Identification of Leaf Disease Using Machine Learning Algorithm for Improving the Agricultural System

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***Abstract*—Diagnosing plant disease is the foundation for effective and accurate plant disease prevention in a complicated environment. Smart farming is one of the fast-growing processes in the agricultural system, with the identification of disease in plants being a major one to help farmers. The processed data is saved in a database and used in making decisions in advance support, analysis of plants, and helps in crop planning. Plants are one of the essential resources for avoiding global warming. However, diseases such as blast, canker, black spot, brown spot, and bacterial leaf damage the plants. In this paper, image processing integration is developed to identify the type of disease and help automatically inspect all the leaf batches by storing the processed data. In some places, farmers are unaware of the experts and do not have proper facilities. In such conditions, one technique can be beneficial in keeping track and monitoring more crops. This technique makes it much easier and cheaper to detect disease. Machine learning can provide a method and algorithm to detect the disease. There should be training in images of all types of leaves, including healthy and disease leaf images. Five-stage detection processes are done in this paper. The stages are preprocessing, segmentation using k-Mean, feature extraction, features optimization using Firefly optimization Algorithm (FA), and classification using Support Vector Machine (SVM). The accuracy rate achieved using the proposed technique, i.e., GA-SVM is 91.3%, sensitivity is 90.72%, specificity 91.88, and precision is 92%. The results are evaluated using the matlab software tool.**

***Keywords*—leaf diseases, k-mean, firefly optimization algorithm, support vector machine**

I. Introduction

Many crops get destroyed due to lack of technical knowledge. One of the important sources of income for people in India is agriculture. A variety of crops are grown by farmers, but one reason for the destruction of crops diseases. Plant disease is the primary cause of crop damage in India. Different plants suffer from different diseases. The central part is the leaf of a plant which is used to examine the disease with the help of agriculture experts. However, this kind of detection of diseases in plants was costly and time-consuming. Hence, a better method was required to detect diseases in the leaf. Computer and software play an important role in the identification and classification of leaf diseases. For leaf disease detection, there are lots of image processing and pattern recognition techniques that can be used. The key to prevent agricultural loss is to identify the disease at the early stage. For every disease there should be a remedy which should be stored in the database for early prevention of damage.

Plant illness can straightforwardly prompt hindered development causing terrible impacts on yields [1]. A financial loss of up to $20 billion every year is assessed all around the world [2]. Various conditions are the most troublesome test for specialists because of the geographic contrasts that might prevent the exact distinguishing proof [3]. Also, customary strategies chiefly depend on subject matter experts, experience, an-d manuals [4], yet most of them are costly, time consuming, and work concentrated with trouble identifying exactly [5]. Consequently, a fast and exact way to deal with recognizes plant infections appear to be so pressing to assist business and nature to agribusiness. In rural harvests, leaves assume a crucial part to give data about the sum and nature of agricultural yield. A few elements influence food creation, for example, environmental change, presence of weed, and infertility of soil. Aside from that, plant or leaf sickness is a worldwide danger to the development of a few horticultural items and a wellspring of monetary misfortunes [6]. The inability to analyze contaminations or microscopic organisms in plants drives consequently to inadequate pesticide/fungicide use. Consequently, plant sicknesses have been generally thought to be in mainstream researchers, with an attention on the organic provisions of illnesses. To resolve these issues, it is important to recognize plant infections by the techniques which are advanced and intelligent. The advanced techniques to detect the disease facing noise related issues while capturing the images. Filtering of noise is used to delete the incorrect instances in the data reduction of noise and

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also important process. k-means clustering in the presence of noise. It is known that k-means clustering is highly sensitive to noise, and thus noise should be removed to obtain a quality solution. A popular formulation of this problem is called k-means clustering with outliers. The goal of k-means clustering with outliers is to discard up to a specified number z of points as noise/outliers and then find a k-means solution on the remaining data [7].

To play out the activities of agriculture, regular Machine Learning (ML) calculations have been applied in many investigations [8]. Nonetheless, as of late, Deep Learning (DL) as a sub-set of ML has been strikingly successful for genuine identification of object and for the purpose of classification [9]. Thus, research in farming has been moving towards the DL-based arrangements. The DL procedures have been cultivated best in class results to play out the rural tasks including crop/weed segregation [10], organic product gathering [11], and plant acknowledgment [12]. Essentially, late examinations have additionally centered around one more significant agriculture issue of plant disease recognizable proof [13]. Several state of art DL approaches have been used to conduct plant infection grouping by utilizing notable DL structures. For instance, a new article introduced a near investigation of different Convolutional Neural Networks (CNN) and DL optimizers to accomplish better consequences of plant infection characterization [14].

One directional Pixel Difference Histogram (PDH) analysis for identification of pixels in image is studied in [15]. As a real-world case study, the GOA-DE algorithm solves visual tracking issues. Visual tracking of several items in a video stream with complex backdrops and objects is useful in next-generation computer vision architecture [16]. The suggested CNN (convolutional neural networks)–GB (Gradient Boosting) and Adaptive Median Filter (AMF) mechanisms increase disease detection performance [17]. Attacks caused by malicious node activity are identified utilizing the Hybrid Reactive Search and Bat (HRSB) method, which prevents hostile nodes from entering the network behind false information [18].

To validate the own user, the Gait pattern authentication mechanism is introduced. To recognize the owner, the current study offers a running Gaussian Grey Wolf Boosting (RGGWB) model [19]. A mixed machine learning system is excellent in predicting heart attacks and arterial stiffness. Initially, we used a Hybrid Fish Bee Optimization (HFBO) method to do feature selection [20]. Jaya Method-based Multi-Verse Optimization algorithm is used to optimize the weight function by combining two meta-heuristic algorithms (JA-MVO). The best features are exposed to hybrid deep learning algorithms such as "Deep Belief Network (DBN) and Recurrent Neural Network (RNN)" [21]. The characteristics of KNN combined with ACO to provide improved Drug Consumption Similarities [22]. In this paper optimization technique is introduced along with machine learning algorithm. The optimization when combined with support vector machine classifier given accurate results in identification of leaf disease. Here in this paper firefly optimization technique is used. The optimization technique helps in obtaining the best features to identify the disease. The discussion of proposed method is studied in upcoming section.

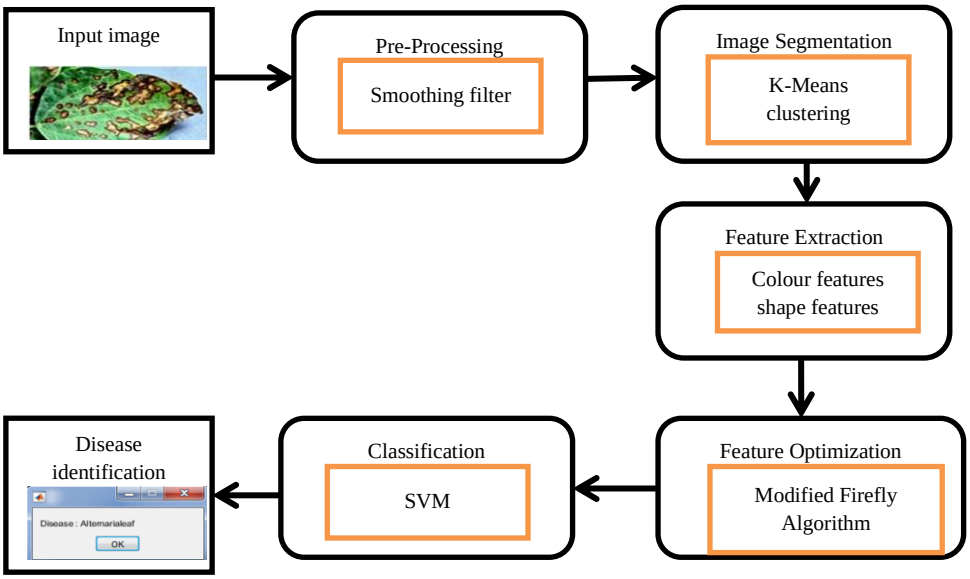


Figure 1. Proposed process flow.

II. Material and Methods

The leaf disease identification model framework based on machine learning technique is shown in Fig. 1, including four steps, the preprocessing and segmentation of plant leaves, the feature extraction of images, the feature optimization of images, and the identification of disease using classification technique. The model employed in this study is described, and the experimental findings are assessed.

A. Data Acquisition

The RGB Color pictures of the leaf are shot with smart phones or digital cameras with pixel sizes of 768×1024 for a clean image. Each of the digitized pictures is 225KB in size. These pictures have been cropped into smaller ones of 109×310 pixel size. Using the matlab image analysis library, images are saved in PNG format. Fig. 2 depicts several sorts of diseased leaves for processing.

Figure 2. Different type of leaf images.

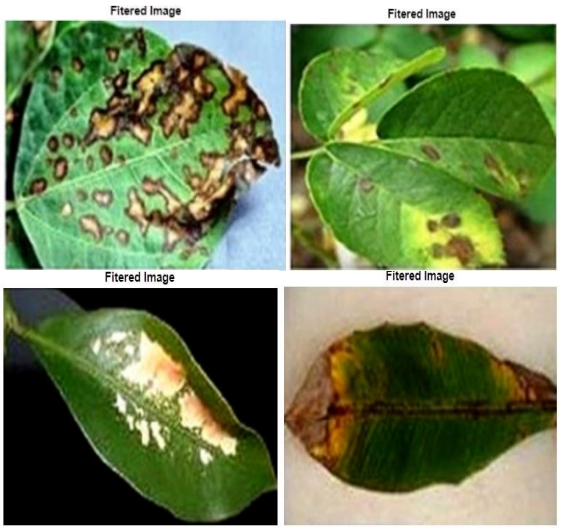


Figure 3. Preprocessing of different leaf images.

B. Image Preprocessing

The work of image preprocessing entails noise removal and image enhancement. A leaf picture with a resolution of 109×310 pixels is utilized. The RGB pictures are transformed into grey scale images to ensure great accuracy. The image's noise is filtered before it is processed further. In this case, a smoothing filter is applied. To improve contrast, use contrast enhancement techniques such as histogram equalization and contrast modification. The probability distribution is used to build the occurrence matrix from the input pictures and processed images shown in Fig. 3.

C. Image Segmentation

Image noises that degrade image quality are identified during image segmentation. The K Mean clustering is performed for segmenting the input images by grouping the pixels in an image with similar attributes [23]. The mean filter is used to eliminate noise and unwanted spots which are segmented using K Mean clustering. The binary picture with noise is transformed to a noise-free image. The filtered pictures are the noise-free images and produce a high-quality image for identifying leaf disease.

D. Feature Extraction

As the diseases in leaf is composed of various forms of disease blast, brown spot, and narrow brown spot, each with a unique lesion shape and colour.

1) Shape feature extraction

One of the image's most essential parameters is its shape. The image's breadth and length are important characteristics for describing the type of image. A straightforward method for determining the image's width and height is to count the object pixels.

2) Color feature extraction

Color is very essential in image processing. Digital image processing generates quantitative colour measurements, which are important for the job of investigating the lesion for early diagnosis. Pixels in colour pictures are frequently represented in RGB format, where RGB stands for RED, GREEN, and BLUE values from the colour image recording equipment.

E. Feature Optimization

The features are optimized based of firefly optimization. The process of optimization is discussed below. Firefly Algorithm (FA) was first developed by Xin-She Yang in late 2007 and 2008 at Cambridge University [14, 24], which was based on the flashing patterns and behaviour of fireflies. Evolution of firefly algorithm in recent years became more significant and many research works are been performed based on Firefly Algorithm.

Fireflies are unisex with the goal that each individual firefly will be pulled into different fireflies paying little mind to their opposite sex. The attractiveness and brightness are directly proportional to each other, and they both lessening as their separation increments. Along these lines for any two blazing fireflies, the less splendid one will attract the more brilliant one. On the off chance that there is no more brilliant one than a specific firefly, it will move randomly. The brightness of a firefly is controlled by the scene of the goal work [24].

As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, can now define the variation of attractiveness β with the distance r by:

$$\beta = \beta_0 e^{-\gamma r^2} \quad (1)$$

where β_0 is attractiveness at r=0.

The firefly 'i' is attracted to another more brighter firefly 'j' and move towards j and the same is determined by:

$$x_i^{t+1} = x_i^t + \beta_o e^{-\gamma r_{ij}^2}\left(x_j^t - x_i^t\right) + \alpha_t \epsilon_i^t \qquad (2)$$

where the second term $\boldsymbol{\beta_o e^{-\gamma r_{ij}^2}\left(x_j^t - x_i^t\right)}$ is concern based on the attraction. The third term i.e. $\boldsymbol{\alpha_t \epsilon_i^t}$ is randomization with $\boldsymbol{\alpha_t}$ being the randomization parameter, and $\boldsymbol{\epsilon_i^t}$ is a vector of random numbers drawn from a Gaussian distribution or uniform distribution at time *t*.

If $\boldsymbol{\beta_0}$= 0, it becomes a regular pattern for determining the optimized value. On the other hand, if γ = 0, FA in generally termed to be particle swarm optimization.

The complexity of firefly algorithm has inner loop and outer loop and the complexity of FA algorithm is given as *O(nt*log*(n))*. This is obtained based on inner loop population size n and number of iteration t [25]. If the value of n is more the ranking of fireflies which are brighter will be obtained more easily.

The progression of firefly close to the ideal arrangement ought to be set little. Also, the progression of firefly far from the ideal arrangement ought to be set substantial. Fireflies between the over two are utilized to adjust the worldwide inquiry and neighborhood look. Accordingly, the progression of firefly ought to likewise be worried about its authentic data and current circumstance. Based on the comments mentioned above and many experiments, the step of each firefly is calculated by (3) and (4), respectively.

$$h_i(t) = \frac{1}{\sqrt{\left(f_{pi}(t-1) - f_{pi}(t-2)\right)^2 + 1}} \qquad (3)$$

$$\propto_i (t+1) = 1 - \frac{1}{\sqrt{\left(f_{best}(t) - f_i(t)\right)^2 + h_i(t)^2 + 1}} \qquad (4)$$

Algorithm for firefly optimized features

The firefly algorithm is implemented in this paper and the process is stated below:

- **Step 1**. Initialization of extracted features from image
- **Step 2**. The population of features is gives as $\{x_1, x_2, \ldots\ldots, x_n\}$.
- **Step 3**. Calculating the brightness value using cost function based on firefly for the assigned images
- **Step 4**. Fireflies' intensity is given as $\{I_1, I_2, \ldots\ldots, I_n\}$.
- **Step 5**. Update the step of each feature
- **Step 6**. Ranking of features and finding current best
- **Step 7**. Moving of each firefly i towards other brighter fireflies (for obtaining optimized features)
- **Step 8**. Update the solution set.
- **Step 9**. Stop when result obtained; otherwise go to Step 2.

Finally the optimized features are fed to support vector machine learning algorithm for identification of disease. And parameters of firefly are shown in Table I.

TABLE I. PARAMETERS OF FIREFLY

Parameter Name	Value
Firefly size	50
β, γ	0.8, 1
Lower boundary	0
Upper boundary	5

F. SVM Classification

SVM is a parallel classifier dependent on supervised learning which gives better execution over different classifiers. SVM characterizes between two classes by building a hyperplane in high-dimensional element space which can be utilized for arrangement. Hyperplane can be addressed by the following condition.

$$w \cdot x + b = 0 \qquad (5)$$

w is weight vector and normal to hyperplane. *b* is bias or threshold.

In this work, a 10-fold cross-approval is utilized as grouping calculation for anticipating the test errors for given datasets. It randomly divides the training set into 10 disjoint subsets. Each subset has the roughly equal size and roughly the same class proportions as in the training set. A SVM model is trained on a large dataset of leaf images to classify different types of diseases in plants when it is provided with a new leaf image. It is based on leaf feature extraction and optimization; the leaf features are orthogonalized into different variables and passed as an input vector to the SVM.

III. RESULTS AND DISCUSSION

All of the experiments are carried out in MATLAB. For disease input data, plant leaf samples such as bacterial disease in rose leaves, bacterial disease in bean leaf, Sun burn disease in lemon leaf, early scorch disease in banana leaf, and beans leaf with fungal disease, among others, are taken into account. The entire process is generated using graphical user interface. Each stage is processed and the output results are obtained.

Case1. Input is paddy leaf

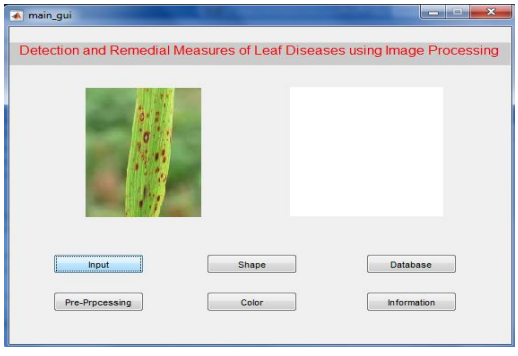


Figure 4. Input image.

The leaf present in the database is given as input for achieving the results and is shown in Fig. 4.

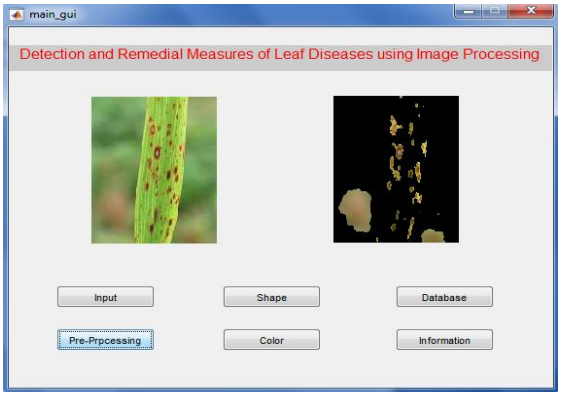
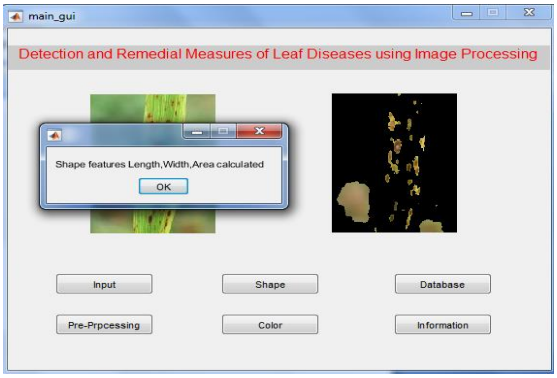
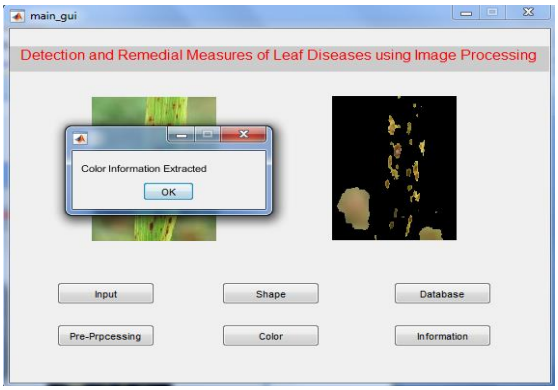


Figure 5. Main GUI block and preprocessed image.



(a) Shape features



(b) Colour features

Figure 6. Features extraction blocks.

In Fig. 5, the input image is been preprocessed by clicking on the pre-processing. The next stage is been accessed after performing the preprocess operation.

The extraction of shape and colour features is shown in Fig. 6. The next step is to spot the disease and identify. Support vector machine algorithm plays a key role for achieving the best results by training and testing the database. For analysis of proposed system the parameters are evaluated.

The paddy leaf which is given as input having a disease name called brown spot and is observed in Fig. 7. After identification of disease the remedy is been displayed and the data is saved into database. Fig. 8 shows the saving of data in database. The information which is saved in the database will be used by farmers for further working of agriculture activities.

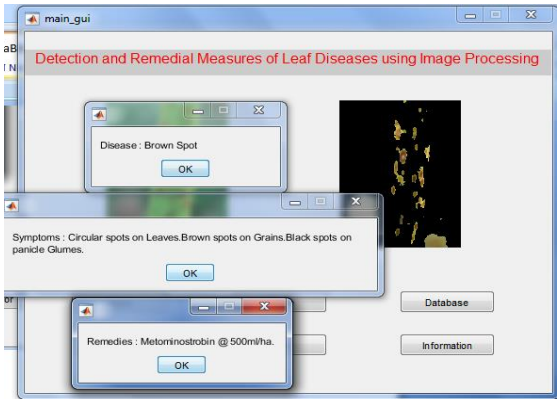


Figure 7. Identification of disease and remedy.

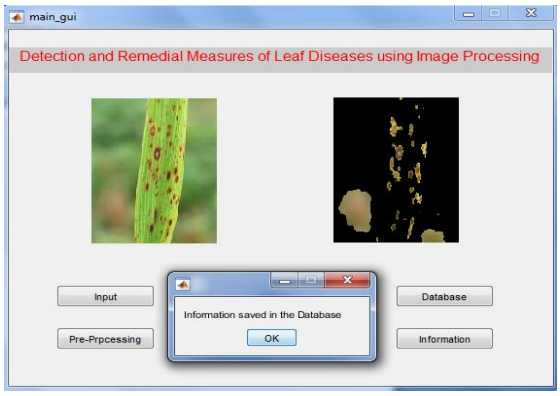


Figure 8. Identification of disease and display of remedy.

Some of the disease names, scientific names, symptoms along with the remedies for different leafs are shown in Table II.

Parametric Values

For evaluating the below shown parameters, 15 types of leaves are considered and processed. Table II shows the calculated values of different images.

1) Area

Area is a shape related parameter for an image and is calculated. This parameter is for estimating the objects area in binary image BW. Total is a scalar whose value corresponds roughly to the total pixels count in the image, but might not be exactly the same because different patterns of pixels are weighted differently.

2) Perimeter

It is also a shape related parameter in an image. It produces a binary image containing just the perimeter pixels of the objects in the input image BW. A pixel is part of the perimeter if it is nonzero and it is connected to at least one zero-valued pixel.

3) Entropy

Entropy is a quantitative metric used to assess picture quality. Entropy is a statistical metric that is used to Table I. Various disease name and remedies describe the texture of an input picture. Entropy measures the amount of information in a picture that is required for image improvement. Entropy quantifies the loss of information or message in a sent signal containing picture data. The entropy is said to be zero if all of the pixels have the same value.

TABLE II. VARIOUS DISEASE NAME AND REMEDIES

Disease Name	Scientific Name	Symptoms	Remedies
Bacterial Leaf Blight	Xanthomonas Oryzae	Seedling wilt or kresek. Water soaked to yellowish strips on leaf blades. Appearance of Bacterial ooze that look like milky or opaque.	Spray fresh cowdung extract 20% twice. Neem oil 60 EC 3% or NSKE 5% is recommended.
Rice tungro	Rice tungro bacilliform virus RTBV	Stunning and Reduced Tillering. Leaves become yellow or orange. Delayed flowering. Partially filled grains.	Thiamethoxam 25 WDG 100g/ha. Imidacloprid 17.8 SL 100ml/ha.
Sheath Blight	Rhizoctonia Solani	Rust coloured spots Discoloration from leaf tip to lower portion. Panicles Sterile	Carbendazim 50 WP @ 500g/ha. Azoxystrobin @ 500ml/ha. Hexaconazole 75% WG @ 100mg/lit
Sheath Rot	Sarocladium Oryzae	Irregular spots or lesions with dark reddish brown margins. Whitish powdery growth. Unemerged panicles rot.	Gypsum @ 500kg/ha. Neem oil 3%. Metominostrobin @ 500ml/ha.
Brown Spot	Helminthosporium Oryzae	Circular spots on Leaves. Brown spots on Grains. Black spots on panicle Glumes.	Metominostrobin @ 500ml/ha.
False Smut	UstilaginoideaVirens	Growth of velvety spares. Rice grains transformed into yellow bodies. Growth of spores result to broken membrane.	Propiconazole 25 EC @ 500ml/ha. copper hydroxide 77 wp @ 1.25 kg/ha.
Leaf Streak	Xanthomonas Oryzaepv.Oryzicola	Initially small, dark green water soaked. Lesions turn Brown. Bacteria ooze out under humid weather.	Spray fresh cowdung water extract 20%. Copper hydroxide 77 WP @1.25 kg/ha.

$$E = -\sum_{i=0}^{L-1} p_i . log_2 p_i \quad (6)$$

Different type of images is processed and identifies the area, perimeter and entropy values and is shown in Table III.

Based on the evaluation of different images the overall accuracy, sensitivity, specificity and precision parameters are evaluated and shown in Table III.

Sensitivity

Sensitivity (also called the true positive rate, the recall, or probability of detection in some fields) determines the percentage of true positives that are accurately detected.

$$Se = \frac{TrulyPositive}{TrulyPoitive+FalsyNeagative} \quad (7)$$

TABLE III. PARAMETERS OF DIFFERENT LEAFS

Parameter	Area (A)	Entropy (En)	Perimeter (P)
Image1	79321	0.9635	2603
Image2	89515	0.8924	2239
Image3	83121	0.9415	3418
Image4	85489	0.9252	2556
Image5	45678	0.9362	4461
Image6	101262	0.7577	6733
Image7	58519	0.9932	6777
Image8	52068	0.9720	7594
Image9	57677	0.9913	6741
Image10	52494	0.9738	6134
Image11	83751	0.9374	4330
Image12	56666	0.9886	4313
Image13	59844	0.9958	8402
Image14	101749	0.7507	2947
Image15	60340	0.9966	3856

Specificity

Specificity (also called the true negative rate) measures the proportion of actual negatives that are correctly identified as such (e.g., the percentage of non-diseased leafs which are correctly identified as not having the disease).

$$Sp = \frac{TrulyNeagtive}{TrulyNegative+FalsyPositive} \quad (8)$$

Accuracy

The accuracy is given as,

$$Ac = \frac{TrulyPositive+TrulyNegative}{TrulyPositive+TrulyNegative+FalsyPositive+FalsyNeagative} \quad (9)$$

Precision

Precision is a description of random errors, a measure of statistical variability and is valuated using the formula given below,

$$P_r = \frac{TruePositive}{TruePositive+FalsePositive} \quad (10)$$

The results obtained using optimization technique and without optimization technique are compared and shown in Table III.

TABLE IV. OVERALL RATE OF PARAMETERS

Technique/Parameter	SVM	FA-SVM
Accuracy	90	91.30
Sensitivity	89.21	90.73
Specificity	90.81	91.88
Precision	91	92

From Table IV it is clear that using optimization technique the rate of accuracy is improved by 1.3%. The changes obtained in overall rate of accuracy, sensitivity, specificity and precision for the entire dataset used for processing is shown in Fig. 9.

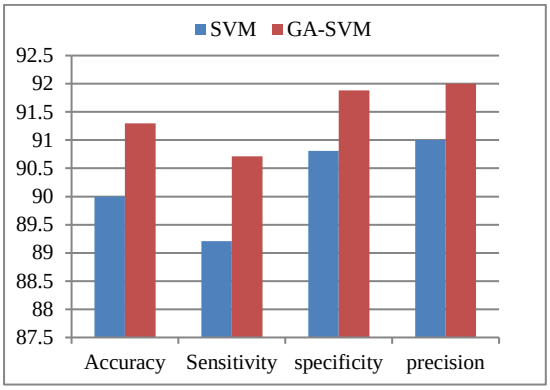


Figure 9. Changes obtained in parameters.

IV. Conclusion

The main goal of this paper was to perform the complex task of plant disease classification and identification in a single framework. A graphical user interface is developed for purpose of identification and giving remedy for the identified diseased. The proposed System shows usefulness of integration of optimization and machine learning algorithms for obtaining an expert system model. The proposed methodology can be effectively utilized in real time process for identifying the disease. In order to diagnose a disorder from leaf image four image processing phases have to be applied: Image preprocessing, Image segmentation, Feature extraction, & classification. Due to integration of optimization and machine learning technique the rate of accuracy in identifying the disease will be increased. The results obtained using optimization and without using optimization technique are compared and the results shows that using optimization technique along with machine learning technique gives more accurate results in identification of diseases. The rate of accuracy using SVM is 90% and using firefly algorithm along with SVM is 91.3%.

Conflict of Intrest

The authors declare no conflict of interest.

Author Contributions

Keerthi Kethineni conducted the research work, collected the data, and wrote the paper. G. Pradeepini supervised the work and approved the final version.

References

[1] Y. Ampatzidis, L. D. Bellis, and A. Luvisi, "iPathology: Robotic applications and management of plants and plant diseases," *Sustainability*, vol. 9, no. 6, 1010, 2017.
[2] X. E. Pantazi, D. Moshou, and A. A. Tamouridou, "Automated leaf disease detection in different crop species through image features analysis and one class classifiers," *Computers and Electronics in Agriculture*, vol. 156, pp. 96−104, 2019.
[3] G. Geetharamani and J. A. Pandian, "Identification of plant leaf diseases using a nine-layer deep convolutional neural network," *Computers & Electrical Engineering*, vol. 76, pp. 323−338, 2019.
[4] V. Singh and A. K. Misra, "Detection of plant leaf diseases using image segmentation and soft computing techniques," *Information Processing in Agriculture*, vol. 4, no. 1, pp. 41−49, 2017.
[5] S. P. Mohanty, D. P. Hughes, and S. Marcel, "Using deep learning for image-based plant disease detection," *Frontiers in Plant Science*, vol. 7, 1419, 2016.
[6] D. C. Duro, S. E. Franklin, and M. G. Dubé, "A comparison of pixel-based and object-based image analysis with selected machine learning algorithms for the classification of agricultural landscapes using SPOT-5 HRG imagery," *Remote Sens. Environ*., vol. 118, pp. 259−272, 2012.
[7] I. Sungjin, Q. Mahshid, M. Benjamin, *et al*., "Fast noise removal for k-means clustering," in *Proc. International Conference on Artificial Intelligence and Statistics*, 2020.
[8] A. Esteva, A. Robicquet, B. Ramsundar, *et al*., "A guide to deep learning in healthcare," *Nat. Med*., vol. 25, pp. 24−29, 2019.
[9] S. P. Adhikari and H. Y. Kim, "Learning semantic graphics using convolutional encoder decoder network for autonomous weeding in paddy field," *Front. Plant Sci*., vol. 10, 1404, 2019.
[10] R. Marani, A. Milella, A. Petitti, and G. Reina, "Deep neural networks for grape bunch segmentation in natural images from a consumer-grade camera," *Precis. Agric*., pp. 1−27, 2020.
[11] Y. Ampatzidis and V. Partel, "UAV-based high throughput phenotyping in citrus utilizing multispectral imaging and artificial intelligence," *Remote Sens*., vol. 11, 410, 2019.
[12] M. H. Saleem, J. Potgieter, and K. M. Arif, "Plant disease detection and classification by deep learning," *Plants*, vol. 8, 468, 2019.
[13] M. H. Saleem, J. Potgieter, and K. M. Arif, "Plant disease classification: A comparative evaluation of convolutional neural networks and deep learning optimizers," *Plants*, vol. 9, 1319, 2020.
[14] X. S. Yang, *Nature-Inspired Metaheuristic Algorithms*, Luniver Press, 2008.
[15] R. Sonar and G. Swain, "Multi-directional pixel difference histogram analysis based on pixel blocks of different sizes," *Sens. Imaging*, vol. 22, no. 11, 2021.
[16] K. N. Reddy and P. Bojja, "A novel method to solve visual tracking problem: hybrid algorithm of grasshopper optimization algorithm and differential evolution," *Evolutionary Intelligence*, vol. 15, no. 1, 2021.
[17] D. Sreelakshmi and S. Inthiyaz, "Fast and denoise feature extraction based ADMF-CNN with GBML framework for MRI brain image," *Int. J. Speech Technol*., vol. 24, pp. 529−544, 2021.
[18] R. Srilakshmi and J. Muthukuru, "Intrusion detection in mobile ad-hoc network using hybrid reactive search and bat algorithm," *International Journal of Intelligent Unmanned Systems*, 2021.
[19] G. K. Chaitanya and K. R. Sekhar, "Verification of pattern unlock and gait behavioural authentication through a machine learning approach," *International Journal of Intelligent Unmanned Systems*, 2021.
[20] A. Elumalai, P. B. Maruthi, and N. Gautam, *et al*., "Optimal prediction of attacks and arterial stiffness effects on heart disease by hybrid machine learning algorithm," *J. Ambient. Intell. Human Comput*., 2021.
[21] A. Ampavathi and T. V. Saradhi, "Multi disease-prediction framework using hybrid deep learning: An optimal prediction model," *Computer Methods in Biomechanics and Biomedical Engineering*, vol. 24, pp. 1146−1168, 2021.
[22] S. Menon and P. Rajarajeswari, "A hybrid machine learning approach for drug repositioning," *IJCSNS*, vol. 20, pp. 217−223, 2020.
[23] Z. N. Zadeh, R. Ibrahim, and A. Selamat, "A hybrid model for class noise detection using k-means and classification filtering algorithms," *SN Appl. Sci*., vol. 2, 1303, 2020.
[24] X. S. Yang, "Firefly algorithms for multimodal optimization" *Stochastic Algorithms: Foundations and Applications. SAGA. Lecture Notes in Computer Sciences*, vol. 5792, pp. 169–178, 2009.
[25] I. Fister, J. I. Fister, X. S. Yang, *et al*., "A comprehensive review of firefly algorithms," *Swarm Evol. Comput.*, vol. 6, 2013.

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