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Reviewing Important Aspects of Plant Leaf Disease Detection and Classification

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***Abstract*—Agriculture, being the dominant industry from the point of view of economical growth of countries like India, plays a vital role in fulfilling the demand of food. However, extreme weather conditions and several climate changes may invite notable infectious diseases in plants caused by fungi, viruses and bacteria. These plant diseases can be a major threat to food supply and hence it is important to identify and prevent the plants from the diseases at the early stages. The conventional approaches were dependent on the experts in the field and hence time consuming. Since the technology is upgrading day by day and has plenty of its advantages in plant leaf disease detection field as well, various disease identification approaches using different domains have been proposed in the literature to detect and cure the plant diseases that occur on the plant leaves. Although, many of the existing approaches have provided better results, challenges exist in order to achieve optimized results of plant leaf disease detection process. This paper reviews different methodologies under image processing, machine learning, deep learning and swarm intelligence domains for plant leaf disease detection. Understanding of various diseases that occurs on plant leaves is very important in order to deal with it; hence this paper provides a detailed taxonomy about the different plant diseases and dataset that is popularly used in various existing approaches for training and testing purpose of plant leaf disease detection and its classifications.**

Keywords— plant leaf disease detection, swarm intelligence, machine learning, deep learning, internet of things, swarm intelligence, plant leaf disease classification, optimization.

I. INTRODUCTION

Economic growth of agricultural countries like India is mostly dependent on food crops, but due to several deadly diseases found on leaves of plants causes major loss in the production of several agricultural products [1][2]. Also, many plants have importance from the medicinal point of view. Ayurvedic medicine industry requires identifying and saving Ayurvedic plants from the diseases. Numerous state-of-the-art approaches for accurate plant leaf disease detection and its classification were invented and studied by researchers in the past. The conventional methodology of the said process was very time consuming and at the same time not always accurate, since farmers or researchers required to appoint an expert in the field to monitor the growth of the plant and suggest remedies. Today is the era of technology and Artificial Intelligence (AI) is the need of the day in every sector. Recently, AI has achieved tremendous appreciation in agricultural field, especially in identifying plants, their diseases and classification. Researchers have employed several approaches in literature to gain good amount of accuracy in the mentioned work. They have researched and touched different aspects of plant diseases under various domains and inspire nowadays researchers to research further considering the challenges they have encountered [25]. This paper reviews notable aspects in the field of plant leaf disease detection and its classification, which can be a guide for future researchers in the said field.

The entire paper is designed as follows. Section II talks about the general concept of plant leaf disease detection and classification. Section III provides a detailed taxonomy of different diseases that occurs in plants. Section IV reviews several existing methodologies from the literature under different domains. Section V is dedicated to dataset that is predominantly used for experimentation in the said area followed by Section VI which concludes the work giving future directions.

II. PLANT LEAF DISEASE DETECTION AND CLASSIFICATION

The generalized procedure of plant leaf disease detection and classification system basically involves five important phases [8] which are discussed in brief as below and it is diagrammatically depicted in Fig.1.

A. Image Acquisition

This phase captures the images of target plant leaf, either clicked in real time environment or with fixed controlled background such as white using digital camera. Acquiring the images from web is also considered as image acquisition.

B. Image Pre-processing

In this phase several necessary pre-processing operations are performed namely; gray scale conversion, noise reduction, binary conversion, resizing of images, quality enhancement etc. The basic objective of image pre-processing is to enhance information about the image in order to remove unwanted disturbance and improves the image features that are going to play an important role in further processing.

C. Image Segmentation

This is one of the important phases in any image processing approach for image classification. Image segmentation segments the area of interest from its background using various segmentation techniques, to name a few Otsu's thresholding, k-Means clustering, Particle Swarm Optimization (PSO) etc. Accurate segmentation results into good quality feature extractions from the plant leaf image.

D. Feature Extraction

Once the segmentation is performed, important features are extracted from the segmented image using various feature extraction methods based on the features which are

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intended to extract. These features will then become a guide for a classifier in next stage to generate good quality results.

E. Image Classification

This final phase is responsible to employ a good classifier to classify whether the fed plant leaf image as an input is healthy or unhealthy and if found unhealthy then it also identifies the name of the disease.

III. Taxonomy of Plant Leaf Diseases

As per the survey stated in [12], it is expected that by 2050 food production must be increased by 70% in order to feed increasing population. Potential yield gets reduced by an average of 40% due to infectious diseases found on plant leaves which is a major loss of the agriculture field. Best quality of yield can be produced by limiting the spread of diseases by identifying the symptoms of the disease at the early stage and save the crop with the cure later [24]. For the said, effective knowledge of the plant diseases is must. Parasitic and Non-parasitic elements are responsible for diseases to occur in any plant. The growth of the plant can be affected by parasitic elements such as Pathogen, Pests, and Weed. Pathogen is a microorganism which is further classified into three well known kinds of diseases namely fungal, viral and bacterial diseases which differ from each other with respect to their symptoms [2]. The destructive insects like Mites, Slugs, Mammals and Rodents are named as Pests and Weeds are normally categorized into Monocots and Dicots which are nothing but unwanted plant entity in the field. The classification of diseases found in plants based on their causes is depicted in Figure 2. Wilt, Blight, Spot, Scab and Rot are common bacterial diseases that are mostly found in plant leaves. The diseases like Aphids, Grey mold, Downy mildew, Powdery mildew, Cylindrocladium and Mealybugs are caused by fungal infection whereas; some of the viral diseases are Mosaic, Spotted Wilt, Curly top [24]. TABLE I, II and III gives the summary of different bacterial, fungal and viral diseases found in plant leaves.

IV. Literature Survey

One of the most important challenging tasks in agricultural industry is the identification of infected plant with the help of digital image of plant leaf. This problem of plant leaf disease detection and its classification is addressed from different domains. The primary domain addressing this problem is an Image Processing (IP) which involves different operations related to pre-processing the images, noise removal, color enhancement, segmentation and feature extraction etc. which are helpful for taking accurate decision when machine is learned to identify and classify the input images. To design accurate system for the said problem, every phase of the process of identifying and classifying the images of plant leaf diseases has to be well addressed. Several approaches are used in various phases of plant leaf disease identification process for better results in the literature. The most dominant approaches involve Machine Learning (ML) algorithms, Deep Learning (DL) algorithms and Swarm Intelligence (SI) algorithms as per the study conducted. This section reviews the existing works in these five categories.

A. Using Image Processing and Machine Learning

Machine Learning is popularly known as subfield of Artificial Intelligence (AI). ML specifies that machine can be fed with data, patterns etc so that it will learn from those data and make intelligent decision with very less involvement of human being. It is proved in the literature that IP which uses ML techniques proves better in simulating the human vision system and especially analyzing the images. Classification is

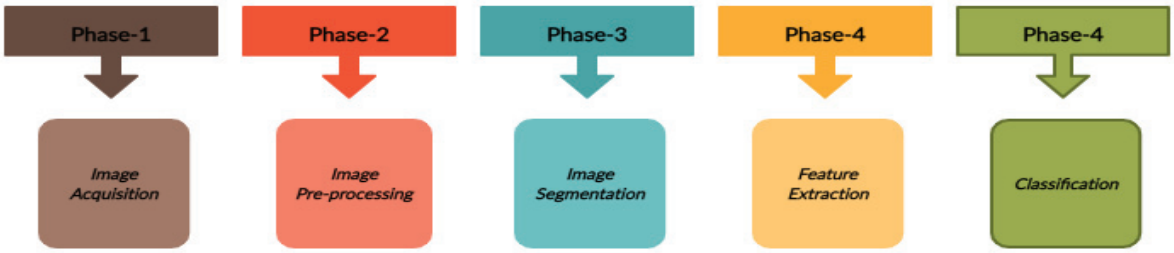

Fig. 1. General Process of Plant Leaf Desease Detection

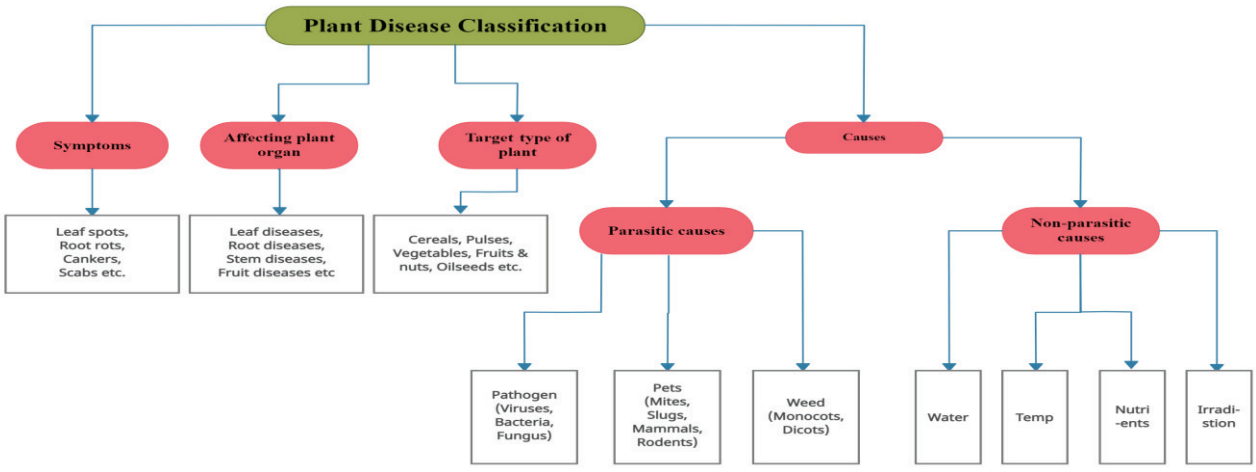

Fig. 2. Plant diseases classification

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one of the important phases in identifying and separating the healthy plant leaf image from diseased one. ML algorithms namely SVM and Random Forest were proved as better choice in plant leaf disease detection and its classification [3][4][9][19]. Table II summarizes the various plant leaf disease detection and classification methodologies under IP and ML domains which were studied in literature review.

B. *Using Image Processing and Deep Learning*

Deep Learning is categorized as artificial intelligence function which is a sub branch of machine learning. DL imitates the working of human brain and also known as Deep Neural Network (DNN). DL has strong models that learn by itself unlike ML and extremely efficient in making decision. There are various deep learning algorithms such as Convolutional Neural Network (CNN), Recurrent Neural Networks (RNNs), Long Short-Term Memory Networks (LSTMs), Stacked Auto-Encoders, Deep Boltzmann Machine (DBM), Deep Belief Networks (DBN) etc. The most predominantly used image classifier is CNN which has numerous transfer learning architectures that helps machine to avoid learning from scratch, since it is very well trained with large image dataset called ImageNet. With the help of transfer learning approaches, one can reduce the training time and provide accurate and efficient results in minimum time. Several transfer learning models were studied and explored from the accuracy point of view and shown best results as compared to other approaches from mentioned domains in research review. AlexNet, GoogleNet, ResNet50, InceptionV3 are few names which have given good results in the past in plant leaf disease detection and classification domain [1][14][19][22]. Table III put forward the comparative review of DL based methodologies in the said domain.

C. *Using Image Processing and Swarm Intelligence*

Swarm Intelligence (SI) is originated as an innovative subfield of Artificial Intelligence (AI) which is based on the observation of the behavior that can be found in several natural entities. The basic idea is to observe the social behavior within colonies of ants, flocks of birds, bee hives, and fish schools etc. In these natural elements, one very interesting fact is noted down that number of agents with very few abilities can still produces an extraordinary solution for various complex problems. The different swarm intelligence motivated optimization paradigms are listed in the alphabetical order of their names as Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), Fish School Optimization (FSO), Particle Swarm Optimization (PSO), the recent Gray Wolf Optimization (GWO) etc. are discovered in the taxonomy of the SI. Although several optimization algorithms are studied and utilized in many notable applications, PSO has its own importance while dealing with non-liner and complex optimization problems [25][30[51]. PSO has also been explored in the field of image processing, machine learning and deep learning as well. In the literature, it has been encountered that PSO has proved to be a good optimization methodology in various phases of plant leaf disease detection and achieved a good accuracy of results as compared to other approaches [5][6][7][8][23]. Table IV has brought together all the studied PSO based methodologies.

TABLE I. SUMMARY OF DIFFERENT BACTERIAL DISEASES FOUND IN PLANT LEAVES.

Sr. No.	Disease Name	Symptoms of Disease	Cause of Disease	Found in plant	Example leaf image
[1]	**Fire Blight** **Scientific Name-** Erwinia amylovora	1. Tip of diseased plant leaf appears brown or black. 2. Leaves do not fall off but dies.	Get into the tree through flowers or any wounds in the spring. During rain, it gets spread at faster rate from infectious to healthy plant. Insects also responsible for spreading.	Rose family, Apple, Pear	
	Cure of Disease: Cut out infected branches 8 inches below the damage. Make sure not to cut the branches when plants are wet and dip the cutting equipment in isopropyl alcohol (70%). Once done, wash and oil shears. These Practicing this during summer or spring regularly stops dispersion of pathogen. Do not make heavy use of nitrogen fertilization during spring time. Splashing water is not a good idea.				
[2]	**Bacterial Spot (Scorch)** **Scientific Name –** Pseudomonas spp	Tiny spots with dark color appears on the leaves with burned tissues and dead areas along the margin or veins.	Due to adverse change in weather such as too hot or dry wind that reduces soil nutrients. Irregular water supply, polluted air and covered surface over roots.	Pepper and Tomato	
	Cure of Disease: Since there is no standard cure for leaf spot diseases, controlling this disease at early sign is necessary. Cutting the branches, watering, use of fertilizers at regular interval of time can be considered as preventive and controlling measure.				
[3]	**Bacterial Blight** **Scientific Name-** Pseudomonas savastanoi	1. Appears like ring structure around brown and scabby spots. 2. Bacterial discharge like milky dewdrops appears on the lesion.	Cause of bacterial blight is very less raining, too much humidity in the air and poor drainage of soil.	Soybean, pomegranate, cotton, rice, beans etc	
	Cure of Disease: Making us of copper and fungicides in combination can control this disease from further spread. Apply it 2-3 times a week as leaves grow.				
[4]	**Bacterial Wilt** **Scientific Name -** Ralstonia solanacearum	1. Due to lack of water diseased plant leaves turned into yellow color and wilt at the time of hot sunny day and at cool night time recovers back.	Due to combination of hot and wet wheather. If soil becomes infertile, with the increase in its pH level to too high, use of farming equipments used for cutting infected plants for healthy ones etc may cause it.	Tomatoes, Potatoes,Cucumber, Chilli, Ginger, Banana,Capsicum,Watermelon Eggplant	
	Cure of Disease: Keep rotating crops at regular interval may help curing it. Provide proper air circulation facility for each plant. Always keep track of pH level of soil and maintain it between 6.2 to 6.5. It's a good practice to wash your hands and farming tools after handling plants.				

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[5]	**Cankers** **Scientific Name-** Xanthomonas axonopodis pv	By killing the plants life, it enlarges its branch.	Due to injuries caused by insects, improper balance of nutrients, root rots, deficiencies, nematodes etc.	Woodie species such as Juniper, Russian olive, Douglas, Citrus	
	Cure of Disease: Removal of infected parts of plant, make use of fertile soil, treating the wood or bark injuries on time, controlling various disease carriers, avoiding overwatering as well as overcrowding can be considered as notable curing approaches.				
[6]	**Scab** **Scientific Name -** crustaceous lesions	1. As the centers drop out, lesions come out with a shot-hole appearance. 2. Leaf lesions appear pale green at the start and gradually water soaked area turned from grey to white.	When vegetable fruits are grown in alkaline soil. Due to sudden raise in pH of soil caused by warm and dry soil condition. Streptomyces scabies may also cause this disease.	Apples, Crabapples, Cereals, Cucumbers, Peaches, Pecans, and Potatoes	
	Cure of Disease: Try using the fertilizers that has no amount of alkaline. Do not use wood ash, lime or fresh compost to the soil. Removing weed/diseased parts, rotating plants at regular interval of time, spraying appropriate fungicides etc can help curing the disease.				
[7]	**Rot** **Scientific Name-** Erwinia carotovora	1. Infection starts from outer petiole and then gradually spreads to its head. 2. Diseased head has a complete head rot with watery, mushy, soft appearance which turns dark.	During hot and wet weather caused due to ample amount of rain.	Fruits, Vegetables, and Ornamentals	
	Cure of Disease: There is no treatment for bacterial rot once it is initiated.				

TABLE II. SUMMARY OF DIFFERENT FUNGAL DISEASES FOUND IN PLANT LEAVES

Sr.No	Disease Name	Symptoms of Disease	Cause of Disease	Found in plant	Example leaf image
[1]	**Measles (Red spot)** **Scientific Name-** Cladosporium paeoniae	1. After blooming season, initial reddish spots symptoms may be visible on the foliage. 3. Diseased leaves get its upper surface with dark purple color whereas brown color generates at lower surface.	This fungal infection is caused by dead plant remained in the soil or spread by rain or wind over the soil.	Peony	
	Cure of Disease: Destroying diseased and dead plant reamains from soil can be ideal cure. Also, avoid making excess use of water.				
[2]	**Grey mold** **Scientific Name-** Botrytis cinereal	Water-soaked, mushy and grayish color red spots appear on the plant leaves.	Wet, mild and cool weather causes this type of fungal disease in flowers.	Flowers	
	Cure of Disease: Destroying diseased and dead plant reamains. Use of sprays to control healthy plants from further infections.				
[3]	**Aphids**:	1. Pear-shaped white color insects with soft bodies appear on plant leaves. 2. These aphides can be of any other color as well.	Honeydew produced by aphides attracts ants, passes viruses from plant to plant and also is the reason for developing mold on the surface of leaves.	Food and Fiber crops	
	Cure of Disease: Try to avoid excess use of nitrogen while fertilizing the farm areas or garden, since it helps plants to grow faster that produces tender flush which attracts aphides. Release ladybus and lacewings which will eat aphides. Spraying neem oil over the plants with aphides will control its infection. Also, strong spray of water can reduce the count of aphides significantly.				
[4]	**Downy mildew** **Scientific Name-** Peronospora Spp	1. At the initial stage, yellowish color spots appear on the upper surface which gradually becomes dark yellow at the end. 2. The inner part of the leaf spot gets brown color with a yellow margin.	Due to poor plant ventilation. Cool and humid moist weather condition is also responsible for this fungal disease.	Cabbage, Basil	
	Cure of Disease: Provide proper air ventilation to plants. Avoid cool, humid and moist environmental condition. With the help of copper spray, it's easy to control this disease. Start the treatment as soon as its symptoms are visible at early stage and repeat it at 7-9 day intervals till it is required. Remove the dead and infectious plants and keep the ground clean after every fall and winter to avoid spreading it over other healthy plants.				
[5]	**Powdery mildew** **Scientific Name-** Erysiphe orontii	1. Begins with circular shaped dusty-white spot that becomes yellow-brown and grayish-black at the end, which are commonly seen on the upper side as well as beneath the leaf.	Overcrowding, dry and warm weather can invite this fungal disease.	Zucchini, Beans, Cucumbers, Squash, Pumpkins, Tomatoes, Roses and Zinnia	
	Cure of Disease: Use of Plant resistant cultivars in the farm or garden. Cut down the plants for proper air ventilation between the plants. Reduce overcrowding of plants. Remove and destroy infected parts from the plants and clean up the ground and use a thick layer of mulch or organic compost to cover the soil. Milk sprays, neem oil, PM wash on weekly basis can act as preventive measure. Drip irrigation and soaker hoses will help keep the foliage dry. Do not make compost of diseased plant remains.				

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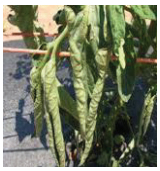
[6]	**Mealybugs**	1. It looks like plant is covered with white/grey mealy wax. 2. It is actually wingless, soft-bodies insects.	Many indoor and outdoor plants during warm climate, which were exposed to heavy nitrogen levels generated from over fertilization attracts these Mealybugs.	Pineapple	
	Cure of Disease: Steady spray of water, cotton ball soaked in isopropyl alcohol, neem oil can be used to kill and remove Mealybugs.				
[7]	**Cercospora leaf spot** **Scientific Name-** Cercospora ocimicola	Circular to irregular dark spots on the surface of plant leaves with light centers.	Fungus	Types of Basil	
	Cure of Disease: Do not over splash plants with water. Eliminate any symptomatic leaves. Potassium bicarbonate spray can control minor infections.				

TABLE III. SUMMARY OF DIFFERENT VIRAL DISEASES FOUND IN PLANT LEAVES

Sr.No	Disease Name	Symptoms of Disease	Cause of Disease	Found in plant	Example leaf image
[1]	**Mosaic** **Scientific Name-**	Appears as pale-yellow or pale-green and white spots which are usually twisted and stunted.	The viruses are spread due to various insects, nematodes, mites, fungi and aphides. Seeds and pollens can also spread infection.	Roses, Beans, Tobacco, Tomatoes, Potatoes, Cucumbers and Peppers	
	Cure of Disease: This viral disease can only be prevented since once it infects the plant, it cannot be cured. Burn or throw infected plant remains in garbage, do not compost it. Keep disinfecting the farming or gardening equipments after every use. Do not use it without disinfecting for healthy plants.				
[2]	**Spotted Wilt**	1. Bronze-colored spots appears on the leaves. 2. It also stunts the growth of the plant leaf. 3. Dies at the tip of the leaf.	Caused due to insects that feed on different plants by sucking the plant's contents and punctures it.	Tomato	
	Cure of Disease: This viral disease can only be prevented since once it infects the plant, it cannot be cured. Remove all infected plant remains. Keep rotating plants and controlling weeds can be helpful for prevention.				
[3]	**Curly top** **Scientific Name-** Begomovirus	1. The leaves turn yellow with vein color as purple and its petioles bend downwards whereas leaves get twisted and curl upwards. 2. The yield gets reduced, and fruit ripens prematurely with odd taste and dies at the end..	If the beet leafhopper feeds on a infected plant with curly top, the insect quickly picks up the virus. Weedy field and infected transplant condition is responsible for this viral disease.	Tomatoes, Sweet and hot peppers, Beans, Potatoes, Spinach, any members of the cucurbit family	
	Cure of Disease: Destroy infected plant remains by burning on throwing into the garbage. Mechanically remove all weeds, sugar beets, beet leafhoppers and their eggs to prevent from this virus.				

V. DATASET

Although, many researchers have utilized their own created databases for the experimentation purpose, but the publically available dataset for plant leaf image's classification to healthy and unhealthy plant leaf diseases ie. PlantVillage dataset, is the most widely used one. Most of the researchers working in this area have used this ideal dataset for their experimentation purpose, for both training and testing the machine developed for accurate detection of plant leaf disease [1][4][19][22]. This dataset can be downloaded from the PlantVillage treasury available on www.plantvillage.org [19]. The details of the PlantVillage dataset used in studied research literature are summarized in the Table VI as below:

TABLE IV. COMPARATIVE SURVEY OF PLANT LEAF DISEASE DETECTION/CLASSIFICATION TECHNIQUES USING IP AND ML

Paper	Methodology	Algorithm	Dataset	Name of diseases	Future work suggested
[3] (2017) Vijay Singh et al	1.Image acquisition using digital camera. 2.Image processing (clipping, smoothing and enhancement) is done. 3. Green masking is performed and each pixel intensity is compared with threshold value, if found less, then zero is assigned to R,G,B components of the pixel. 3.Color Image segmentation is done using genetic algorithm	GA, Color co-occurrence method, SVM **Accuracy %**	Images of 10 plant species (both healthy and infected	Bacterial and Fungal diseases **Plant species**	To improve recognition rate in classification process using notable classifiers viz, ANN, Bayes classifier, Fuzzy Logic and Hybrid

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	4. Color and texture feature extraction is done using color co-occurrence method. 5. Minimum Distance Criterion and then SVM classifier are used for classification.	95.71	with 5 diseases)	Bananabeans jackfruit, lemon, mango, potato, tomato, rose, rice and sapota	algorithms etc.
[4] (2019) Pravin Kumar S.K. et al.	1. Image acquisition. 2. Image pre-processing images are resized to 256 by 256 pixel size and Background subtraction is done using Gaussian Mixture Model. 3. Disease image segmentation is done using Particle Swarm Optimization (PSO)–based fuzzy c means. 4. Vein and shape features, edge-based feature extraction, and texture characteristics or texture features (TF) are computed. 5. Multiple Kernel Parallel Support Vector Machine (MK-PSVM) classifier.	**Algorithm** PSO-FCM, GMM MK-PSVM **Accuracy (%)** -- k-Means, BP-ANN, SVM **Accuracy (%)** 96	Plant Village 350 of tomato leaf images 250 healthy & 100 infected	**Name of diseases** Cedar_apple rust **Plant species** Tomato Powdery Mildew, Septoria, Wheat Rust **Plant species** --	Further work can be extended by using different capable classification algorithms from other domains.
[21] (2020) Khushal Khairnar et al.	1. Image acquisition using digital camera with 150*150 resolution. 2. Image pre-processing includes image color space conversion (RGB to L*a*b). 3. In Image segmenta tion, the affected and useful area are segmented using K-means clustering. 4. Color and texture features are extracted using color co-occurrence matrix and GLCM respectively in feature extraction phase. Best features that represent given image have been selected and also the feature redundancy has been minimized. SVM classifier is used for disease classification. 5. After detecting the disease, it provides guidelines for fertilizers, symptoms and remedies of affected disease.	**Algorithm** K-means, SVM **Accuracy (%)** 94	40–50 images of each considered diseases	**Name of diseases** Bacterial blight, Cercospora leaf spot, Cercospora leaf spot, Leaf curl **Plant species** Cotton	--

TABLE V. COMPARATIVE SURVEY OF PLANT LEAF DISEASE DETECTION/CLASSIFICATION TECHNIQUES USING IP AND DL

Paper	Methodology	Algorithm	Dataset	Name of diseases	Future work suggested
[1] (2019) Rishab Yadav et al.	1. Image Acquisition 2. Image Pre-processing (colored resized images of size 256 by 256 pixels). 3. Feature Extraction using Deep CNN architecture AlexNet (transfer learning) 4. Feature Selection using PSO with k-fold cross validation fitness function. 5. Classification by SVM.	Deep CNN, PSO, SVM **Accuracy %** 97.33	Plant Village 8750 images both healthy & diseased, 7 crop species, 23 diseases	Rot, Scab, Rust, Blight, Measles Spot, Powdery Mildew, Scorch (23 diseases) **Plant species** AppleCorn, Grape Peach, Pepper, Potato, Squash Strawberry	1. Different NN architecture can be analyzed and employed for better performance. 2. Increased no of classes of plants and diseases to be used. 3. Smartphone app can be built.
[14] (2020) Thangadurai. Net al.	1.Image acquisition using digital camera in a controlled environment. 2. Image segmentation with leaf region segmentation and disease region segmentation. 3. Leaf region segmentation involves RGB to grey scale conversion, region filling, wiping openings in the white areas and filtering entire leaf from start to finish and left to right. 3. In disease region segmentation, triangle thresholding technique is used over grey image. 4.CNN is used for disease detection.	**Algorithm** CNN **Accuracy %** 98.60	--	**Name of diseases** Fungi caused diseases:Brown Spot **Plant species** Sugarcane	1. More classes of plant leaf diseases can be covered and verified 2. New IOT methodology using proposed approach can be built.
[19] (2020) Marwan Adnan Jasim et al.	1. Image acquisition of color images from plantvillage website. 2. Image pre-processing includes resizing images from 256*256 to 128*128. 3. CNN is built with input layer, convolution layer, non-linear layer (activation function), pooling layer, normalization, fully connected layer, softmax function layer. 4. Training using SGDM with 15 epochs. 5. Testing is performed with different set of images. 6. Detection and classification of disease.	**Algorithm** SGDM, CNN **Accuracy (%)** Training: 98.29 Testing: 98.029	Plant Village 20636 images of 15 classes of plants and their diseases	**Name of diseases** Bacterial spot, Early blight, Late blight, Leaf mold, Septional leaf spot, **Plant species** tomatoes, pepper, potatoes	1. Increase the dataset size with more number of classes of disease. 2. Use of different optimizers for improving learning rates.
[22] (2020) Abhinav	1. Image augmentation techniques namely shearing, zooming, flipping and brightness change are performed on 256*256 resized images using Keras Deep Learning Libraries in Python.	**Algorithm** SGD, CNN **Accuracy (%)**	PlantVillage	**Name of diseases** -- **Plant species**	--

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Sagar et al.	2. Optimization of CNN weights for every iteration for each instance present in training set is achieved using SGD. Dropout is performed to prevent neural networks from overfitting. 3. Visualization of feature maps is performed to know how well our network has learned. 5. Five pre-trained models are experimented .	ResNet50: 98		apple, blueberry, cherry, grape, orange, peach, pepper, potato, raspberry, soy, squash,strawberry and tomato	
[25] (2016) Sharada P. Mohanty et al.	1.Choice of deep learning architecture: AlexNet, GoogLeNet. 2. Choice of training mechanism: Transfer Learning and Training from Scratch. 3.Choice of data set type: (Color, Grayscale, Leaf Segmented.) 4. Choice of training-testing set distribution: Train:80%,Test:20%, Train:60%,Test:40%, Train:50%,Test:50%, Train:40%,Test:60%, Train:20%,Test:80%.	**Algorithm** Deep CNN, AlexNet, GoogleNet **Accuracy (%)** 99.35	PlantVillage	**Name of diseases** Rot, Scab, Rust, Blight, Measles Spot, Powdery Mildew, Scorch **Plant species** 14	1. To improve the accuracy more diverse set of training data can be employed. 2. A real world application can be built with proposed approach.

TABLE VI. COMPARATIVE SURVEY OF PLANT LEAF DISEASE DETECTION/CLASSIFICATION TECHNIQUES USING IP AND SI

Paper	Methodology	Algorithm	Dataset	Name of diseases	Future work suggested
[5] (2019) Prabira Kumar Sethy et al.	1.Image acquisition of image with primary color using digital camera is done. 2. Input image is converted to L*a*b color space & image resizing and enhancement is done. 3.K-means based image segmentation. 4. Gray Level Co-occurrence matrix (GLCM) is used for feature extraction (Correlation, Entropy, Variance,Homogeneity, Contrast, Energy and Mean). 5. Extracted features are first optimized by PSO and then Classification is done by SVM.	k-Means multi-class SVM, PSO, GLCM **Accuracy %** 97.91	Images of Rice plant (both healthy and infected with 5 diseases)	Brown Spot, Bacterial Blight, Leaf Blast and Leaf Scald **Plant species** Rice	--
[6] (2017) Prabhjeet Kaur et al.	1. Image acquisition. 2. Image pre-processing involves image contrast enhancement using histogram equalization method. 3.Image segmentation by K-means into three different types of ROI. 4.Select the ROI from the segmented image and convert RGB color ROI Image to grey scale to maintain GLCMs 5. Texture Feature extraction and disease detection using SVM. 7. Apply PSO for optimization & final classification.	**Algorithm** SVM, PSO **Accuracy %** 95.16 to 98.38	Expert dataset having leaf of four different types of diseases	**Name of diseases** Cercospora leaf spot, bacterial blight, anthracnose Alternaria alternata. --	--
[7] (2019) Vijay Singh	1.Image acquisition using digital camera. 2.Image pre-processing is done for noise removal and contrast enhancement using median filtering and clipping of image is performed to get ROI. Green masking is performed. 3.Image Segmentation is done by PSO. 4. Color and texture features are extracted using color co-occurrence method. 5.Minimum distance classifier is used for classification purpose.	**Algorithm** PSO,Minimum Distance Classifier **Accuracy %** 98	Dataset with sunflower (both healthy &	**Name of diseases** White rust, Bacterial leaf spot, Downy mildew, Powdery mildew, Septoria leaf blight, **Plant species** Sunflower	Combination/ hybridization of PSO with other methods like gradient search method may yield faster speed.
[8] (2019) Moumita chanda et al.	1.Image acquisition using digital camera. 2. Image pre processing by resizing (256 by 256), contrast enhancement, green pixel masking, and color model transformation. 3. Image segmentation using K-means clustering. 4. Texture, color and shape feature's extraction using GLCM. 5. Feed Forward NN training using Backpropogation followed by PSO algorithm for optimizing the NN weights to classify further.	**Algorithm** BPNN, PSO **Accuracy %** 96.2	--	**Name of diseases** Alternaria AlternataAnthracnose, Bacterial Blight Cercospora Leaf Spot **Plant species** --	The work can be extended by finding out some method to simplify the process of choosing the initial values of parameters of PSO and applying it on a large dataset
[23] (2019) Moumita Chanda et al.	1. Image acquisition using digital camera or selecting images from any source. 2. Image pre-processing involves resizing (256*256), green pixel masking, contrast adjustment, and RGB to L*a*b conversion. 3. K-means clustering based image segmentation is performed. 4. Color, Shape and Texture feature extraction using GLCM. 5. Number of features are reduced using PCA. 6. First back-propagation is used to train the feed forward neural network and then NN weights are further optimized using particle swarm optimization.	**Algorithm** BPNN, PSO, PCA **Accuracy %** 96.42	Dataset of 6 types of diseases leaves and healthy too.	**Name of diseases** Alternaria alternata, Anthracnose, Bacterial blight, Bacterial leaf scorch, Cercospora leaf spot, and Downy mildew **Plant species** --	To achieve better accuracy and classification with increased number of samples in the dataset.

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TABLE VII. DETAILS OF PLANTVILLAGE DATASET

Name of Dataset	PlantVillage
Useful for	Training the Model for crop diseases detection and classification
Total Images	54303 (both healthy & unhealthy)
Class Labels	38 (crop-disease pair)
Plant species	13 (Apple, Blueberry, Cherry, Grape, Orange, Peach, Pepper, Potato, Raspberry, Soy, Squash, Strawberry, Tomato
Diseases	16- basic diseases 4- bacterial diseases 2- diseases caused by mold 2- viral diseases 1- disease caused by mite
Type of diseases covered	Scab, Rust, Mildew, Leaf Spot, Leaf Blight, Black Rot, Measles, Bacterial Spot, Early Blight, Late Blight, Leaf Scorch, Leaf Mold, Leaf Curl etc. associated with different plant species
Size of images	256 × 256
Image type	JPEG Color Images

VI. CONCLUSION AND FUTURE WORK

Study of plants from the point of view of its species identification and their disease detection is been carried out since more than a decade. Recently, a lot of work is done in the field of disease identification in crops by employing various techniques, algorithms and approaches under notable domains. The detailed discussion about the several plant diseases from their important aspects is done in this work which can help people working in this area to know about plant diseases and their remedies. This paper has also reviewed different methodologies from machine learning, deep learning and swarm intelligence along with image processing techniques for detecting and segregating the plant leaf diseases into their accurate categories. The most popularly used dataset for efficiently identifying and classifying the diseases found in crop's or plants leaves ie. PlantVillage dataset is discussed with its primary details. At last, it concludes that this study will be a helpful guide for the researchers working in this area to explore this field from various dimensions. The future work suggests exploring more on the findings, limitations and future directions specified in the existing work of the literature.

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