Theory and Practice of Science and Technology
2025, VOL. 6, NO. 11, 122-124
DOI: 10.47297/taposatWSP2633-456923.20250611

Exploration of Accurate Recognition Method for Tomato Diseases Based on Deep Learning

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ABSTRACT

Tomatoes, as an important economic crop in China, suffer from frequent diseases that seriously affect yield and quality. Traditional disease identification methods rely on manual experience and have problems such as low efficiency and accuracy. This article proposes a deep learning based method for accurate recognition of tomato diseases, aiming to address the limitations of traditional methods. A tomato disease image dataset is constructed, covering common disease types and healthy leaf samples. Data augmentation processing is performed to improve the model's generalization ability. A suitable deep learning network is selected as the basic model, and the model is improved by adjusting the network structure and optimizing hyperparameters. The results show that the proposed method can quickly and accurately identify common tomato diseases, with higher recognition accuracy than traditional methods, providing technical support for early warning and precise prevention of tomato diseases.

KEYWORDS

Deep learning; Tomato diseases; Image recognition; Accurate identification; Convolutional neural network; Data augmentation

1 Introduction

Tomatoes are an important component of agricultural production in China and are widely cultivated in various regions. However, tomatoes are susceptible to various diseases such as late blight, early blight, and leaf mold caused by fungi, bacteria, and viruses during their growth process. If not identified and controlled in a timely manner, it can lead to significant yield reduction or even complete crop failure. Against the backdrop of the continuous development of computer vision and deep learning technologies, image-based disease recognition methods have become a research focus in current agricultural disease recognition due to their high efficiency, objectivity, and accuracy. This study is based on deep learning technology to explore accurate identification methods for tomato diseases and construct effective identification models, in order to provide technical guarantees for rapid diagnosis and scientific prevention and control of tomato diseases in agricultural production, which is conducive to the development of smart agriculture.

2 Overview of Tomato Diseases

Tomato diseases pose significant challenges to tomato growth, involving both infectious and non infectious categories. Infectious diseases are diseases induced by biological factors such as fungi, bacteria, viruses, and nematodes. Common diseases include late blight, early blight, ulcer disease, and yellowing leaf curl virus disease. Fungal diseases such as late blight mostly originate from the lower leaves. When the humidity is high, there is a white mold layer on the edge of the disease spot on the back of the leaves. In severe cases, the stem and fruit are also affected, causing the plant to wither and die; The prominent feature of early blight is the appearance of concentric wheel like lesions on the leaves. When the environment is humid, black mold like substances grow on the surface of these lesions. Bacterial diseases such as ulcer disease occur throughout the entire growth period. During the seedling stage, the true leaves are withered from bottom to top, and there are concave and necrotic spots on the petiole or embryonic axis. During the adult stage, the leaves are green brown and wrinkled, the stems have faded green spots, and the fruits have wart like protrusions. Virus diseases such as yellowing and leaf curl virus are transmitted through vector insects, causing yellowing and curling of leaves, which seriously affects tomato growth and yield. The root system of tomatoes is mainly affected by root knot nematode disease, which leads to the formation of nodular root nodules and hinders nutrient absorption [1]. Non infectious diseases are often caused by unsuitable environments or improper management, such as fruit rot, browning and hardening inside the fruit, mostly due to low temperature, weak light or nutrient imbalance; Umbilical rot is a disease associated with the necrosis of the navel and calcium absorption disorders in fruits; Fruit cracking is usually caused by rainstorm or improper irrigation, which will cause cracks in the peel, thus reducing the quality of the fruit. The occurrence of such diseases is not only related to the infection of pathogenic organisms, but also influenced by many factors such as climate, soil, and cultivation management. For example, high temperature and humidity environments are favorable for fungal and bacterial diseases, while adverse conditions such as drought and low temperature can induce non infectious diseases.

3 The value of precise identification of tomato diseases based on deep learning

3.1 Promote the Efficiency and Accuracy of Disease Detection

Traditional tomato disease detection mainly relies on manual observation, which has low detection efficiency and is easily affected by subjective factors, resulting in misjudgments and omissions. By adopting a deep learning based tomato disease accurate recognition method and combining it with convolutional neural network and other technical models, disease features can be automatically extracted from a large amount of image data, achieving rapid and accurate disease detection results. For example, through the training of deep learning models, tomato leaf images can be analyzed in real-time and various diseases such as late blight, early blight, and leaf mold can be quickly identified. This utility model significantly improves detection efficiency and reduces manual detection time and cost. At the same time, deep learning models have strong feature extraction capabilities, which can capture subtle features of disease images to improve disease recognition accuracy and provide reliable basis for the formulation of subsequent prevention and control measures.

3.2 Promote Precise Pesticide Application and Save Resources

Accurately identifying tomato diseases is of great significance for precise pesticide application. Using deep learning for disease identification technology can accurately judge the type and severity of diseases, and provide targeted pesticide application suggestions to farmers. Farmers can choose appropriate pesticide types and dosages based on the identification results to avoid blind and excessive use, reduce pesticide residues, and environmental pollution. For mildly affected tomato plants, biological control or local control with low toxicity pesticides can be adopted, while for severely affected areas, centralized spraying can be used to improve the control effect. This precise pesticide application method not only saves pesticide resources and reduces production costs, but also reduces the adverse impact on the environment, which is conducive to sustainable agricultural development.

3.3 Promoted the Development of Agricultural Intelligence and Informatization

The precise identification technology of tomato diseases based on deep learning is of great significance in the development of agricultural intelligence and informatization. Combined with the Internet of Things, big data, and cloud computing, it can remotely monitor and intelligently manage tomato planting parks. Management personnel can real-time understand the disease situation in each park through terminal devices such as mobile phones or computers and take timely measures. At the same time, the system can also deeply analyze historical disease data, providing data support for agricultural production, which is beneficial for farmers to predict the development trend of diseases, scientifically formulate production plans and disease prevention and control strategies. In addition, this technology can be integrated with agricultural supply chain management systems to share disease information in real-time, enhance supply chain transparency and collaborative efficiency, and promote the upgrading and transformation of the agricultural industry.

4 Accurate recognition method of tomato diseases based on deep learning

4.1 Collection and Enhancement of Disease Image Data

When achieving accurate recognition of tomato diseases based on deep learning, the collection and enhancement of disease image data are key basic steps. Data collection should ensure comprehensiveness and diversity, and can take on-site photos of different tomato planting areas, covering various planting environments such as greenhouses and open fields. During the filming process, it is necessary to collect images of tomato plant diseases at various growth stages from multiple angles and under different lighting conditions, including the lesion characteristics of leaves, stems, and fruits. At the same time, relevant images can also be collected through agricultural research institutions, open plant disease databases, and other channels to enrich data sources. However, relying solely on raw collected data may not meet the needs of deep learning model training, so data augmentation is necessary. There are many methods for data augmentation, such as image rotation, flipping, scaling, and cropping. Rotating images can simulate diseases from different perspectives, flipping operations can improve image symmetry changes, and scaling and cropping can highlight local features of diseases. In addition, by adjusting the brightness, contrast, and saturation of the image, it is also possible to simulate the performance of diseases under various lighting and environmental conditions. The above data augmentation methods can effectively expand the dataset, enhance the model's ability to identify tomato diseases in different scenarios, reduce overfitting, and make the model more robust and accurate.

4.2 Architecture Design and Screening of Deep Networks

The design and screening of deep network architecture are directly related to the accurate recognition results of tomato diseases. During the design phase, it is necessary to fully consider the image features and recognition task requirements of tomato diseases. A commonly adopted strategy is to refer to existing classical deep network frameworks, such as convolutional neural networks (CNN). CNN has strong feature extraction capabilities and can automatically extract useful features from images. Based on the size and complexity of tomato disease images, CNN layers, convolution kernel sizes, and pooling layer parameters are designed reasonably. On the basis of classical architecture, attention mechanism is combined to design deep networks [3]. The attention mechanism can make the model more focused on the key areas involved in diseases in the image and improve recognition accuracy. For example, by adding channel attention modules or spatial attention modules in the network environment, the model can have the ability to adaptively adjust its attention to various channels and spatial positions. After designing various possible network architectures, it is necessary to discern them. The screening process can be tested on a validation set to compare recognition accuracy, recall, and F1 score under different structures. At the same time, it is necessary to comprehensively consider factors such as model training time and computational resource consumption, and select a deep network architecture with high recognition accuracy and efficiency as a good foundation for accurate identification of tomato diseases in the future.

4.3 Optimization and Regularization of Model Training

The optimization and regularization of model training are key steps in ensuring the accurate recognition of tomato diseases based on deep learning. The first step in model training is to choose an appropriate optimization algorithm. Common optimization methods include techniques such as stochastic gradient descent (SGD) and adaptive moment estimation (Adam). The SGD algorithm has the characteristics of simplicity and intuitiveness, which can ensure the convergence of the model to the local optimal solution within a certain range; And the Adam algorithm combines momentum with adaptive learning rate, which can converge quickly. Choosing the most suitable optimization algorithm based on the characteristics of the model and the size of the dataset can improve training efficiency. Setting the learning rate is crucial during optimization. When the learning rate is too high, the model may jump out of the optimal solution and fail to converge; If the learning rate is too low, the training speed will be slow. The learning rate decay strategy can be applied in the early stages of training, utilizing the high learning rate to accelerate convergence, and gradually reducing the learning rate with training to enable the model to converge more accurately to the optimal solution. Meanwhile, it is necessary to introduce regularization methods to avoid overfitting of the model. The commonly used regularization methods are L1 and L2 regularization methods, which constrain model parameters by adding additional penalty terms to the loss function, making the model simpler and more generalizable. In addition, Dropout technology can be used to randomly discard some neurons for training, in order to reduce inter neuron dependencies and enhance model robustness. Through continuous training, optimization, and regularization of the model, it can achieve good performance in tomato disease recognition tasks [2].

4.4 Recognition Strategy Based on Multi-scale Feature Fusion

When using deep learning as the basis for accurate recognition of tomato diseases, the multi-scale feature fusion recognition strategy can fully utilize the feature information of diseases at different scales to improve recognition accuracy. Tomato diseases exhibit different characteristics at different scales, such as observing the overall distribution and general shape of the disease at the macro scale, and observing its subtle texture and cellular structure at the micro scale [3]. Therefore, utilizing multi-scale feature fusion can comprehensively utilize the above information, such as multi-scale feature fusion methods, including the construction of multi-scale feature extraction modules on deep networks, which can use convolution kernels of different sizes to extract features of various scales and further fuse these features together. For example, using 3x3, 5x5, and 7x7 convolution kernels to convolve images separately to obtain feature maps of different sizes, and then using concatenation or accumulation methods to fuse the feature maps. In addition, pyramid structures can also be used for multi-scale feature extraction, such as Spatial Pyramid Pooling (SPP) or Feature Pyramid Network (FPN). SPP can pool features of different scales at a fixed scale, facilitating subsequent feature fusion and classification; FPN achieves the integration of multi-scale features by transmitting information in feature maps at various levels through paths from bottom to top and from top to bottom. The use of multi-scale feature fusion recognition strategy can more comprehensively capture the characteristics of tomato diseases, enhance the model's ability to recognize different types and severity of diseases, and thus achieve accurate identification of tomato diseases.

5 Conclusion

This study focuses on the precise identification of tomato diseases and proposes a method for identifying tomato diseases based on deep learning. Through methods such as dataset construction, model improvement, and experimental verification, common tomato diseases are effectively and accurately identified. The results show that deep learning technology can fully explore the deep features of tomato disease images, significantly improve recognition accuracy and efficiency, and has significant advantages over traditional methods. This method provides a reliable technical means for early diagnosis of tomato diseases, which is conducive to reducing pesticide abuse, lowering production costs, ensuring tomato yield and quality. This has important practical significance for promoting the development of smart agriculture and has also promoted the widespread application of this method in actual agricultural production processes.

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