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Plant Health Monitoring (using Sensors)

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***Abstract*—Plant diseases remain a major threat to food security in many parts of the world.The yield and quality of plants are greatly influenced by plant diseases and pests. By using digital image processing, plant diseases and pests can be identified. Deep learning has made significant advances in digital image processing in recent years, far superior to traditional approaches. Researchers are interested in using deep learning technology to identify plant diseases and pests. This paper defines the difficulty of identifying plant diseases and pests and makes a comparison to conventional techniques for doing so. As a result of the differences in network structure, this study outlines the research on plant diseases and pests detection using deep learning in recent years from the perspectives of classification networks, detection networks, and segmentation networks, and summarizes both the advantages and disadvantages of each method. Several common datasets are introduced, and existing studies are compared. Therefore, this study discusses practical challenges in applying deep learning to plant disease and pest detection. In addition, several suggestions are provided for resolving the challenges and developing new research ideas. Lastly, this study analyzes and predicts the future trends in plant diseases and pests detection using deep learning.**

I. Introduction

Detecting plant diseases and pests is a key area of research in the science of machine vision. It is a system that gathers photos of plants using machine vision equipment and determines whether any pests or illnesses are present [1]. Plant diseases and pests detection tools based on machine vision are currently being used in agriculture and have partially replaced the old-fashioned naked eye identification methods. Traditional image processing algorithms or human feature creation combined with classifiers are frequently employed for machine vision-based methods for detecting plant diseases and pests [2]. To obtain uniform illumination, this method makes use of the different properties of plant diseases and pests to design an imaging scheme and to choose an appropriate light source and shooting angle. While carefully designed imaging schemes can significantly reduce the complexity of classical algorithm design, they can also increase the cost of the application. It is also unrealistic to expect classical algorithms to completely eliminate scene changes from their impact on recognition results under natural conditions. In real complex natural environment, plant diseases and pests detection is faced with many challenges, such as small differences between the lesion area and the background, low contrast, huge variations in scale and type of lesion, and a lot of noise in the lesion image. Additionally, when photos of pests and diseases are taken under natural light, there are a lot of disturbances.
In the recent years, with the successful application of deep learning models represented by convolutional neural networks (CNNs) in many fields of computer vision (CV, computer vision), for example, traffic detection [4], medical image recognition [5], scene text recognition [6], expression recognition [7], face recognition [8].

It is common to use deep learning methods to detect plant diseases and pests in agriculture, and some domestic and foreign companies have developed photo recognition software and Wechat applets that use deep learning to detect plant diseases and pests. Hence, a deep learning-based method for detecting plant diseases and pests is not only important for academic research, but also greatly applicable to the market.

The content of this study is arranged as follows: “Definition of plant diseases and pests detection problem” section gives the definition of plant diseases and pests detection problem; “Image recognition technology based on deep learning” section focuses on the detailed introduction of image recognition technology based on deep learning; “Plant diseases and pests detection methods based on deep learning” section analyses the three kinds of plant diseases and pests detection methods based on deep learning according to network structure, including classification, detection and segmentation network; “Dataset and performance comparison” section introduces some datasets of plant diseases and pests detection and compares the performance of the existing studies; “Challenges” section puts forward the challenges of plant diseases and pests detection based on deep learning; “Conclusions and future directions” section prospects the possible research focus and development direction in the future.

II. Definitions

A. Plant diseases and pests:

Natural disasters such as plant diseases and pests can adversely affect the normal growth of plants and may even result in plant death during the entire plant’s growth cycle, In

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machine vision tasks, plant diseases and pests tend to be concepts from human experience rather than purely mathematical descriptions.

B. Plant diseases and pests detection:

The requirements of plant diseases and pests detection are very general, as compared with the precise classification, detection, and segmentation tasks in computer vision [9]. The requirements can actually be broken down onto three distinct levels: what, where, and how [10]. "What" in the initial step is equivalent to the computer vision classification task. According to Fig. 1, It is labelled with the category to which it belongs. In this stage, the task is classification, which identifies only the image's category. This stage is the rigorous sense of detection in the second stage. "Where" is the location task in computer vision. This stage not only determines what types of diseases and pests are present in the image, but also where they are located. Figure 1 shows a rectangular box marking the plaque area with gray mold. During the third stage, "how" relates to segmentation in computer vision.In Figure 1, gray mold lesions are separated from the background pixel by pixel, which can be used to obtain a series of information, including the size, location, and length of the gray mold lesions, which can be used to evaluate plant diseases and pests at a higher severity level. As a result of feature expression, classification describes an image globally, and then determines whether it contains a particular type of object through classification operations; whereas object detection focuses on local descriptions, that is, identifying what objects exist in which positions in an image. Therefore, apart from feature expression, object structure is the most obvious difference between object detection and object classification. In other words, object classification focuses primarily on feature expression, whereas object detection focuses primarily on structure learning. Accordingly, the following text refers collectively to plant diseases and pests detection as a convention, with terminology differing only when different network structures and functions are used.

III. Comparison with traditional plant diseases and pests detection methods

In traditional image classification and recognition methods, only the underlying design features can be extracted, and it is difficult to extract deep and complex image feature information [18]. And Deep learning method solves this problem. Using the original image, it is possible to obtain multi-level features such as low-level features, intermediate features, and high-level semantic features through unsupervised learning. The traditional method of detecting plant diseases and pests is to identify them manually by designing features, and that's hard and depends on experience and luck, and is not capable of learning and extracting features automatically. Deep learning, on the other hand, can automatically identify features from large sets of data without the need to manually manipulate them. Multiple layers are used in the model, which has good autonomous learning capability and flexibility in expressing features, and can classify and recognize images automatically based on their features. In this regard, deep learning can be a very useful tool in helping to detect and identify plant diseases and pests.

IV. Machine vision technology based on deep learning

As compared to other image recognition methods, deep learning does not require the extraction of specific features, but rather requires iterative learning to identify appropriate features. This method is robust and has higher recognition accuracy, acquiring global and contextual features of images.

V. Deep learning theory

Deep learning is based on using neural networks to analyze data and learn features. Multiple hidden layers are used to extract data features, and each hidden layer is considered a perceptron. A perceptron is used to extract low-level features, and then low-level features are combined to obtain abstract high-level features, which reduces the problem of local minimization significantly. In recent years, deep learning has

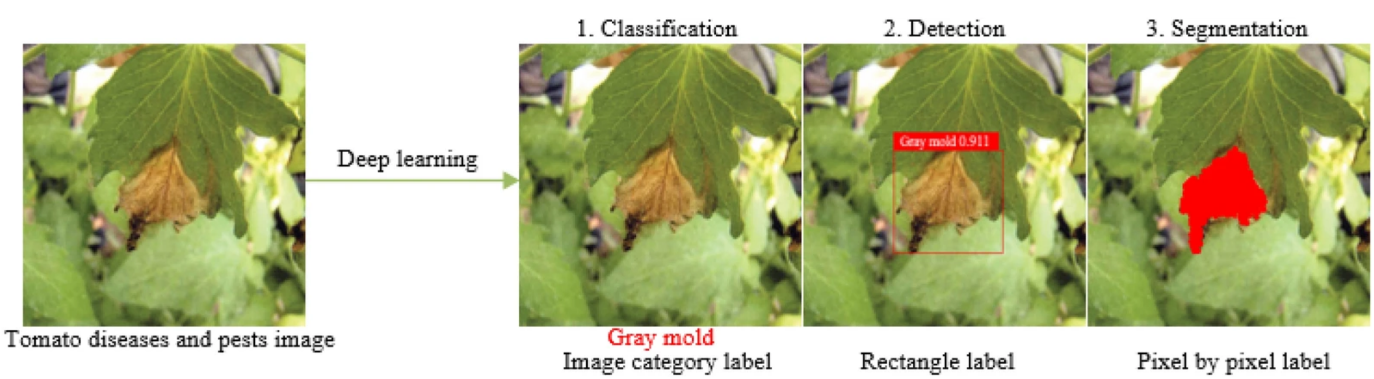

Fig. 1. Defnition of plant diseases and pests detection problem

attracted more and more attention due to its ability to overcome the disadvantage of traditional algorithms, which rely on artificially designed features. Currently, it is being used in computer vision to recognize patterns, recognize speech, process natural language, and provide recommendations. Regarding Image recognition with deep neural networks, image recognition can be automated by automatically extracting features from a high-dimensional feature space than with traditional methods. Further, as the number of training samples and computational power increase, deep neural networks' characterization power improves. In the present day, deep learning is sweeping both industry and academia, and deep neural networks outperform traditional models by a significant margin. In section VI, the most popular deep learning framework known as deep convolutional neural network will be further explained.

VI. Convolutional neural network