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Exploring OMFA-CNN for Potato Leaf Disease Identification: An Assessment against Existing Models

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Abstract*:* Nowadays, cultivation acts as a most important regions for the survival of humans. Imaging and adapting technology are very important for the area of agriculture and consequently advantageous to the farmer and the user. Due to imaging, adapting technology and systematic monitoring it is much possible to verify the disease at the very initial phase and that can be avoided to achieve increased harvest production. This research work was implemented for the classification of Potato Leave (PL) diseases. For this case, the publicly accessible dataset, famously known as "Plant Village" dataset, was considered. For the process of IS (image segmentation), k-means were measured, for the combination of FE (feature extraction) purposes, the GLCM and PCA concepts were used, and for the detection and classification the research methodology,OMFA-CNN, was used. The PL disease dataset comprises images acquired in real-time and from the famous Kaggle (PlantVillage) dataset. The research methodology can obtain a precision of 99.3%, recall of 99%, and MSE of 4.0 was used. The developed technique is also compared with existing techniques like Mask R-CNN, SVM, Vgg16, Vgg19, ResNet50, etc., and it shown a high precision and recall than others.

Keywords: *DL (Deep Learning), GLCM (grey level co-occurrence matrix), OMFA-CNN (optimized matrix feature analysis-convolutional neural network), Potato leaf disease detection, PlantVillage dataset, PCA (principle component analysis).*

1. Introduction

In a tropical country like INDIA, the potato holds great significance as one of the vital vegetables. It is an accepted vegetable that finds its way into the daily meals of several households worldwide. Potatoes play a significant role in providing economical food as they offer a minimum cost of energy in the human diet. They are abundant in starch, vitamins, particularly vitamin C and B1, as well as minerals. Among the Indian states, West Bengal stands out as a major producer of potatoes, contributing approximately 33% to the national output [1]. However, the production of potatoes faces significant challenges due to various fungal and bacterial diseases. These diseases can have severe consequences, leading to reduced production and ultimately impacting the national economy. Two of the most disturbing diseases affecting potatoes are early blight, also called Alternaria Solani[2], and late blight[3].

Several analyses on PDC (plant disease classification) using LIs (leaf images) are presented in the technical studies. Dechat et al. [5] utilized a CNN (convolutional neural network) to spontaneously classified diseased plants in domains from LIs. Amara et al. [10] utilized a DL-based method for leaf disease classification and attained a maximum of 97 percent accuracy rate. The performance of several pre-trained models such as ResNet[6], Inception modules [7], DenseNet [8], and Vgg networks [9] are compared.

In the proposed work [19], the imaging method merged with optimized feature matrix firefly-CNN with DL gives a solution to the problem of farming efficiency and gives good quality food. The primary goal of this work is to implement imaging and DL-based efficient and exception-free disease classification for potato leaves. This dataset used for the work is obtained from a subset of an online available dataset known as "Plant Village" dataset. It consists of four classes of PL images, such as Alternaria saloni, virus, healthy and insect bite. The dataset comprises a total of 3,262 leaf images. To train the model, the dataset is randomly shuffled and divided into a 60:20:20 ratio for training, validation, and testing. The implemented model performance is subsequently assessed by quantitatively calculating the precision, recall metrics, etc., and visually examining the outcomes.

The main contribution of this research work has been described as:

- Analysis of the recent plant disease detection & classification methods with their results. The existing methods have been developed for the detection of PL images using SVM, and the Mask-CNN model.
- Propose and implement an improved classification with a hybrid feature (OMFA-CNN) based improved

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model to detect the PL disease on image dataset. OMFA-CNN model has attained maximum precision rate and lowered the MSE rate compared to the rest of the models. It has consumed the minimum time consumption and energy saving factor.

- Evaluate the proposed model by performance metrics such as precision, recall, etc, with currently present classification methods with several test cases to prove research improvements.

The work of research article is managed as follows: Section 2 discusses the existing analysis of the potato leaf disease images and classification models. Section 3 describes the material and methods. Section 4 explains the PLANT VILLAGE dataset of research work and the proposed model with architecture and framework. The simulation result analysis is defined in section 5, and lastly, section 6 concludes the research work comprising the further improvements.

2. Review of Literature

This section described several potato plant leaf diseases related to some research methods utilized in the agriculture area. The potato plant is widely consumed food all over the world. Thus, different approaches and models have been established for potato leaf disease inhibition and examination. Joe Johnson (2020) [11] described traditional potato leaf disease detection made the procedure more complex, costly, and time-consuming. To eliminate these issues, the authors planned an automatic model with the help of Mask Region-based CNN recognized as Mask R-CNN. This proposed model utilized the TL (Transfer Learning) technique and 1423 images of potato leaves as a dataset. The proposed model was capable of appropriately distinguishing the unwell area or spot of the root vegetable leaf and observing for soil areas, which could mix up the twofold classification results. The proposed model reached a precision rate of 98%. Soumik Ranjan Dasgupta (2020) [12] described food deficiency issues throughout the world. The major essential potato is a food that was consumed widely annually. To challenge the massive data requirement for DL (Deep Learning) an alternative deeply employed TL method was used. That was offered a fast process of training and more precise through a comparatively small database. The accurate presentation of the recommended model was validated quantitatively with the help of the performance parameter of accuracy. The recommended model was more well, lightweight, and strong as compared to the other one. Monzurul Islam (2017) [13] described imaging and computer visualization-based phenotyping deals in the direction of learning computable plant composition. The authors presented a disease detection method that fits in IP (Image Processing) as well as ML (Machine Learning) to tolerate analysis of potato leaf sicknesses from leaf datasets. The proposed automated method utilized a public database termed 'Plant Village' and reached better performance with 95% of accuracy. Neeraj Rohilla et al., (2022) [14] elaborated the role of agriculture in economic development role in India. Plant leaves were the more vulnerable, and initially show disease signs. The authors utilized pre-processing mode for image processing at the preliminary phase and offered perfect objects and standardized images. It was also supported by improving the image performance. The proposed model utilized K-means, histogram of oriented gradients, and GLCM (Grey Level Co-occurrence Matrix) for the features extraction and segmentation correspondingly. GLCM and HoG (Histogram Orientation Gradient) methods were required to extract the features efficiently. The segmentation process was completed with the K-means Clustering method and reached better performance as compared to other methods. Neeraj Rohilla et al., (2021) [15] described various critical threats in the agriculture field that was responsible to degrade the economic growth of any country. In India, approximately 70% of people were spoiled in cultivation for their source of revenue. Several types of viruses, fungal and bacterial infections degrade the production of any plant. For the elimination of these issues as well as switch this spread of disease agriculturalists required expert guidance. So, the accurate caring and precise quantity of antiseptic, antiviral, and antifungal spray could be prepared in farmhouses. Several ML and DL methods were utilized for the automated classification of plant disease. So, the writers suggested a review of various ML and DL models with their significance and potential carried into the agriculture field. Aditi Singh et al., (2021) [16] defined the cultivation field as an active region for people. Digitalization was accomplished in all arenas for several subjects and was determined expressively. Both methods such as adaptive as well as digitalization were of utmost importance for helping the profits of farmers and trades in the farming. So, the authors built a model for various potato disease detection and classification using an openly available PVD (Plant Village Dataset). The proposed model utilized K-means utilized for segmentation as well as GLCM for feature extraction correspondingly. The proposed model used the MSVM method for the potato plant disease classification and reached better performance with an accuracy of 95.99 %. Several DL and clustering approaches were recycled to organize the potato's leave spitting image illnesses and segmentation of the image. Several types of datasets, methods, comparative methods, tools, parameters, and problems are described in Tables I and II.

Table 1. Investigation of Existing Methods.

Author Name	Proposed Methods	Problems	Dataset	Parameters
Joe Johnson (2021) [11]	Mask Region-based CNN model called Mask-R-CNN.	DL technique is prepared to threaten gradients and dimensionality through improved different layers.	MS COCO	Recall = 81.9% Precision = 98% IoU
Soumik Ranjan Dasgupta (2020) [12]	Leaf detection method using Transfer learning models.	The dull and error-prone detection process of diseased potato leaf.	PlantVillage (PV) dataset	Accuracy = 98%
Monzurul Islam (2017) [13]	Potato leaf detection method using MSVM method.	More computational cost and time consumption.	PV dataset	Precision =95% Recall =95% F1-score=95% Accuracy = 95% ROC = 96%
Neeraj Rohilla et al., (2022) [14]	A hybrid method by using GLCM and HOG methods.	Identification of plant diseases is a critical task as well as more time taking.	PV and COCO dataset	Entropy=2.88 RMSE =8.4 Mean= 14.13 SD = 2.88 Smoothness =1
Neeraj Rohilla et al., (2021) [15]	KNN Naïve Bayes SVM Backpropagation (BP) DT Neural Network (NN)	Lack of the automated disease detection model.	Imagenet dataset.	----
Aditi Singh et al., (2021) [16]	Detection method using SVM and KNN methods.	Complications due to Environmental conditions.	PV dataset	Accuracy Recall Precision F1-score

Table II. Comparison Analysis of Existing Methods

Author Name	Comparison Methods	Tools	Findings
Joe Johnson (2021) [11]	HSV LAB XYZ RGB HSL YCrCb	Python 3.6	The proposed model provides better performance by using color spaces that allowed the model to have a good study of features of the diseased leaf and soil area, and the area with different colors, textures, and leaf shapes.
Soumik Ranjan Dasgupta (2020) [12]	Resnet-34 Resnet-18 Resnet-101 Resnet-50 Resnet-152 Inception-4 Densenet-161 Densenet-121 Densenet-201 Densenet-169 VGG-16 GG-19.	-----	The proposed method is lightweight, better in performance and robust as compared to others.
Monzurul Islam (2017) [13]	Hyperspectral Imaging Texture Analysis and PNN KNN	MATLAB	The proposed method provides a feasible, well-organized and a quick method of disease detection as well as identification.
Neeraj Rohilla et al., (2022) [14]	GLCM KNN HOG	MATLAB	A novel hybrid method provides a higher accuracy ratio and reduces the chance of errors than existing methods.
Neeraj Rohilla et al., (2021) [15]	----	-------	CNN method delivers better outcomes in the disease detection process and is also suitable for large and complex datasets.
Aditi Singh et al., (2021) [16]	-----	Python	Digitalization provides better results in all fields with limited time and to get better safety in development and revenue.

3. Material and Methods

3.1 Mask R-CNN Model

The selection of train data for CNN importantly affects the efficiency of the model in several cases. Parameters like the imagined sensor's features, the imaging protocol employed, variations in illumination based on the time of day, the presence of shadows from neighbors objects, complex background data, and occlusion all need detailed consideration for the development of a model that can be effectively useful to domain-based imaging. Fig 1 shows the introduction of Mask R-CNN model. This model has interchanged the RGB colour space dataset into different colour spaces such as LAB, HSV, HSL, YCrCb, and XYZ forming a different Mask R-CNN method for individual colour space.

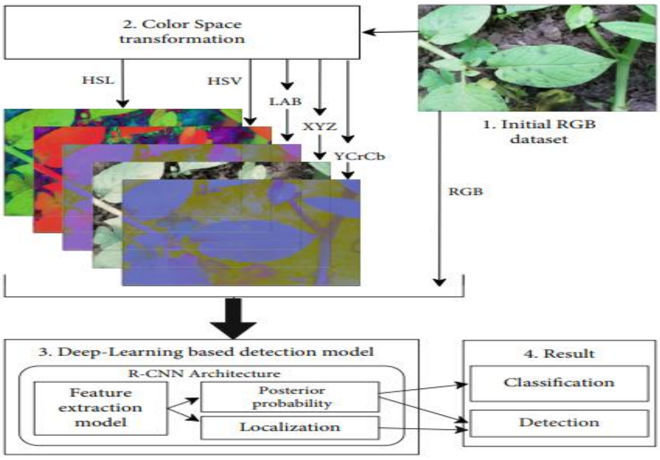

Fig 1. DL-based potato leaf disease detection and classification model [11]

Fig 2 defines the block diagram of Mask R-CNN model. It is an extended version of a R-CNN model with a prediction and segmentation process. The further tuning of the real Mask R-CNN model involves the utilization of ResNet-50, as a foundational architecture by setting the RPN anchor scales to 32,64,128, and 512 and the aspect ratio for the anchor is 1:2,1:1, and 2:1. A separate R-CNN Model is trained for each colour space dataset.

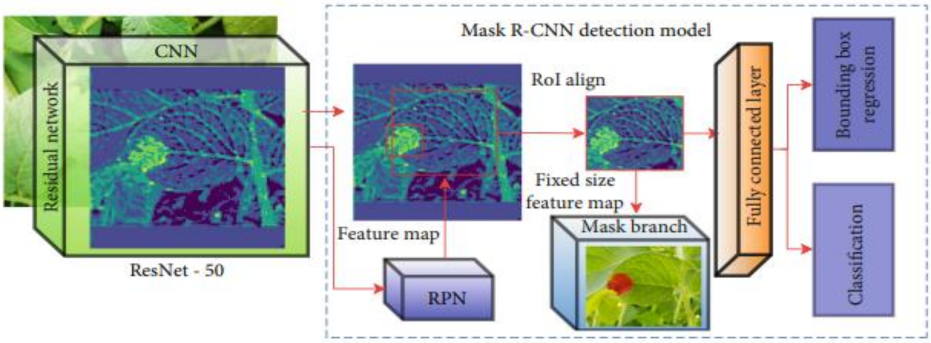

Fig 2. Block Diagram of the Mask R-CNN Model[11]

3.2 SVM (Support Vector Machine)

Based on extracted features the potato LIs required to be classified into different types like healthy, virus, insect bites, and alternalia solaris leaves. Here classification task employed the SVM [16] technique, an SL (Supervised Learning) method which uses HP (HyperPlanes) for classification. It is an optimization issue and its definition is presented by eq (i). The training set may be described as $(A_i, B_i), i = 1,2, \dots\dots\dots, j$ where $A_i \in C^d$ and $B_i \in \{1, -1\}$j .

$min_{k,l,\xi}\ \frac{1}{2}\ k^t k + D\ \sum_{i=1}^{j} \xi_i$ subjected to $B_i = (k^t\ \phi\ (A_i) + e) \geq 1 - \xi_i, \xi_i\ \geq 0$ ………… (i)

The mentioned rule is used for BC (Binary Classification). But, in this specific setup, the detection or classification is not 1,0 (binary), therefore present process will be taken as a generalized one to attain the multi-class classification. The generalisation will be carried out so that the first category is believed to belong to one class, whereas the another two are regarded to belong to different classes and it will be recurrent for the no. of classes.

3.3 Proposed Steps of OMFACNN Model

The proposed steps of the OMFACNN model are discussed in Fig 3, and its research flowchart is defined in Fig 4. The research procedures of each phase of the OMFACNN model are described here:

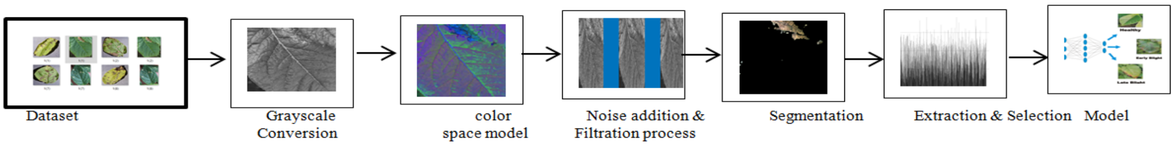

Fig 3. General Diagram of different phases: OMFACNN Model

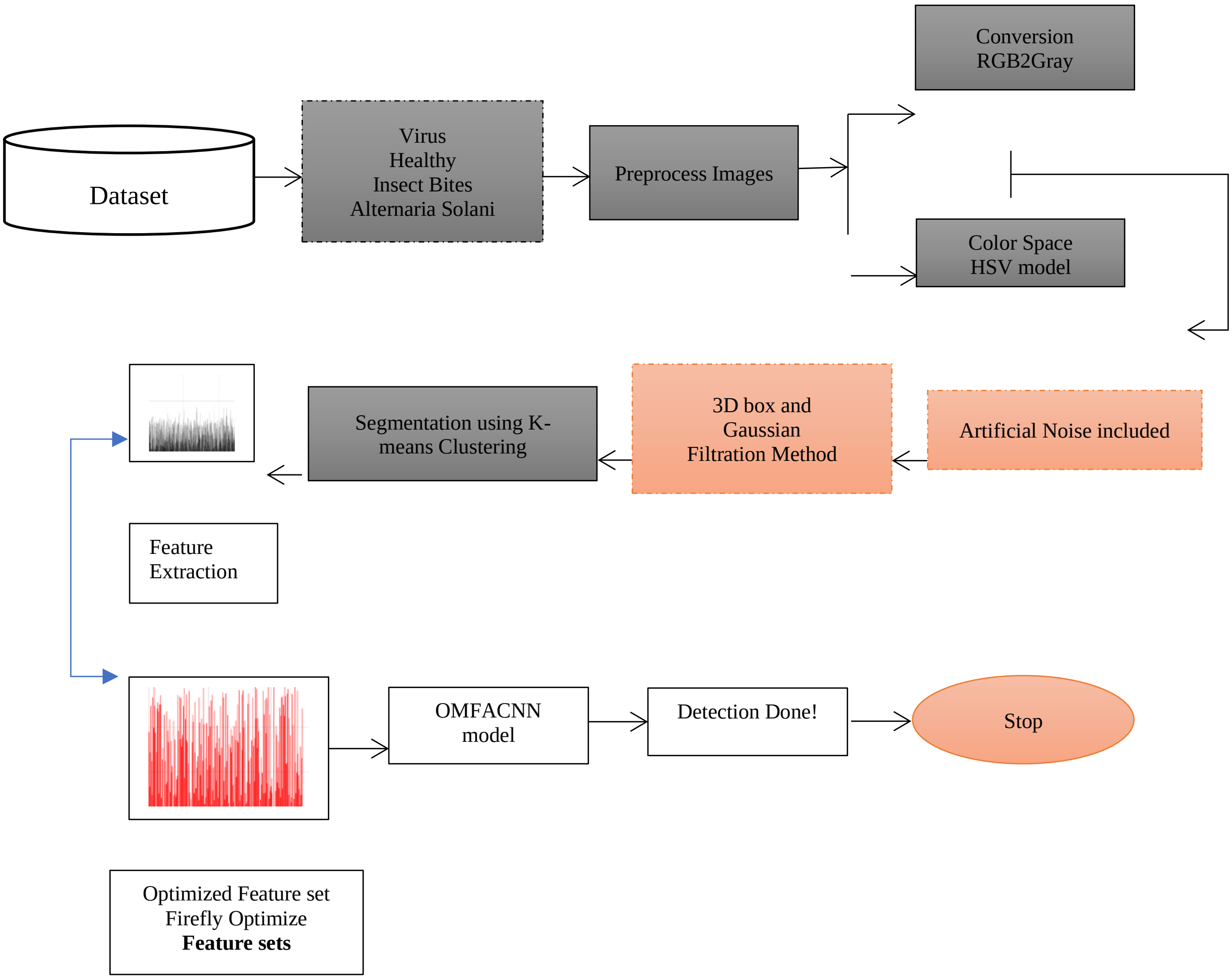

Fig 4. Research Flow chart with OMFACNN Model

3.3.1 Image Acquisition

This step measures the acquirement of data from a consistent source (Kaggle) to handle the stability and standard so that it can be likened for further analyses. Table 3 defines the different classes of potato LIs. Potato LIs classes are defined in Fig 5.

Table 3. Summary of Dataset

Class Labels	No. of Images
Healthy	893
Alternaria Solani	1055
Virus	1,012
Insect Bite	302
Total Images	**3262**

The dataset of potato LIs was parted into two datasets one is training set and other is testing set. The training dataset comprises of 60% of the image dataset, validate potato LIs dataset 20%, and the testing dataset comprises the enduring 20% of the potato LIs dataset. The research architecture was designed on the Windows 10 Operating System with the Intel i7 processor along with 8GB RAM. The proposed architecture was designed using MATLAB 2018a.

The main stages of the PLs disease detection includes segmentation, feature extraction, and optimization with the CNN model (OMFACNN). The sections are discussed below:

3.3.2 Preprocessing

It is an essential step of the proposed framework. It generally promises the de-noising of the PL (potato leaf) image, improvement of the PL image, and managing normal image size for all categories of images. Improvement and denoising of potato LIs are important to get improved outcomes.

3.3.3 Segmentation

The potato LIs have been segmented to get the ROI (region of interest). In this step, the ROI is the area on the leaf that is vital to distinguish infected area from rest of the section of the present potato leaf image. It was designed by means of the k-means clustering method. Following phases are being considered for this method:

- Set the number of clusters.
- Each cluster's center will be chosen at random, and the number of centers counted equals the number of defined clusters.
- The distances between each point and the cluster's center will be calculated for each cluster.
  - All the distances evaluated in a cluster are mainly considered by the mean of the distances.
  - Update the center with the MEAN value.
- Repeat the previous steps until each cluster's center rarely changes at all.

For distance parameters like ED(Euclidean distance), Manhattan, and Minkowski distance several approaches are utilized as defined in eq (ii) to (iv) resp.

$$d(A,B) = (|A_j - B_j|^r)^{1/r} \qquad \text{…………… (ii)}$$

$$d(A,B) = (|A_j - B_j|) \qquad \text{………………. (iii)}$$

$$d(A,B) = (|A_j - B_j|^2)^{1/2} \qquad \text{…………… (iv)}$$

MD (Minkowski's Distance) approach is highly generalized eq in terms of ‘d’ parameters. Other ‘d’ parameters can be calculated from the MD.

3.3.4 Feature Extraction

Based on the attained ROI now it requires to verify the designs that exist. A different ROI will have dissimilar designs, from that case, one to fetch the crucial properties deciding the detection and classification. When IS (Image Segmentation) was done and it attained the ROI then from this ROI, the features or properties will

be taken out. As the final dataset's feature vector turned out to be rather vast, a considerable number of attributes needed to be eliminated for before classification task. It is measured as a DR (dimensional reduction) practice as it removes the less significant data present in the feature vector such that classification can be eased out without compromising the correct output. The idea of combining PCA (Principal Component Analysis) with GLCM was used to extract the features using several parameters. Eigen Values (E) and Eigen Vectors (V) are the forms in which PCA extracts the features. GLCM parameters are shown in Table 4.

Table 4. Summary Of Feature Values And Names

Feature Names	**Values**
Correlation	0.8152
Contrast	1.0181
Homogeneity	0.891
Energy	0.2735
SD (standard deviation)	57.58
Mean	53.82
RMS	11.19
Entropy	4.449

3.3.5 Feature Selection

An effective algorithm FFO (firefly optimizer) is taken into consideration for the selection of the most important features out of Potato LIs image dataset processed via steps 3.3.1 to 3.3.4. This is one of the important steps in whole methodology which optimizes the final prediction result by retaining only the most significant and relevant features.

3.3.6 Train and Test Data

The managed potato leaf image data has been separated into three parts. Around 60% to train the classifier model. Around 20% of the data used for validation and 20% of data used to test the classification model.

3.3.7 Classification

The test set of potato leaf image dataset is being considered to spply to the trained classifier to categorize the images into several classes like viruses, healthy, etc. The detection or classification system OMFACNN model is simulated using the DL library in MATLAB 2018a to implement a detection method with reliable and precise values. The implemented "Optimized matrix feature analysis – convolutional neural network" model is from the DL-based model. The optimized matrix feature analysis-CNN model is introduced in this proposed work for choosing the optimal feature sets. The system becomes faster and more accurate when the features are chosen optimally. The objective function specified in eq (v) is measured by choosing the best feature sets, where accuracy is defined as the classified accuracy.

$OF = \max(accuracy)$ …………… (v)

For the classification procedure, an optimized matrix feature analysis-CNN is used in this research work, where the amount of convolution layers (CLs) is optimal.

Pseudo code – OMFA-CNN Model

```
Input: Potato leaf image: different categories (virus, healthy, etc).
Output:  disease detection
Start
Upload D as dataset image (RGB)
Img = grayscale(D);
Cstransform = hsv(Img);
Nimg = imnoise('Cstransform,'salt &pepper',0.02);
Fimg1 = imgaussian(Nimg);
Fimg2 = im3Dbox(Fimg1);
Cdata = kmeans(Fimg1,Fimg2);
Applied GLCM and PCA method
// Feature Extraction
stats = graycoprops(glcm,{'contrast','homogeneity'})
[r,c] = size(Da);  // Da: Data extracted features matrix
Data1 = double(Da);
find bb=trans(Data1);
compute cc = Data1'*Data;
for i = r
Data1_ij < th;
for j = 1:cc
jj'= Data1*j;                    // j matrix
end for
end for
re-order all eigen_values (V)
```

```
find mm = FFV matrix
extract_feature matrix;
// feature selection method using Firefly optimizer
Initialize max_iter, a, b, c
Create initial_pop;
Define obj_fun F(x)
Regulate I (intensity) at cost (x) of separate determined by F(xi)
While (j<iter_max)
   For k = 1 to N
    For l = 1 to N
     If (kj >ki)
       Move fires k to l in m dim
     End if
Calculate novel solutions and update light I
End for l
End for k
Rank the fires and search the current_bets
End while
Process outcomes
End process
//projected OMFA-CNN model
        Get the OMFA-CNN model trained by using processed PL images.
        Get the validation of OMFA-CNN model done using validated potato leaf images.
        Save the trained OMFA-CNN model.
        Get the testing of OMFA-CNN model done using test potato leaf images in the test phase
        Calculate the value of metrics such as precision, recall, accuracy, etc. for the model’s performance
        measurement
```

4. Experiment Results

4.1 Dataset

The dataset being used is the PVD [12] that creates from PLANT VILLAGE, a research and growth unit linked with PSU (Pennsylvania State University) and open accessed KAGGLE. This primary aim is to empower farmers by giving them cost-effective and accessible skills and democratizing their access to information which gives them to improve their CP (Crop Production). The dataset initially comprises 50k images [17] of infected disease leaf images of thirty-eight categories of plants. The LIs (leaf images) of potatoes are taken differently and then divide into 60:20:20 ratios to achieve the train and validate dataset. The division is arranged in a manner where the test and train sets comprise an equal % of each category. Fig 5 defines the division of the dataset as a pie chart. There are four types in the dataset divided depending on the disease-moving potato manufacturers such as healthy, virus, insect bites, and alternalia solaris potato leaves. Given the non-uniform resolution of the potato leaf images, they are resized to dimensions of 256*256 pixels before being input into the model.

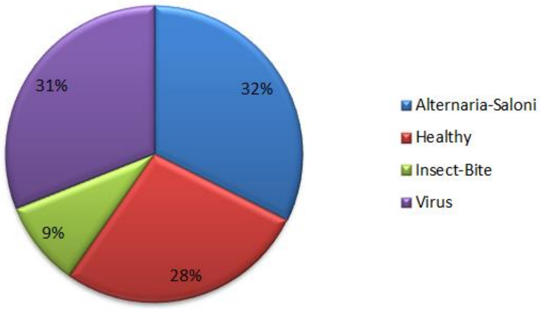

Fig 5. Leaf Dataset Division

4.2 Result Analysis

The proposed model used was a publicly opened dataset and it was separated into the train dataset comprised of 200*4 = 800 potato Lis and the test dataset comprised of 100*4 = 400 PL images. The HSV model is used for the color space transformation model, the K-means clustering technique is utilized for segmentation, the GLCM and PCA methods are used for feature extraction, the Firefly method is used for feature selection, and the CNN research methodology along with different layers was used for the detection of potato LIs. The investigation architecture was calculated using particular parameters like precision, recall, FAR, FRR, MSE, etc. The research model attained a complete accuracy of about a recall of 99%, a precision of 99.3%, MSE value of 4.01. Table 5 represents several classification models as compared with different existing models. The train and test data is calculated in the open access dataset for detection and classification based on MSE, Precision, Recall, FAR, and FRR values measured by using eq (vi), (vii),(viii), (ix), and (x).

Metrics are:

Recall = $\frac{true_{pos}}{true_{pos}+false_{neg}}$ ………. (vi)

Precision = $\frac{true\_pos}{true_{pos}+false\_pos}$ ………………….(vii)

MSE = $\frac{1}{n}\sum_{j=1}^{n}(kj - kj')^2$ …………………….(viii)

FAR = $\frac{no.of\ FAs\ (false\ acceptance)}{no.of\ imposter\ attempts}$ *100 ………….(ix)

FRR = $\frac{no.of\ FRs\ (false\ rejection)}{no.of\ real\ attempts} * 100$………….. (x)

Here,

n = no. of data points; MSE = mean square error rate; kj' = predicted values, and kj= observed; FRR = false rejection rate and FAR =false acceptance rate.

Table 5. Comparison

References	Models	Recall	Precision
Proposed model [19]	OMFA-CNN	99	99.3
Johnson, J et al. [11]	Mask-RCNN	86	97
Singh, A., et al. [16]	SVM	90	90.05
Islam, M et al.[13]	MSVM	95	95
Nishad, M et al [18]	Vgg-16	95.7	95.4
	Vgg19	90.5	90.4
	ResNet50	65.5	63.5
	Kmeans+Vgg16	96.9	96.6
	Kmeans+Vgg19	94.3	94.3
	Kmeans +ResNet50	67.3	67.3

The experiment was shown to calculate the demonstration of the proposed OMFA-CNN model. All simulations utilized the firefly optimizer, loss function, and 100 epochs. The implemented model metrics are exposed in table 6.

Table 6. Performance Metrics along with different categories

Parameters	Precision (%)	Recall (%)	FRR	FAR	MSE
OMFA-CNN Model	99.3	99	0.00009	0.006	4.014

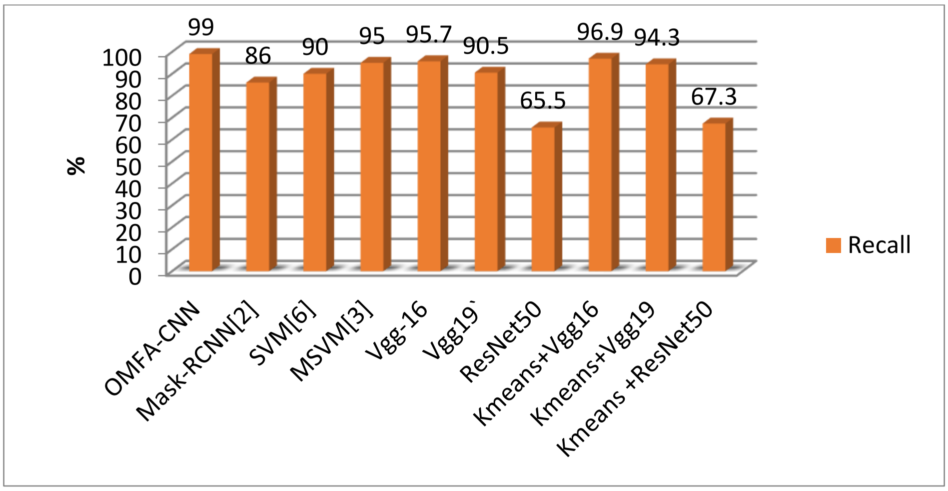

Fig 6. Comparison Analysis – Recall %

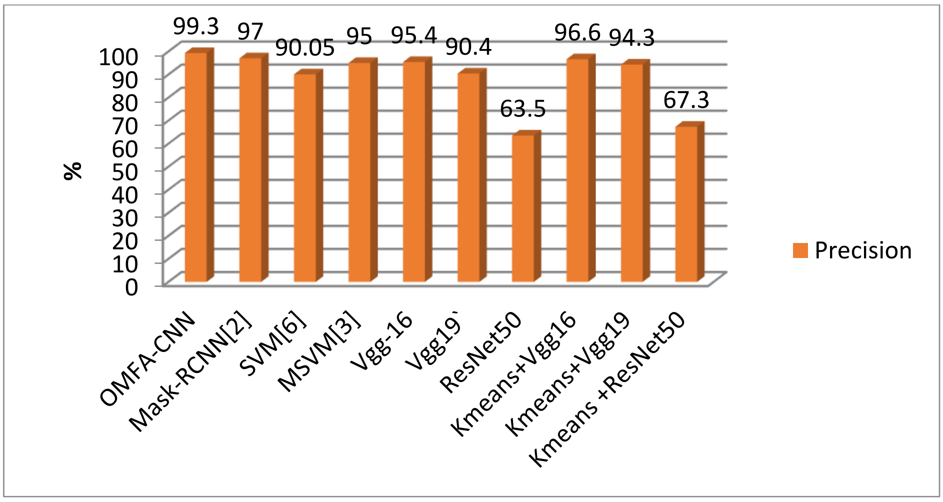

Fig 7. Comparison Analysis – Precision (%)

The implemented method is also compared to other classification and detection methods in Table 5. Fig 6 and 7 define that the precision of the implemented method is 99.3% and recall for the implemented method is 99% which shows the proposed model[19] has achieved more accurate outcome. These figures define the comparative analysis of the different DL and ML methods of potato leaf disease detection systems.

5. Conclusion and Future Scope

This article discussed and implemented a model (OMFACNN) as an automatic and efficient system for detecting disease in potatoes plants such as viruses, insect bites, healthy, etc. The proposed and recommended model will give farmers an effective, time-saving, and feasible way of disease detection. We are forecasting to development of more diseases of several vegetables plants in the system. The research work explains the research analysis of the DL-based classification method designed for leaf disease detection and classification using the potato leaf disease detection simulation dataset. Several analyses were completed using the dataset for detection and classification. An OMFACNN shows a novel approach for detection that is based on feature extraction, features selection and DL-based classification. The experiment results in a search that noticeable improvement in the classification, dependable improvement in these classes, and reliable feature values. The researched metrics values achieved a precision of 99.3 % and a recall value of 99% compared to the existing classification and detection methods that have improved precision and recall values.

In a further improvement, the design automatically calculates the severity of detected disease in potato leaf. Besides, a smartphone-assisted system, application can be designed further to automate the detection procedure. It can be saved on a public REPOSITORY that can then be utilized by numerous farmers around the world.

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