Advances in Rice Plant Disease Detection: A Survey of Machine Learning and Deep Learning Approaches

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Abstract: ***Rice is the major crop worldwide, which provides sustenance for a substantial part of the world's population. But the rice plant is prone to different diseases that seriously damage the quality and crop yield. Accurate and earlier detection of this disease is crucial to implement effective and timely disease management strategy. Recently, the incorporation of machine learning (ML) and deep learning (DL) approaches has exposed great potential to automate and enhance the uncovering of crop diseases. This survey paper's aim is to provide a detailed study of the present research on crop disease recognition using ML and DL algorithms. We begin by deliberating the significance of earlier disease recognition in rice plants and the challenges related to the conventional technique. Consequently, we presented a review of the challenges and need to be associated with the crop disease recognition system. Moreover, we analyze and review the present study that utilizes ML and DL approaches for detecting rice plant diseases. Furthermore, we inspect the evaluation methodologies, performance metrics, and datasets applied in this case for evaluating the efficiency of the presented method. Additionally, we highlight the emerging trends and recent advancements in this field, such as the incorporation of image augmentation approaches, transfer learning, and ensemble algorithms.***

Keywords: Plant disease detection; Rice; Computer vision; Deep learning; Machine learning

1. Introduction

Rice is staple food consumed globally as a major source of diet for countries with dense populations namely China, India, Pakistan, and so on [1]. Rice classification is under the type named Orza, for example, cereal, wheat, and corn. The reason behind its popularity is containing minerals, nutrition, and supplements in it. It is a fundamental food for above 3 billion people. The major production of rice can be seen in the east of India and Pakistan. In recent times, there was a significant decrease in rice productivity for several reasons [2]. The major factor is rice plant maladies or diseases. The unwanted maladies can be represented as brown spots, sheath blight, and leaf blasts since they seriously damage grain quality or rice production [3]. The maladies, though different, in effect, generally have spots on the plant leaves. Earlier diagnosis could prevent or reduce the associated damage like other diseases. The main problem occurs if there is no constant plant observation [4]. Other reasons are that farmers who are novel to the domain could not aware and attentive to diseases which occur inplants [5]. However, continuous observation of plant's growth period can prevent infection.

Detection of diseases of rice needs continuous crop monitoring, which can be possible by the automation of the monitoring procedure [6]. Machine learning (ML) had a significant role in automatic rice disease detection system. Once the images are collected, they are segmented and pre - processed. Features extracted from various methods are given in the classification methods for identifying the diseases from the test imagery [7]. ML serves crucial role in supporting the agriculturalists in the agricultural field. Currently, in plant disease detection research, DL technology has done more progress. Deep learning (DL) technology can automatically classify plant disease spot extract image features, eradicating the conventional image detection technology of feature extraction and classifier can express original image features. Such features make DL technology in plant disease detection gain lot of attention, and it is been an active research topic [8]. This is because of 3 factors: the progress of training deep neural network (DNN) and support software libraries, like the CUDA (computing unified device architecture) from NVIDIA, the obtainability of larger data, and the adaptability of multicore graphics processing unit (GPU). Fig.1 illustrates the process in rice plant disease detection system.

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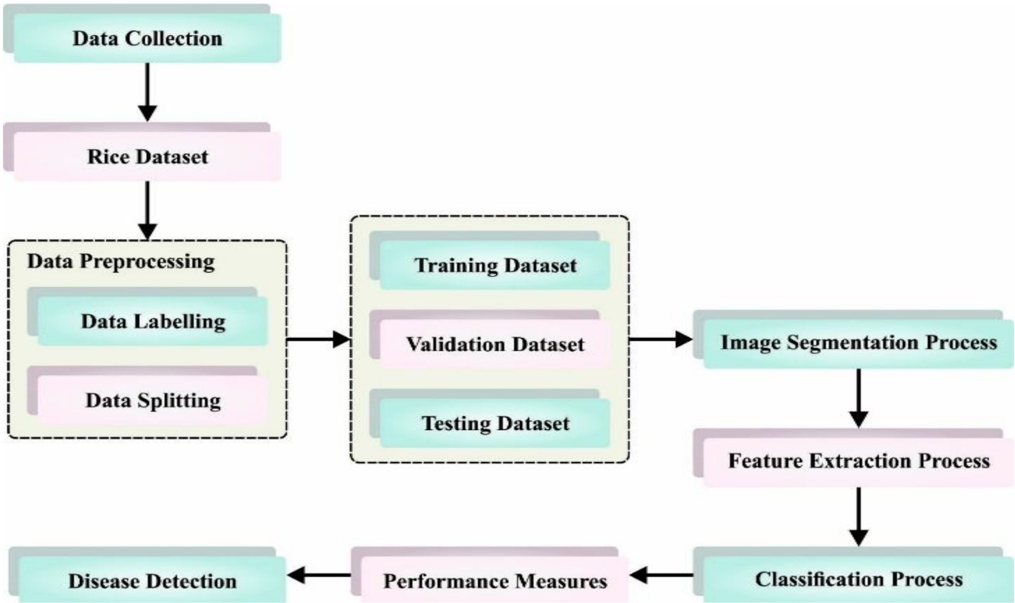

Figure 1: Process in Rice Plant Disease Detection Systems

However, good outcomes were seen in the literature, but, the variety of utilized datasets is limited [9]. Large data are essential for CNNs training. Inappropriately, for plant leaf disease detection, scholars have not yet gathered such diverse and large datasets for use. Presently, transfer learning was the potential way for training the robustness of CNN methods for plant leaf disease detection. TL allows the application of pre - training CNN by re - educating them with small data whose distribution varies in the large data utilized earlier for training the network fromscratch. Certainly, it can be potential that utilize CNN methods pre - training on the ImageNet database and re - educating them for detecting leaf diseases [10]. Hence, the mixture of transfer learning and DL presents solution to the issue of limited data on plant diseases.

This survey paper aims to offer a detailed study of the existing research on crop disease recognition using ML and DL algorithms. We begin by deliberating the significance of earlier disease recognition in rice plants and the challenges related to the conventional technique. Consequently, we presented a review of the challenges and need to be associated with the crop disease recognition system. Moreover, we analyze and review the present study that utilizes ML and DL approaches for detecting rice plant diseases (RPD).

2. Background Information

Conventionally, the human vision - based model was used for the detection of leaf disease, however, this method was expensive and time - consuming. In addition, this model relies on the opinion of specialists or individuals to define the performance. On the other hand, the automatic leaf disease diagnoses method streamline the diagnoses system, which allows farmer to make accurate and prompt decisions regarding the plant condition. This could help farmers to improve crop yields and more effectively utilize resources [3]. The usage of ML and DL algorithms for disease diagnoses in paddy crops is a region that hasn't been considered in detail. Notwithstanding the potential advantages, these fields have not gained more popularity. Due to disease outbreaks, further research in this field might assist in mitigating losses and improving rice crop yield. However, the usage of this technique has possibly considerably greater accuracy and efficiency of disease diagnosis in crops.

2.1. Need for Automatic Rice Leaf Disease Detection

- Rice is prone to a large number of diseases caused by different pathogens and viruses that could heavily affect the quality and quantity of rice grains. This could outcomes in decrease in global food supply and financial losses for the farmers.
- Rice is main energy source and food crop for over half of the global population, which makes it a crucial crop for food safety and alsoensure a bountiful and stable rice harvest is critical to feed the growing population of world.
- The increasing demand and the growth in population for food are crucial to optimize agricultural productivity. Therefore, earlier diagnosis of disease might assist in increasing crop yield [10].
- Advancements in agricultural technology including ML and DL, have made it possible to construct efficient and accurate disease recognition systems for paddy crops. Using this technique might considerably enhance crop productivity and disease management.
- Conventional disease detection methods namely visual inspection, might lead to insufficient farming practices and are time - consuming. Pathologists could more effectively and efficiently manage and identify crop diseases by developing automated detection techniques [11].

2.2. Challenges Associated with Automatic Rice Leaf Disease Detection

There are large number of problems related to the detection of rice diseases [12], such as:

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- Diversity of rice disease: paddy crops are mainly affected by a large number of diseases caused by different viruses and pathogens that could affect various parts of the plant and present with various symptoms. This makes it complex to precisely diagnose and detect dissimilar diseases.
- Limited availability to technology: several farmers in remote rural regions might have limited access to the resource and technology required for precise detection of disease. This makes it challenging to efficiently protect their paddy crops and manage diseases.
- Lack of standardized methods: Currently, there are no standardized and universally accepted methodologies for the detection of rice disease. This makes it hard to efficiently diagnose disease in various regions and compare the performance of detection techniques.
- Balancing accuracy and computation difficulty: Evolving a disease diagnosis method that is computationally efficient and highly accurate can be challenging. Several existing approaches might be computationally intensive or very challenging for real - time usage.
- Difficulties in data collection: Gathering diverse and large databases for testing and training automated diagnosis methods can be very difficult, especially if the images of leaf disease are not taken in same condition and lighting.
- Studies had been conducted to devise AI and technical - based methodologies for the disease recognition of rice plant leaves.

2.3. Overview of CNN Model

DL is a famous ML approach which are analyzed broadly recently, is a multi - layered approach utilized for extracting and defining features in huge data counts [22]. It comprises distinct layers with particular tasks like pooling, convolutional, fully connected (FC), activation, and flatten layers.

Convolution layer: The convolutional layer is an efficient layer utilized for extracting features in input data. An input vector can be scanned with determined filtering and the data has been changed as to feature space with nearby weight sum aggregation. During this layer, it is 1st convolutional layer directly linked to set of images, low level extraction feature like edges and colors are carried out.

Activation Layer (Nonlinearity layer): An activation layer is the layer on that a non - linear function can be executed to all the pixel on the image. Recently, the ReLu activation function is begin that utilized rather than the frequently utilized sigmoid and hyperbolic tangent activation function.

Pooling (Down - sampling) layer: Additional building block of CNN infrastructure, the pooling layer, decrease the parameter counts and the count of calculation from the network that takes 2 benefits. A primary is to decrease the computation count for the following layer, and secondary is to restrain the network in learning. Sum, maximum, average, and mean pooling are processes generally utilized for pooling layer.

Flatten layer: This task of layer can easily for preparing the input data for the final layer. As NNs has input data as 1 - D array, it is layer but matrix - type data in the other layers can be changed as 1 - D arrays. But, all the pixels of images are defined by single line, this procedure is termed as smoothing.

FC layers: This layer is depends on every field of the preceding layer. The count of this layer can differ in various structures. At the nodes in these layers, the features can retained, and the learning procedure was executed by altering the weighted and biased values. This layer can responsible to perform the actual processing by taking input in distinct extraction feature steps, examines the outcomes of every processing layer.

3. Review of Existing Rice Plant Leaf Disease Detection and Classification

In this section, a detailed review of existing ML and DL based rice plant leaf disease detection approaches are given in Table 1. In [11], presented an image based ML algorithm to find and categorize plant diseases. The author has concentrated especially on RPD. The imageries of diseased symptoms in stems and leaves were taken in the paddy field. The authors utilized an SVM as classifier and pre – training DCNN as feature extractors. Wang et al. [12] introduced the ADSNN - BO method relevant to MobileNet framework and augmented attention method. Additionally, for tuning hyper parameters of the method, Bayesian optimization method is implemented.

In [13], presents a potential RPD recognition algorithm relevant to CNN approach. This study focused on three rice diseases, including, bacterial leaf blight caused by bacteria, leaf smut, and brown spot caused by fungus. This study devises a potential method to identify and recognize paddy plant disease depending on color, size, and shape of lesion in the leaf images. In [14], adopted the SVM classifier for combining a deep CNN. The TL method was utilized for enhancing the presented method. Then, to re - train presented method, 1080 imageries of data of 9 paddy diseases are utilized. SVM method can be trained with the attributes that are removed from the DCNN method.

Ahmed et al. [15] develop a rice leaf disease recognition process with the use of ML methods. Three different paddy crop diseases brown spot, leaf smut, and bacterial leaf blight diseases are recognized in this study. Clear images of infected rice leaves are exploited as input. After pre - processing, the data was trained by distinct ML methods namely NB, LR, KNN, and J48. In [16], concentrated on 4 paddy diseases Leaf Smut, Brown Spot, Bacterial Leaf Blast, one healthy leaf, and Leaf Blight. This study chose the DCNN and trained the data on the 4 DNN related pre - training methods called Resnet101, VGG19, Inception - ResNetV2, and Xception.

In [17], introduced a Faster R - CNN for finding paddy leaf diseases in realtime. The presented method solves the object location more accurately for generating candidate regions. The strength of the presented approach can be boosted by accomplishing model training with own online real - field

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paddy leaf data. Senan et al. [18] use a potential ML and image processing method for classifying and identifying the pests and paddy diseases more precisely and in less time processing. To do this case, 3355 images cover 4 classes, paddy imageries are leaf blast, healthy, hispa, and brown spot has been exploited. Then the presented five layers of CNN method were utilized for categorizing the images.

In [19], developed a DL method with testing on 647 images and training on 1509 images of rice leaves. TL utilizing fine - tuning the pre - defined VGGNet has enhanced the model performance for suitable outcomes on small data. In [20], implemented the SVM method for integrating an AI method called CNN. The TL method was exploited for enhancing the presented approach. Then 1080 images of dataset of 9 rice diseases were exploited for re - training the presented method. SVM is trained with attributes that are removed from the DCNN approach. Su et al. [21] compare automated plant disease detection approaches utilizing DCNN and pointing for mobile platforms. A dataset of 120 imageries of the 3 disease instances has been gathered, and the method was trained for finding them on rice. Islam and Mazumder [22] focused on organization and recognition of paddy crop illnesses by exploiting simple image processing methods relevant to wavelet transformation. Classification is done through an Ensemble of Linear classifier executing the Random Subspace Method (RSM).

Chawal and Panday [23] intend to devise a prototype mechanism for identifying paddy disease. Image detection of the disease has been carried out depending on Image Processing methods for enriching the image quality and Twin SVM (TSVM) approach for categorizing the rice diseases. Afterward, every segmented paddy disease samples are transformed into binary data in dataset before continuing with the help of the TSVM for testing and training. In [24], exploited CNN for extracting the features of rice leaf disease images. After the SVM, approach can be adopted for predicting and classifying the particular disease. The best variables of SVM method can be gained with utilize of 10 - fold cross validation approach.

In [25], modelled Classification and Recognition of Paddy Leaf Disease utilizing Optimized DNN with Jaya Optimization Algorithm. During pre - processing, for the background exclusion, the RGB imageries are transformed as HSV imageries, and depending on hue and saturation part binary imageries were removed for dividing the non - diseased and diseased parts. Utilizing Optimized DNN_JOA, Classification of diseases has been done. In [26], implemented AlexNet approach to find the 3 rice leaf diseases called bacterialsblight, brown spot, and leaf smut and got incredible outcomes instead to the earlier works. AlexNet refers to a special kind of classifier method of DL.

In [27], presented the DL method to solve the task as it has revealed incredible efficiency in classification and image processing. Merging both the advantages, the Inception module and DenseNet pre - training on ImageNet are chosen in the network, and this method presented a better performance in terms of other existing methods. In [28], discussed image segmentation utilizing Mask RCNN approach and diseases image feature pre - pre - processing with high, edge, multiple correlations, area, image enhancement, color space analysis, and width.

Shrivastava et al. [29] sight seen the performance of different pre – training DCNN methods like Xception; AlexNet; MobileNet; ResNet152V2; InceptionV3; Vgg16; InceptionResNetV2; NasNetLarge DenseNet169, and NasNetMobile for image related RPD classification. Anandhan and Singh [30] devised system for finding different rice plant leaf image disease detection using Fast RCNN, and mask RCNN methods. The author has studied 5 paddy diseases and implemented them in southern India for enhancing the quantity of paddy.

Table 1: Review of Present Rice Plant Leaf Disease Detection and Classification

Reference	Year of Publication	Aim	Methodology	Dataset	Metrics
Shrivastava et al. [11]	2019	RPD Classification Utilizing Transfer Learning	Deep CNN and SVM	large rice disease dataset	$Accu_y$ of 91.37%
Wang et al. [12]	2021	Rice Diseases Recognition and Classification Utilizing Attention-based NN	MobileNet and Bayesian optimization	public rice disease dataset	$Accu_y$ of 94.65%
Upadhyay and Kumar [13]	2021	RPDs classification with deep CNN	CNN	Kaggle dataset	$Accu_y$ of 99.7%
Hasan et al. [14]	2019	Rice Disease Identification and Classification by SVM	SVM and DCNN	image dataset	$Accu_y$ of 97.5%
Ahmed et al. [15]	2019	Rice Leaf Disease Detection Using ML	LR, KNN, DT, and NB	UCI machine learning repository and WEKA	$Accu_y$ of 97.9167%
Islam et al. [16]	2021	CNN-Based Model for Paddy Leaf Disease Detection	DCNN	UCI machine learning repository and Kaggle	$Accu_y$ of 92.68%
Bari et al. [17]	2021	A realtime technique of analyzing rice leaf disease utilizing DL	Faster-RCNN	Kaggle and on-field datasets	$Accu_y$ of Rice blast: 98.09%, Brown spot: 98.85%, Hispa: 99.17%, Healthy rice leaf: 99.25%
Senan et al. [18]	2020	Paddy Leaf Disease and Pest Classification	CNN	Kaggle repository dataset	$Accu_y$ of 93%
Ghosal and Sarkar [19]	2020	Paddy Leaf Diseases Classification Using CNN	VGG-16	rice image dataset	$Accu_y$ of 92.46%
Hasan et al.	2019	Paddy Disease detection and	SVM and DCNN	image dataset	$Accu_y$ of 97.5%

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[20]		Classification utilizing ML			
Su et al. [21]	2022	Rice Leaf Disease Classification Utilizing Deep Learning	DCNN	UCI: Machine Learning Repository	$Accu_y$ of 81.87% on training data and 81.25% on validation data.
Islam and Mazumder [22]	2019	Feature Extraction for RPD Detection and Classification	DWT	Rice Leaf Diseases Data Set	$Accu_y$ of 95%
Chawal and Panday [23]	2019	RPD Detection Utilizing Twin SVM	TSVM		$Accu_y$ of 95%
Jiang et al. [24]	2020	Image recognition of 4 rice leaf diseases	SVM	rice leaf dataset	Correct recognition rate is 96.8%
Ramesh and Vydeki [25]	2020	Detection and classification of paddy leaf diseases	DNN and JOA		$Accu_y$ of 98.9% for blast affected, 95.78% for bacterial blight, 92% for sheath rot, 94% for brown spot, and 90.57% for normal leaf image
Matin et al. [26]	2020	Effectual Disease Detection Approach of Rice Leaf using AlexNet	AlexNet	Kaggle dataset	$Accu_y$ of 99%
Chen et al. [27]	2020	Detection of RPDs using DL	DenseNet	rice leaf disease dataset	$Accu_y$ of 98.63%
Das et al. [28]	2020	Disease Feature Extraction and Disease Detection from Paddy Crops	Mask RCNN	Rice Leaf Disease dataset	$Accu_y$ of 99.9%
Shrivastava et al. [29]	2021	Pre-Trained Deep CNN for RPD Classification	deep CNN	RPD dataset	$Accu_y$ of 93.11%
Anandhan and Singh [30]	2021	Recognition of Rice Crops Diseases and Early Diagnosis	Fast RCNN	Rice lead images dataset	$Accu_y$ of Blast-96%, Brown spot-95%, and Sheath blight-94.5%

4. Discussion

In this section, the rice plant detection results of the ML and DL approaches. Fig.2 represents the sample images

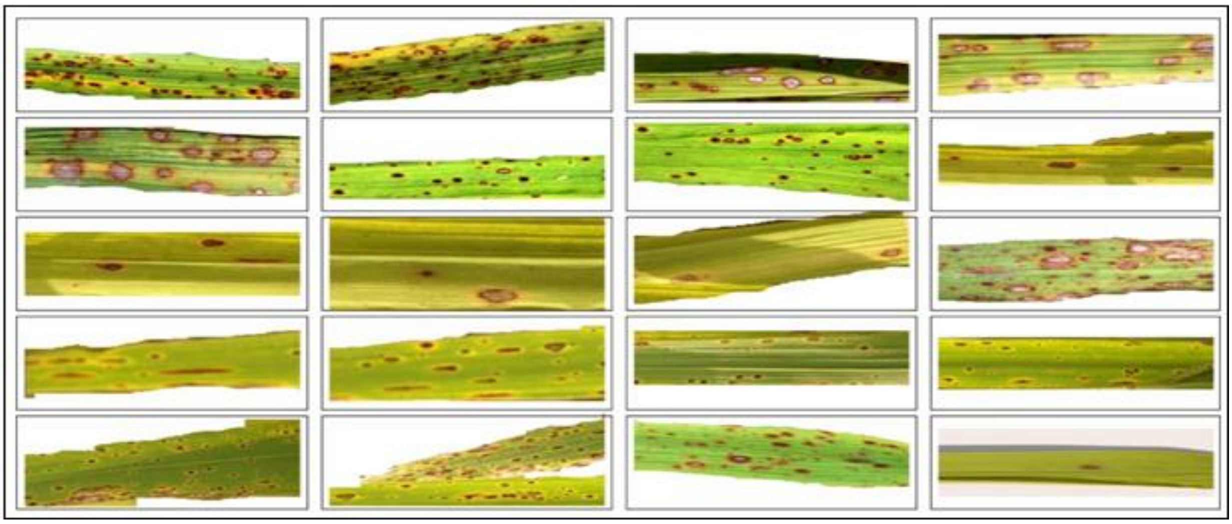

Figure 2: Sample Images

Table 2: Comparative outcome of ML and DL approaches with distinct measures

METHODS	Accuracy	Precision	Recall	F1 Score
ANN Algorithm	86.81	87.15	86.51	86.71
MLP Algorithm	86.12	87.19	86.16	86.98
SVM Algorithm	86.35	87.16	85.95	87.91
VGG Algorithm	96.81	95.98	96.15	96.29
AlexNet	93.79	92.66	93.45	94.1
CNN + SVM	91.65	92.15	92.66	91.41
CNN Model	96.61	97.11	96.66	95.95
VGG19	81.43	81.76	80.35	80.41
ResNet - 101	91.52	92.15	90.56	90.56
InceptionResNet - V2	92.86	93.71	92.62	92.86
Xception	89.42	89.63	88.65	88.23

To demonstrate the improved rice plant detection results of the existing ML and DL approaches, a widespread comparative outcome is made in Table 2 and Fig.3 [27]. The experimental values highlighted that the VGG19, ANN, MLP, SVM, and ResNet - 101 algorithms reported least classification results. Followed by, the CNN+SVM, AlexNet, and CNN models accomplished moderately improved results. However, the VGG technique reaches better performance with maximum $accu_y$, $prec_n$, $reca_l$, and $F1_{score}$ of 96.81%, 95.98%, 96.15%, and 96.29% correspondingly.

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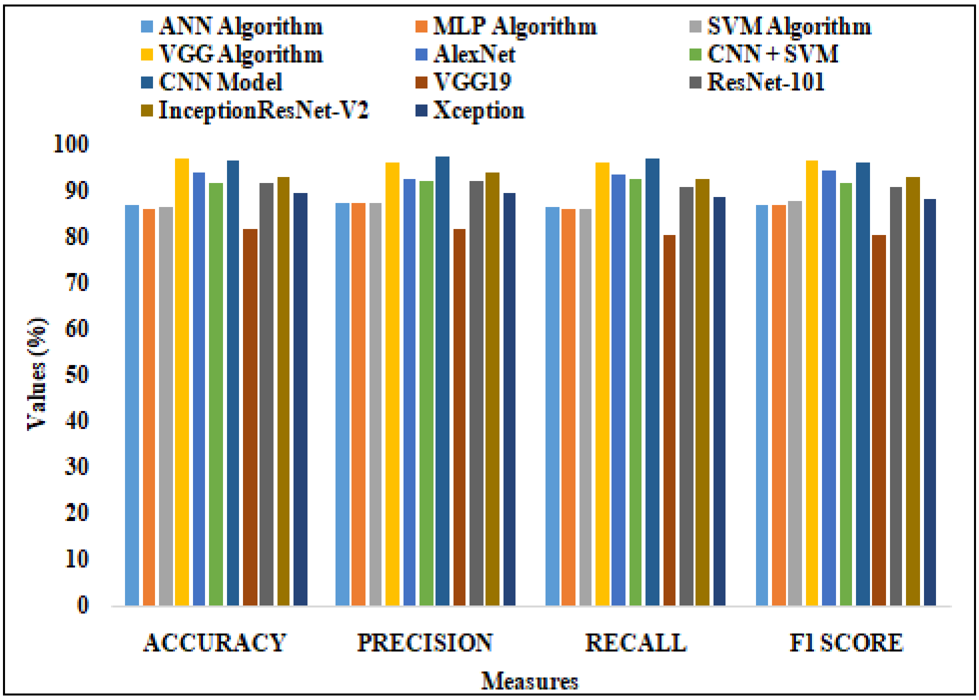

Figure 3: Comparative outcome of ML and DL approaches with distinct measures

5. Conclusion

This survey paper offers a widespread understanding of the current research landscape in RPD detection utilizing ML and DL. It serves as a valuable resource for agronomists, researchers, and practitioners involved in leveraging artificial intelligence techniques to combat RPDs effectively and promote sustainable agriculture. Furthermore, it identifies potential research directions and opportunities for further advancements in this field, ultimately contributing to the development of robust and reliable disease detection systems for rice cultivation. In future, multimodal fusion based DL models can be developed to improve the rice disease detection performance. In addition, more focus should be made on the utilization of remote sensing images for plant disease detection process.

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