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REVIEW ARTICLE

A review on the use of artificial intelligence and deep learning algorithms in crops Phytosanitary Monitoring

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Abstract

The article presents a review of current applications and capacities of artificial intelligence in identifying pests and diseases of common agricultural crops. The review is created based on the literature search, conducted using Google Scholar engine. In total, 42 recent scientific papers (22 published in journals and 20 conference proceedings), which were published within last five years, were analysed and included into this review. Scientific papers providing incomplete data, controversial and biased information were excluded from the review. Mainly open access sources were included into the review. As a result, it was established that current artificial intelligence applications in phytosanitary monitoring of crops allow a great decrease in the mistakes in pests and diseases identification, as well as a reduction in the expenses of labour and time for manual observations. Generally, most AI-based models for plants pests and diseases identification provided identification accuracy and specificity exceeding 85%-90%, some of them reaching the peak of 99%-100% accuracy. The best results are mainly recorded for convolutional neural networks and their combination with other machine learning techniques. However, no clear unified algorithm is recommended for this purpose. The best results are usually associated with neural network-based algorithms. Further deeper scientific research is necessary to clarify the advantages, drawbacks and pitfalls of artificial intelligence application in phytopathological surveys.

Keywords: Crop monitoring, Deep learning, Diseases, Neural network, Pests

Introduction

Artificial Intelligence (AI) refers to the ability of machines to simulate human intelligence, encompassing tasks like logical reasoning, learning, problem-solving, and decision-making (Morandin-Ahuerma, 2022). Major functions and tasks, aimed by AI, encompass speech and image recognition with further automated classification of the objects and/or decision-making. AI technologies aim to replace humans in some complex routine tasks to save time and labour (Singh &

Haju, 2022). Overall, AI plays a crucial role in enhancing productivity, efficiency, accuracy, and automation across diverse fields of science and practice.

AI could be used in phytosanitary monitoring of agricultural crops by enabling the early detection of plant diseases and pests. Techniques such as computer vision, deep learning, and convolutional neural networks are applied for accurate disease identification from multiangle and multispectral images of plant leaves and fruits, captured by drone sensors and cameras, or retrieved from satellites (Soni et al., 2022; Sornalakshmi et al., 2022). AI algorithms help predict disease types and facilitate timely interventions to mitigate crop loss, thus enhancing agricultural productivity and food security (Poornima et al., 2022). AI-driven systems are an integrative part of precision agriculture and ensure sustainable crop management for improved crop quality and yield.

Literature Review

The review was carried out using the current scientific literature on the use of artificial intelligence in the field of the identification of pests and diseases in crops, mainly including scientific studies on the subject, conducted in recent years (2020-2024). Scientific search was performed using Google Scholar platform. 42 scientific papers (22 published in journals and 20 conference proceedings) in total were analysed to create this review. The articles and proceedings with incomplete data, controversial and biased information were excluded from the study, as well as the sources, which are difficult to identify and access.

Results and Discussion

Artificial intelligence plays an important role in disease identification in crops, offering innovative solutions for their early detection and rational management, including more efficient and environmentally friendly application of chemical measures of plant protection (Harsha et al., 2022). While conventional methods for plant disease identification, e.g., field surveys, face challenges in terms of cost, accuracy, and labour expenditures, AI-based tools are recommended for enhancing disease detection and decrease in the costs for crops phytosanitary monitoring (Mahenge et al., 2023). Machine Learning (ML) approaches are effective for early plant disease detection. The AI system detects plant diseases using image processing techniques. The features extracted from the images train AI for accurate diagnosis. Image processing using AI can enable early and accurate detection of diseases or distinguishing between the infested and healthy plants in a crop (Ahmed et al., 2021; Bhargavi et al., 2021). Machine learning and image processing techniques can diagnose plant diseases through leaf images. Using these techniques can help reduce excessive use of chemicals to treat plant diseases (Zhou et al., 2021). AI-based techniques gradually substitute traditional visual and laboratory methods for disease recognition in crops (Das et al., 2022). Various deep learning algorithms such as ResNet50, MobileNet, and Inception V3 are successfully applied to the identification of plant diseases (Prajapati et al., 2023).

Transfer learning with pre-trained models such as Convolutional Neural Network (CNN), MobileNet, and VGG16 has proven their efficiency and reliability in detecting bacterial, fungal, and viral diseases in such agricultural plants like tomato, potato, and apple, with VGG16 exhibiting the highest accuracy fluctuating within 89% to 95% (Mehta et al., 2023). Additionally, integration of AI with the Internet of Things (IoT) is especially useful for precise diagnosis and timely intervention in the intercourse of diseases in crops, ultimately boosting yields (Venkatamohan et al., 2023). The use of AI systems for image-based plant leaf disease diagnosis showcases high accuracy rates, emphasizing the importance of AI developments for efficient disease management and improved crop production (Velmurugan et al., 2023). Plant disease identification using Siamese Networks and AI-based image processing achieved 80.6% recognition accuracy in crop disease classification (Shang et al., 2022). The technique, proposed by Kethineni & Pradeepini (2023), provides an accuracy rate of 91.3% in identifying leaf diseases. The technique involves a five-stage detection process with preprocessing, segmentation, feature extraction, feature optimisation, and classification stages. Plant disease classification using machine learning algorithms within the framework of a CNN achieved 94% accuracy in disease prediction (Singla et al., 2023). Ensemble ML algorithms generally outperform conventional disease detection models (Ahmed & Yadav, 2023). Great results were achieved with transfer learning with the Efficient NetV2L algorithm, the highest accuracy was 99.63%.

Explainable AI technique (LIME) was implemented to provide clear explanations for plant disease predictions and are prospective for scientific and practical implementations (Mehedi et al., 2022). Automation in disease identification is extremely important for large fields, where field surveys are greatly expensive, time-consuming, and laborious (Chen et al., 2023). Detection of plants diseases using Support Vector Machine (SVM) deep learning algorithm for plants disease image processing resulted in 99.56% accuracy of detection (Varshney et al., 2022). The improved DenseNet AI-based model algorithm for crop pests and disease identification achieved real-time detection and early warning with a correctness rate of 96.7%, providing operational detection of harmful organisms (Alatawi et al., 2022). Plant disease detection using CNN for the extraction of disease image features and SVM for further classification achieved 88.77% training accuracy outperforming traditional classification methodologies (Jung et al., 2023). ML VGG-16 model achieves 95.2% accuracy in plant disease detection. This model is believed to be prospective for further large-scale implementation for practical purposes (Tripathy et al., 2022). (Anand et al. 2022) developed a deep learning-based model, which detects diseases in crops with high accuracy. The model includes crop classification, disease detection, and disease classification algorithms combined in one integrated system. The disease detection model achieved high accuracy (97.09%) in the classification of crop disease types. Pre-trained neural networks using ImageNet technique improve performance of disease identification up to 91.83% of correctness using public image dataset (Rao et al., 2022). The model using conventional k-means computation algorithm for picture fragmentation and segmentation achieved an accuracy of 92.5% in mango disease detection, which is a good result considering the less computation power needed to perform the task in comparison to AI-based neural networks (Pandey & Ramesh, 2021). Disease detection using CNN models based on content filtering technique achieved 97.53% accuracy (Singh et al., 2021). A comparative study on machine learning techniques for plant disease detection using various ML algorithms such as SVM, CNN, and random forest testified that CNN provides the best detection accuracy (Kanaan et al., 2021). Deep Neural Networks (DNN) and CNN are of the greatest importance for crops disease detection. Screening strategy can diagnose plant diseases from photography images taken by drones or manually. The KNN classification algorithm achieved high precision (98.23%) in the recognition of plant leaf diseases. Probabilistic latent semantic analysis and Bayesian network are effective algorithms for the analysis and visualisation of plant disease features (Torai et al., 2020). The automated disease detection model using CNN achieved 87.47% efficiency for potatoes and 91.96% efficiency for grape disease classification (Ghosh & Roy, 2021). The AI-based neural network-powered platform that was demonstrated by was utilized to identify tomato diseases caused by *Cladosporium* and powdery mildew. The method's performance on this test was more than excellent as it was able to identify the symptoms accurately, with at least some of them showing a mAP of 0.41. The combined model CNN-LSTM (Long Short-Term Memory) was successfully applied to detect yellow stem border disease of rice (Urbieta et al. 2023; Jain & Ramesh, 2021).

Machine learning and image recognition can address the shortcomings of manual identification and quantification in insect monitoring. AI aids in the automated identification of plant insect pests. Automated identification of individuals through image recognition software has potential for aphid pests monitoring (Batz et al., 2023). Several DL applications have emerged for insect classification and detection. Methodologies have been developed to improve insect detection results (Teixeira et al., 2023). A CNN based on the You Only Look Once (YOLO) network accurately detects and classifies fruit fly species in real-time (Tannous et al., 2023). An AI-based system of pest detection by the corresponding pictures was proposed by Chen et al. (2021). Deep-learning-based identification models, such as faster region-based convolutional networks (Faster R-CNNs), single-shot multi-box detectors (SSDs), and You Only Look Once v4 (YOLO v4), were utilized to identify the pests in the images. The results showed that YOLO v4 achieved the best classification accuracy of 100% for mealybugs, 89% for *Coccidae*, and 97% for *Diaspididae*, respectively. The AI-based model for insect identification using CNN and the generative adversarial network (GAN) provided high accuracy in insect identification. Weighted multipath CNN and GAN integration shows significant performance improvement compared to separate use of the algorithms (Gupta et al., 2023). The AI system developed for the identification of arthropod specimens in leaf litter minimises the time and expertise required for the identification of insect specimens. The model accurately segments insect side profiles, but struggles with wings detection. The model needs more variety in training data for better results; therefore, extended and versatile datasets are welcome to enhance the quality of current AI-based pest recognition (Helton et al., 2022). The AI-based soybeans pest detection models achieved the accuracy 98.75%, 97%, and 97% using YoloV5, InceptionV3, and CNN algorithms, respectively (Tirkey et al., 2023). The deep learning DenseNet121 model outperformed other networks in insect classification accuracy. The classification accuracy ranged from 46.31% to 95.36% for eight crops studied (Mohsin et al., 2022). Integration of the AI model, which detects pests, with the IoT provides a prospective tool for crop producers to get pest alert notifications via mobile phone applications (Thomas et al., 2023). The DeepPestNet framework achieved amazing 100% accuracy in pest recognition and classification. The proposed framework is the most effective and robust for pest recognition and classification at the moment (Ullah et al., 2022). The EfficientNet B0 model used for crop insect identification transfers DL algorithms to improve insect classification and recognition accuracy. K-fold cross validation enhances the model robustness and prediction scores (Monis et al., 2022). The GoogleNet model achieved 96.35% precision in crop pest identification through the use of computer vision technology combined with AI (Luo et al., 2020). The CNN-based AI algorithm using transfer learning and data augmentation for pests' detection in citrus fruit trees in India resulted in relatively high accuracy of 90%, providing reliable practical solution for farmers (Saini et al., 2021). In summary, there are numerous different AI-based approaches to the classification and detection of plant diseases and pests. Rani et al. (2023) suggests that such DL algorithms as Identification Model Improvement (IMI), Few Shot Learning (FSL), Generative Adversarial Networks (GANs), and Self Supervised Learning (SSL) are among the most prospective ones in AI-based phytosanitary monitoring systems. There is no universal solution, which fits everyone, therefore, local investigations in this field are of great importance for Ukraine as an agrarian country. Unfortunately, the current level of domestic developments in this field is extremely low, and a few scientific studies have been performed to cover this subject. Thus, the issue of creating robust scientifically-based AI algorithm for crops pests and diseases detection is of a great importance for Ukrainian science and practice.

Conclusions

The results of this review point out on broad possibilities for the application of artificial intelligence in the field of phytosanitary monitoring in agriculture. There are numerous methodological approaches to the classification and identification of pests and diseases in crops, with different accuracy, sensitivity, and specificity rates. Each method has its own advantages and disadvantages, which must be considered when making the decision about its application in certain scientific and practical purposes. All in all, deep learning algorithms and artificial neural networks are among the most prospective methods for the use in agricultural phytosanitary monitoring of crops. Domestic studies should be conducted to create the best toolkit for AI-based phytosanitary monitoring of crops cultivated in Ukraine.

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