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Detecting Diseases in Potato Leaves using Deep Learning and Machine Learning Approaches: A Review

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***Abstract*—As a mostly agricultural country, India is deeply concerned about its crop production rate. When crop yields drop, food prices rise, and people who can't afford even potatoes go hungry. Physical examination is a component of conventional approaches for spotting diseases in plants. This approach is exceedingly costly, laborious, and doesn't yield good outcomes. A unique approach for diagnosing potato leaf ailments should be developed to detect sick leaves at the start of their developmental period, which will assist to boost the output and consequently reduce the financial losses suffered by agriculturalists. Fortunately, new Deep Learning (DL) and Machine Learning (ML) models have flourished as a method of reducing plant disease and increasing crop yields, alleviating some of the burdens on farmers. Deep Neural Networks (DNN), a kind of artificial intelligence technology, may be used to identify disease-infected plants so that they can be treated early on, in the bud stage, before the sickness has spread too far. Based on a comprehensive literature assessment, the authors of this research concluded that Convolution Neural Networks (CNN) are superior to other methods for detecting leaf diseases and it is determined that CNN provides the highest achievable accuracy of 91% to 100%.**

Keywords—Agricultural Workers, Comprehensive Analysis Convolution Neural Network, Crop Yields, Deep Neural Network, Potato Leaf Diseases.

I. INTRODUCTION

Everyone on Earth will feel the consequences of Covid - 19. Humans know that the best defense against illness is a healthy body. Agriculture is a sector that focuses heavily on health. Agriculture is a sector that mainly relies on rainfall [1] [2]. In any nation, agriculture will be crucial. India is one such nation. The agricultural sector employs the vast majority of Indians. Potatoes, the most adaptable crop they cultivate, account for 28.9% of India's total agricultural crop output. The potato, as everyone knows, may be mixed and matched with any other vegetable. According to studies, white potatoes have the highest potassium content of any vegetable or fruit and are also the most cost-effective option. Since we are aware of the value of potatoes, we must make them available to the public in enough supply. Proper cultivation of potato plants is essential for achieving high yields in potato farming. Disease infection in plants should be kept to a minimum for optimal output, and although farmers are generally capable of identifying problems when they arise, doing so manually may be a time-consuming and error-prone process. It has been observed that modern farmers often fail to recognize the first signs of illness in their crops. There is currently no reliable technique for early-stage disease detection in crops. There is an increasing prevalence of AI applications.

The agricultural sector has also benefited from recent developments. The potato is an important crop for India. Potato farms in India have become more common in recent decades. But as a consequence of a variety of diseases as shown in Fig.1, the costs of producing potatoes are growing for farmers. However, several diseases are damaging the leaves, which is disrupting the agricultural worker's schedule and driving up the cost of producing potatoes. Automation has been employed to speed up illness diagnostics and modernize the potato sector. Despite denials to the contrary, potato leaf disease is a major issue that may drastically cut harvest output. Early, Septoria, and late blight are just a few of the diseases that may manifest on the leaves of potato plants. If these epidemics are detected early and adequately addressed, the

farmer will not suffer major financial losses. Almost every nation in the world has a commercial potato farming industry.

Diseases of many kinds have wreaked havoc on the crop. The gardener has to know what the source of the pollution is if they are going to respond quickly. They reasoned that by studying the leaves, they may get insight into the illnesses that were ravaging their people. To aid agricultural workers in the identification of illnesses affecting potato leaves, several CNN models and ML approaches have been developed. In comparison to other Machine Learning methods like k-NN and Decision Trees, CNN models benefit from this. The Pre-skilled CNN is famously difficult to program because of the huge variety of data types, it must process. But it can create stunning masterpieces when it wants to. Table I displays the 2022 potato harvest in the USA, India, China, and Russia. The work will be structured as follows. Section 2 covers works that are relevant to the topic at hand, while Section 3 addresses current obstacles. The last chapter wraps up the whole research.

(a) Early Blight infected Potato leaf diseases

(b) Late Blight infected Potato leaf diseases

(c) Pepper bell Bacterial spot infected leaves

(d) Latent and mild mosaic viruses

(e) Leafroll Virus

(f) Verticillium wilt

Fig. 1. Types of potato leaf disease

TABLE I. PRODUCTION OF POTATOES IN 2022 BY VARIOUS COUNTRIES

Country	Production of Potatoes in 2022(Millions of Tons)
Bangladesh	19.5
Germany	20.5
United States of America	22.5
Russia	23.5
Ukraine	40.1
China	49.6
India	50.3
World	370.8

II. RELATED WORKS

Weed recognition, microbial disease diagnosis, crop bug recognition, and fruit categorization are just some of the agricultural problems that CNN-based DL models that have been successfully applied in recent years. By training the network using photos of healthy and diseased plants, the CNN model can correctly identify plant diseases. The process of identifying diseased plants by analyzing photographs of their leaves using a CNN model is discussed in this section. Since CNN systems make it easier to monitor a wide variety of crops, they are gaining popularity across a wide range of industries. To rephrase, once further indicators of a disease appear in the leaves of a plant, the plant may be diagnosed automatically, without the need for human involvement. This may happen as soon as the first plant symptoms appear. Precision agriculture is now economical enough to be used even in underdeveloped nations thanks to recent technical developments. Various techniques are used in conventional farming to diagnose plant diseases. One of the quickest and least complicated ways to diagnose a condition is by visual estimate. However, this is highly dependent on the unreliable experience or knowledge of farmers in the agricultural sector. Researchers have developed new methods and equipment for illness detection to address the shortcomings of the already-used methods. Even though there are methods such as the prism spectroscope and Polymerase Chain Reaction (PCR), treating leaf samples, having highly trained workers, and having ideal laboratory settings are all prerequisites. Early disease diagnosis is crucial for long-term yield success, and this is now feasible with the use of sophisticated sensor devices and wireless communication networks. Automatic plant disease diagnosis is now in progress, thanks to cutting-edge technology like machine vision and artificial intelligence. It's also been shown that deep learning has the best promise for rapidly and correctly diagnosing plant leaf diseases. This aids in early disease prevention without the need for human intervention, which increases agricultural output with no decrease in yield. Deep learning, when combined with cutting-edge tools and algorithms, greatly aids in the early diagnosis of plant diseases. Pattern recognition, transformation, image processing, classification, and feature extraction are all areas that benefit from this approach. Inspired by biological neural networks and the visual system, CNN is the most popular deep learning model. CNN outperforms competing models despite using a very modest number of neurons over many convolutional layers; yet, it needs a massive amount of training data. Table II shows various existing methods for Potato leaf disease identification.

TABLE II. A REVIEW OF POTATO LEAF DISEASE DETECTION TECHNIQUES

Research	Method Employed	Leaf Diseases considered for the study	Dataset Used	Performance Metric & Merits	Demerits
C. C. Bonik et al., (2023). [3]	CNN	Early and Late Blight	The data obtained from open-source databases are supplemented with photographs of potato fields in the community.	Accuracy= 94.2%	This study includes only two leaf diseases. It is suggested to include more leaf diseases in their dataset.
S. Bangari et al., (2022). [4]	Based on a comprehensive literature assessment, the authors of this research concluded that CNNs are superior at identifying leaf diseases and provide the best detection accuracy.				
S. G. Joseph et al.,(2022). [5]	CNN	Early and Late Blight	Plant Village from Kaggle	Accuracy= 98%	Experiments should be done on real-time datasets.
B. Vadivel et al.,(2022). [6]	VGG19	Early and Late Blight	PlantDoc[17]	Accuracy= 99%	This study includes only two leaf diseases.
M. S. Hylmi et al.,(2022). [7]	Multi-Class SVM with Linear Kernel	Early and Late Blight	Plant Village from Kaggle	Accuracy=97.56%	Training time is more.
K. S. Krishna et al.,(2022). [8]	CNN	Early and Late Blight	Plant Village from Kaggle	Accuracy=98%	Experiments are conducted on standard datasets.
P. K. Shukla et al., (2022). [9]	CNN + fast API user Interface	Early and Late Blight	Plant Village from Kaggle	Accuracy=99.76%	Training time is more.
T. H. H. Aldhyani et al., (2022). [10]	Novel 2D CNN	Early and Late Blight	Plant Village from Pennsylvania state university	Accuracy=91.28%	Accuracy can be improved.
A. H. T. Rusli et al., (2022). [11]	ANN	Early and Late Blight	New plant diseases dataset from Kaggle	Accuracy=94%	Accuracy can be improved.
H. Shah et al., (2022). [12]	MobileNet	Early and Late Blight	Plant Village from Kaggle	Accuracy=96.12%	Accuracy can be improved.

III. OPEN CHALLENGES

Table III shows that despite the many approaches offered for disease detection in potato plant leaves, there are still significant obstacles that must be overcome before we can achieve improved disease identification. Some such difficulties and impediments include the following:

(1) There is not yet a central data repository for potato leaf diseases such as Latent and moderate mosaic viruses, Verticillium wilt, Leafroll virus, and Pepper bell bacterial spot [13].
(2) Many scientists are making use of the Plant Village data set that is available in the Kaggle repository. Since the Kaggle dataset has already been cleaned, it cannot provide a reliable analysis or prediction. In addition, there is no real data collection from which to make a rough estimate [14].
(3) Previous studies have been criticized for the insufficient use of picture enhancement techniques.

TABLE III. OPEN CHALLENGES

Disadvantages of Existing Systems	Open Challenge
Most existing methods focus on only two diseases: early and Late blight [15].	It is recommended for young researchers extend their study to diseases other than Early and Late Blight.
Most Existing systems used CNN for identifying potato leaf diseases. The main drawback of CNN systems is they require huge data for training.	Researchers may use transfer learning to modify pre-trained networks without the need to collect massive datasets in the agriculture sector.
The Class Imbalance Problem (CIP) [16] in the potato leaf diseases dataset was not considered. That's why most existing methods has got an accuracy of more than 90%. Even some researchers got 100% accuracy.	It is suggested that young researchers think about CIP while doing experimental studies. It is very easy to get 100% accuracy by negotiating CIP in datasets. The biased nature of datasets should be considered for getting accurate and unbiased results [17].

IV. CONCLUSION

The agricultural sector supports the global economy. Food quality and production are both threatened by the industry's inability to solve the problems of bacterial infections in potato crops, malady forecasting, insect management, weed identification, and productivity prediction. Accurate plant disease diagnosis and weed categorization are essential for ensuring food security, high resilience, and higher crop yields. The analysis of this research indicates that if plant diseases were detected early enough, they might be contained to some degree, resulting in a rise in the production of crops. To enhance plant leaf disease prediction, the current strategies used several DL models. To further enhance the accuracy of the categorization, numerous experts have used a transfer learning strategy. This study demonstrated that, when compared to other deep neural networks, CNN provided the greatest accuracy for identifying and classifying potato leaf illnesses such as early blight, late blight, and non-infected. This study also revealed that most Researchers employed CNN models to detect potato leaf infections. Therefore, it is determined that CNN provides the highest achievable accuracy of 91% to 100%. It can be concluded that current methods such as manually inspecting every plant in an area, are time-consuming and inefficient compared to the CNN technique of identifying potato leaf diseases. To aid the agricultural industry, and particularly farmers, in identifying and diagnosing potato plant diseases at lower cost and, most significantly, in less time, it is recommended that a study may be conducted for the categorization of numerous potato leaf diseases using CNN.

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