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Advanced computational models to predict diseases in crop plants

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Abstract

Crop diseases pose a significant threat to both farmers' incomes and food security. Various environmental factors lead to plant diseases which results in significant production losses. Manual detection of plant diseases is a time-consuming and error-prone process. Adopting advanced technologies such as Deep Learning (DL) can help to overcome these challenges by enabling early identification of plant diseases. DL methods have shown to be effective in detecting plant diseases and pest infestation at a high level of accuracy, which can support farmers and agricultural professionals in taking appropriate action to prevent crop losses.

Introduction

Crop diseases have the potential to cause devastating epidemics that threaten the world's food supply and vary widely in their dispersal pattern, prevalence, and severity. Plant disease modelling is an important field for assessing the intensity or severity of the disease. It is a management system enabled to forecast the occurrence and any change in severity or intensity of plant diseases. Forecasting the occurrence of diseases under a specific area and time; however, appropriate preventive and control measures can be taken in advance to obtain potential yield. Applying management practices at the appropriate time reduces the wastage of crops and chemicals by forecasting disease and making it cost-effective.

Plant disease modelling

A plant disease model is a simplified representation of the relationships between pathogens, crops, and environment (the pathosystem) that cause the development of epidemics; these relationships involve a large number of interactions at different levels of hierarchy over time and/or space. Basic components of plant disease are needed to investigate to make plant disease forecasting model. There are seven basic requirements for successful disease prediction. Intensity, incidence, and severity are primary disease measuring terms used to study disease

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forecasting. Modelling involves field observations, disease measurements, and weather conditions favoring disease spread, mathematical formulas, and computer use. The mathematical and analytical relationship gives information about interaction among the host, pathogen, and weather variables in mathematical equations presented as simple statements, tables, or graphs. Disease prediction can be made based on parameters involved like inoculum, weather variables, and comparative information.

Models combining plant, disease, and environmental factors have been developed since the middle 1900s. The early plant disease models, which were developed following an empirical approach, consisted of simple rules, graphs, or tables showing relationships between components of the disease cycles (e.g., infection and sporulation) and the concomitant weather conditions. Dynamic modelling of plant disease epidemics was introduced in the early 1960s with the conceptualization of the temporal progress of diseases by Van der Plank (1963) and with the further development of those concepts by Zadoks (1971). After these landmark achievements, many plant disease models have been developed by plant pathologists, mathematicians, or statisticians (De Wolf and Isard 2008). Empirical models organizing data and standardizing their relationship in terms of mathematical or statistical representation whereas mechanistic models predict pathogen and disease levels based on underlying processes.

Deep learning models for prediction of plant diseases

Recently, different approaches of deep learning are being used for plant diseases detection and the most popular of these are convolution neural network (CNN). Deep learning (DL) is a new trend in machine learning (ML), with state-of-art results in many areas of research, including computer vision, pharmacy and bioinformatics. DL model makes predictions more quickly and precisely than manual plant leaf observation. DL employs multiple-layered artificial intelligence (AI) networks to learn and represent complex patterns in data. It is extensively employed in object recognition, object detection, speech analysis and speech-to-text transcription. In natural language processing, DL-based models are used for tasks such as language translation, text summarization, and sentiment analysis. Additionally, DL is also used in recommendation systems to predict user preferences based on previous actions or interactions. AI vision is a subfield of artificial intelligence concerned with the construction of computers to process and understand the visual contents from the world. DL benefits from the capacity to use raw data directly without the use of handcrafts. The use of deep learning, for two main reasons, has recently produced good results both academically and industrially (Kumar and Raghavendra, 2019). First, every day is generated large amounts of data. These data may therefore be used to develop a profound model. Second, the computational power of the Graphics Processing Unit allows deep models to be

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trained and leveraged in computing parallelism. Different ML approaches such as K-means clustering, support vector machine (SVM), convolution neural network (CNN), deep belief networks (DBNs), Boltzmann's Deep Machine (DBM), Deep Denoising Autoencoder etc. have been employed for plant and disease classification and detection. Out of these, the CNN model are the best model for achieving higher detection accuracy using imaging data. The higher accuracy of the CNN model for plant disease classification has proofed to be the best then all other kinds and CNNs can achieve high accuracy rates in the range of 99-99.2% in classifying images of plant leaves affected by diseases and pests (Shoaib et al., 2023).

CNN models are ideally suited for image classification tasks such as leaf disease detection. CNN's architecture comprised of multiple layers, such as fully connected layers, maxpooling, and normalization layers. The first layer is the input layer while the second layer in most of the CNNs is convolutional layers which extract features by applying various kind of 2D filters on the image, the amount of images increase which can then dimensionally reduced pooling also known as down sampling layers, resulting in a more compact representation of the image. Fully connected (FC) layers in a CNN are also known as learnable features, the extracted features are processed in the FC layer for learning and weights optimization. These layers are also responsible for making classification which can be used to recognize various plant diseases. The learning process of CNN model begins with training, the input to the CNN are images along with their labels, after the successful training of the model, the model is able to identify disease types. The decision-making process in a CNN for leaf disease detection starts with the input of an image of a leaf. The image is then passed through the convolutional layers, where features are extracted. The feature vectors are then processed by pooling layers, where the spatial dimensions are reduced. The feature vectors are then transmitted *via* the FC layers, where a decision is made about the presence of a disease.

Advances in image recognition have made it possible to identify complicated diseases. However, most research in this area is limited to lab-based studies and heavily relies on collected plant disease photos. It's important to gather images from various plant growth stages, seasons, and regions to enhance the robustness and generalization of the model. Early identification of plant diseases and pests is crucial in preventing and controlling their spread and growth, thus incorporating meteorological and plant health data, such as temperature and humidity, is necessary for efficient identification and prediction. Unsupervised learning and integrating past knowledge of brain-like computers with human visual cognition can aid in DL model training and network learning. Achieving the full potential of this technology requires collaboration between specialists from agriculture and plant protection, combining their knowledge and experience with DL algorithms and models, and integrating the results into farming equipment.

Conclusion

Plant disease detection through some automated technique is useful since it reduces a large amount of monitoring work in large crop farms and detects disease symptoms at an early stage. Computer simulation is beneficial for growers to understand the effect of components and subcomponents of the epidemic on yield loss.

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