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Review of Wheat Disease Classification and Severity Detection Models

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Abstract: Wheat is an important cereal crop that feeds more than a third of the world's population. The yield of wheat depends on various factors. Among them, disease is an important factor affecting the yield and quality of wheat. To combat these diseases, researchers have been studying the use of advanced techniques such as deep plant disease learning and image processing methods for identification. In the current study, there are many researches for wheat disease classification, but less for wheat disease severity recognition or estimate. The existing wheat disease severity detection is basically achieved by classification. Moreover, the same disease shows different symptoms at different periods or at different degrees of infection, which increases the difficulty of disease identification. In order to fully grasp the core technology of wheat disease recognition, this paper reviews the research of deep learning technology in wheat leaf disease classification and wheat disease severity. Special attention is paid to the application of image segmentation technology in wheat disease severity recognition. This paper mainly aims to explain deep learning-based wheat diseases identification algorithm, and to discuss the benefits and drawbacks of present wheat disease detection approaches. The main conclusion is that the classification of wheat diseases and the severity of wheat diseases have made good progress, but they are still in the state of independent research. Hybrid algorithm is a new way and a new challenge to link the two tasks.

Keywords: Classification; Deep learning; Disease severity; Review; Segmentation; Wheat disease.

1. INTRODUCTION

Wheat is one of the world's most important grain crops, providing food for more than 40% of the world's population. Wheat is one of the most important crops in China and has been cultivated in China for more than 5,000 years. Its cultivation area and yield account for more than a quarter of total grain output, while the annual purchase, sale, and inventory of national commodity wheat account for over one-third of total grain [1]. However, many people in the world still face hunger because they do not have enough food. Therefore, new scientific methods are needed to increase wheat yields to meet the growing demand. In agricultural production, disease is a main factor directly affecting plant yield and quality. Wheat diseases seriously affect the yield and quality of wheat [2, 3, 4]. According to the statistics of the Agricultural Research Institute, 6-7% of the annual decline in wheat grain quality is caused by wheat diseases [5]. Wheat diseases not only affect the normal growth of wheat, but also reduce the yield and quality of agricultural products and bring food security problems.

In the computer-aided diagnosis of plant diseases, it is not only necessary to predict the types of diseases, but also to distinguish the severity of diseases. Most of the existing plant disease recognition focuses on the classification of plant diseases. Similarly, the wheat disease classification task can only identify different disease types and cannot detect the severity of the disease. But severity detection researches are all detect one disease. Therefore, the previous wheat disease classification and severity recognition are independent. Whether the classification of diseases and the detection of disease severity can be combined into a model is a problem to be studied. At present, there is no perfect method to accurately and quickly identify the severity of multiple diseases. The integrated application of disease identification and severity still faces some challenges. Although severity detection for multiple diseases is involved in many researches [6, 7, 8, 9], but they are concerned with diseases of different plants. The algorithms used in these studies are designed to classify the severity of different diseases with significant differences between classes and are not suitable for diagnosing multiple disease types with low similarity in a single plant and detecting the fine-grained severity of multiple diseases simultaneously.

Image segmentation assigns a specific category to each pixel. Therefore, image segmentation techniques have a great impact on the performance of any disease detection and classification model [1]. Vishwas *et al.* presents a novel approach for the multi-classification of Wheat Stripe Rust (WSR) disease into five different severity levels using the You Only Look Once

version 4 (YOLOv4) model [10]. The model was trained on a dataset of 5000 images and achieved a mean average precision (MAP) score of 0.85 and overall accuracy of 85.98%, demonstrating high accuracy and performance across all severity levels. By quantifying the severity of loose smut in wheat using Mask Region-based Convolutional Neural Networks (MRCNN), Deepak *et al.* [11] achieved a 97.8% F1 score for loose smut identification with bounding boxes. The severity of loose smut has been calculated through the disease severity index. With the help of Disease Severity Index (DSI), a total of 63% severity for loose smut has been estimated in different wheat spikelet.

In this study, relevant techniques for identifying plant diseases based on deep learning and image processing methods are reviewed and a comprehensive analysis is conducted to evaluate their effectiveness in practical applications. In order to detect wheat disease and severity more effectively, the focus of this study is to study the existing classification and segmentation algorithms, and investigate the methods of classification and segmentation fusion to obtain the optimal comprehensive model.

The main contribution of this paper has two aspects. First, the methods of improving model accuracy and lightweight in wheat leaf disease classification literature were compared and analyzed, which provided a theoretical basis for the design of hybrid model with high precision and lightweight at the same time. Second, the existing methods of wheat leaf disease severity were compared and analyzed. The two methods are label classification and area segmentation. The discussion and analysis in this paper are the preparation for the subsequent design of a more accurate multi-disease severity recognition model.

The rest of this systematic literature review is divided into four parts: Section 2 outlines the research background and the types and characteristics of wheat diseases. Section 3 summarizes the main methods and key technologies of deep learning in wheat disease detection. Section 4 focuses on the identification and evaluation methods of disease severity. Lastly, the conclusion of the review and the recommendations on future trends are demonstrated in Section 5.

2. WHEAT DISEASE

The main cause of wheat grain quality loss is damage to the leaf structure, resulting in a decrease in chlorophyll and water concentration in the leaves [12]. There are 38 common wheat diseases, such as powdery mildew, rust, and fusarium head blight (Scab) [4]. Rust is divided into leaf rust, stripe/yellow rust and stem rust. Stripe rust can lead to total output loss of up to 40% [13]. If not controlled and prevented, the wheat rust pathogen can affect 50% to 100% of the crop area [14]. Global losses from rust pathogens are estimated at $5.5 billion per year [15]. Wheat powdery mildew is one of the three most common and devastating diseases in the middle and late stages of the growth and development of wheat. It is characterized by rapid spread, difficulty in prevention and control, and severe yield decline.

The impacts of several illnesses on wheat production were investigated based on the time of disease incidence, the location of disease beginning, and the primary features of disease spots. Table 1 shows an overview of some common wheat leaf diseases and their symptoms characteristics. Wheat diseases have serious impacts on the yield, mild symptoms can cause 10% to 30% reduction, severe symptoms can cause 40% to 50% reduction. The symptoms of various diseases are reflected on the leaves, so observing the leaves is a good way to help us identify different diseases. For example, rust and powdery mildew are different in color, rust is generally yellow and brown; powdery mildew is generally white. In addition to color, the most important and most difficult to distinguish is the shape of the disease spot. Different disease spot shape represents different diseases. Therefore, the shape of the lesion is an important feature to distinguish different diseases. But sometimes, even with the same disease, the shape of the plaques varies greatly at different levels of severity. Here, rust disease is taken as an example for detailed explanation. Leaf rust spots are small spots in the early stage, but it will evolve into a large area in the middle and late stages. At the same time, different rust diseases are very similar in colour and shape, which is the more difficult part of the identification. Therefore, a strong learning ability is needed to be trained on more sample data.

To reduce the impact of disease on crop yield loss, it is becoming increasingly important to recognize, identify, evaluate, and control crop diseases. It has been noticed that over the past decade, image processing has made significant strides. It has been exciting to see how deep learning has been applied to plant disease recognition, particularly through CNN in plant disease imaging. The success in this area has been impressive. AlexNet have achieved a 99.35% accuracy rate in identifying crops and disease types in the Plant Village dataset. In addition, there have been recent advances in the performance of CNNs for diagnosing plant diseases.

3. ADVANCEMENTS OF RESEARCH ON WHEAT DISEASE RECOGNTION

Compared with the early plant disease recognition methods, plant disease recognition based on deep network can automatically preprocess the image, and no longer need to manually process the image, so the efficiency of disease recognition is improved. At the same time, with the increase of network depth, the learning ability of the model is stronger, and the extracted features are richer. However, due to the increase of network depth, the training process will consume a lot of time, and there may be overfitting problems during training. Many researchers try to use CNN-based deep neural networks in plant disease recognition to improve the accuracy of recognition. Over the years, researchers have created several algorithms and strategies for wheat leaf disease detection, and these efforts have generated some very effective applications.