitation, the lowest and maximum temperatures, the type of soil, the humidity, and the significance of soil pH. The study of soil fertility using ML methods in agriculture [18] was covered. One of the study areas of interest for a long time has been agriculture. This study aims to assess, categorize, and improve soil data in light of various variables. Scientific advancements in agriculture have benefited from technological advancements like automation and data processing. Although there are many commercial database mining products and domain-specific data mining applications available today, data mining is still a relatively unexplored area of research in agricultural soil datasets. It is possible to process and fully utilize the enormous amounts of data currently virtually acquired in relation to plants [19]. Harvest failures are pretty typical. Even more factors, including agricultural degradation, excessive use of fertilizers and pesticides, radiation exposure risks, etc., have an effect on agriculture at the same time. There is evidence that many insects are immune to insecticides. Crop production problems will be resolved by early plant prediction. A suitable method of decision-making is thus necessary for the gathering and production of agricultural products.

The authors suggested an approach regarding the identification of tomato plant leaf disease with respect to deep learning methodologies [16]. This suggested method is presented to identify the crop leaf infection using picture-preparation techniques for the tomato crop. It is reliant on image segmentation, bunching, and open source methodologies, all of which contribute to a reliable, secure, and accurate arrangement of leaf illness with the focus on tomato crops. They demonstrated a deep learning-based strategy, the most cutting-edge study in computer vision to date. It is the most hopeful one for a fine-grained classification of disease similarity because it avoids segmentation based on threshold and labor-intensive feature extraction.

CONCLUSION

Professional knowledge is needed to distinguish minute characteristics from dubious samples for manual detection and classification of different plant leaf diseases. Further complicating the classification process are the extreme differences in plant size, color, and structure. Today, timely detection and identification of diseases that influence the leaves is crucial because they seriously impair both the quantity and quality of crop output. This research studies a variety of techniques, including deep learning, machine learning, pattern recognition, neural networks, support vector machines, and others, to identify and categorize plant leaf illnesses. Here, the work discusses different leaf diseases as well as the basic concept of plant leaf disease detection. In the agricultural industry, leaf disease detection is important and necessitates greater precision for real-time disease detection. In comparison to other models, the early leaf disease detection model can help with disease detection with less time for discovery. The article provided a review of leaf disease detection algorithms and current detection algorithm methodologies.

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