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Potato Leaf Disease Detection Using Image Processing

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Abstract: The economics of a nation is significantly influenced by agricultural productivity. Finding plant leaf disease is crucial since it significantly reduces agricultural productivity. Traditional detection methods like observing with the naked eye can lead to time-consuming and less accurate results. Farmers can’t always tell the difference between leaf diseases because sometimes they look the same. That’s why researchers have started using automation techniques to accurately detect the main diseases and their symptoms. This research proposed potato leaf disease detection using an image processing technique where the dataset was obtained online. In the proposed method, several image pre-processing techniques are used including data augmentation, gaussian smoothing, image normalization, dimensionality reduction and one hot encoding. CNN, KNN and SVC were used as classifiers. CNN gives the best result with an overall accuracy of 97%. Previous works with different classifiers had several limitations and using CNN the researchers didn’t get satisfying result. For this research a new hybrid model is introduced which can utilize the best of CNN classifier and it will be much more reliable and effective.

Index Terms: Potato disease detection, Image processing, Data augmentation, Image normalization, One hot encoding

1. Introduction

Agriculture has emerged as a substantial contribution to Bangladesh's overall economic prosperity. Agriculture is Bangladesh's principal sector and contributes significantly to the country's gross domestic product. Therefore, crop damage would result in a large decline in total production, which would have a negative effect on the economy.

Because they are the most vulnerable part of the plant, the leaves are the first to show symptoms of illness. From the beginning of a crop's lifespan, until it is ready to be harvested, it is vital to keep an eye out for and cure any plant illnesses. Traditional naked-eye monitoring has been used for a very long time to detect diseases in plants. This is an extremely laborious and time-consuming operation that needs specialists to manually check agricultural fields. Initially, this technique was used. In recent years, a variety of approaches have been adopted to create an autonomous and semi-autonomous plant leaf disease detection system. The conventional method of manual observation used by farmers has been demonstrated to be slower, more costly, and less precise than the technologies produced to date. As a result, it is crucial that scientists apply technological methods for recognizing plant leaf diseases that are more sophisticated and do not need human involvement. There are existing solutions for plant leaf disease detection using image processing. One of the widely used solutions is the Deep Plant Phenomics (DPP) framework, which utilizes deep learning techniques to detect plant diseases from leaf images. One of the main limitations of current image processing-based plant disease detection systems is the requirement for large amounts of annotated data to train the deep learning models. This can be a time-consuming and costly process, especially for rare or new plant diseases.

In this paper potato plant leaf disease detection using image processing algorithms like KNN, CNN, and SVC has been proposed. Several steps have been followed throughout the detection procedure. The proposed method can detect two types of disease which are potato late blight, potato early blight, and healthy plants. The authors hope to reduce the cost and time for leaf disease detection by using a hybrid model.

2. Background

The classification of plant disease using image processing has been used in many research works. The researchers used various techniques of deep learning as well as machine learning for these works.

Ref. [1] Methods for machine learning and deep learning include the Support Vector Machines (SVM), Random Forests (RF), K-nearest Neighbor (KNN), Artificial Neural Network (ANN), and Convolutional Neural Network (CNN), along with models such as AlexNet, GoogleNet, and Caffe. The researchers used traditional image processing steps involved in plant leaf disease detection like image acquisition, pre-processing of image, image segmentation, feature extraction, and classification. Here, many methods for spotting leaf disease are examined by various researchers.

This paper [2] proposed a method that could detect and classify 4 plant leaf diseases. The process includes image acquisition which was done using a digital camera as well as taken from the internet. Image pre-processing improved the image data by removing the background, and noise reduction. RGB images were converted to HSV. Image smoothing was done using a median filter and histogram equalization was applied to enhance the images. K-means clustering method was used for segmentation. For feature extraction texture feature and HSV color were used for description. For extract the disease symptoms, Local Binary Pattern (LBP), and Gray Level Co-occurrence Matrix (GLCM) were used. For classification Support Vector Machine (SVM) was performed.

The proposed work [3], classifies and detects leaf diseases of plants using deep learning techniques. In this work, specific plants were chosen like tomatoes, pepper, and potatoes. For this research images were acquired from the website of the plant village treasury. In the image pre-processing stage, the pictures of the dataset were resized to the resolution of 128 x 128. In this paper, the authors used CNN structure design. The structure includes an input layer which contains the images that were taken. Convolution layer, the authors used 4 convolution layers for this work. A Max-pooling layer was used in this research. For the non-linear layer, the structure used Rectified linear units (ReLU). In this proposed work, a batch normalized layer was used as a fully connected layer. In the SoftMax layer, the SoftMax function was applied to determine the correct class of diseases. For training and testing, 70% data was used.

In another paper [4], the authors presented a machine-learning model that includes canny edge detection technique for edge feature extraction, grid color movement for extracting color features, and the local binary pattern (LBP) for texture analysis. The features which were extracted, combined to create a combined feature vector which was used for training the artificial neural network (ANN). The convolutional model is also capable of differentiating the plant leaves and recognizing rice plants and their diseases.

The proposed study [5], detects leaf diseases based on soft computing. The leaf images are captured using a smartphone. In the pre-processing stage, noise is removed using MATLAB features energy, homogeneity, mean, and others to enhance the image. Then k-means clustering was applied for segmentation. Features were extracted using a texture descriptor known as local binary pattern (LBP). Finally, classification was done using the KNN classifier.

In this research [6], the authors detected potato leaf diseases using random forest classifiers. Image pre-processing was done in two steps: image normalization and color space conversion. Segmentation was done using thresholding HSV images in RGB color space. Global feature descriptor (GFD), gray level co-occurrence matrix (GLCM), and color histogram were used for extracting features. Then, classification was done using random forest (RF) classifiers.

3. Proposed Methodology

The proposed methodology consists of steps like image acquisition, data augmentation, gaussian smoothing, image normalization, dimensionality reduction, one hot encoding, and classification. Initially, the images are acquired then the images are pre-processed using augmentation, smoothing, normalizing, etc. Potato leaf images are obtained online containing 2152 images.

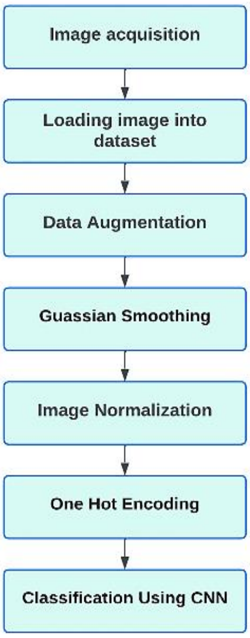

Fig. 1. Flow chart for proposed methodology (CNN)

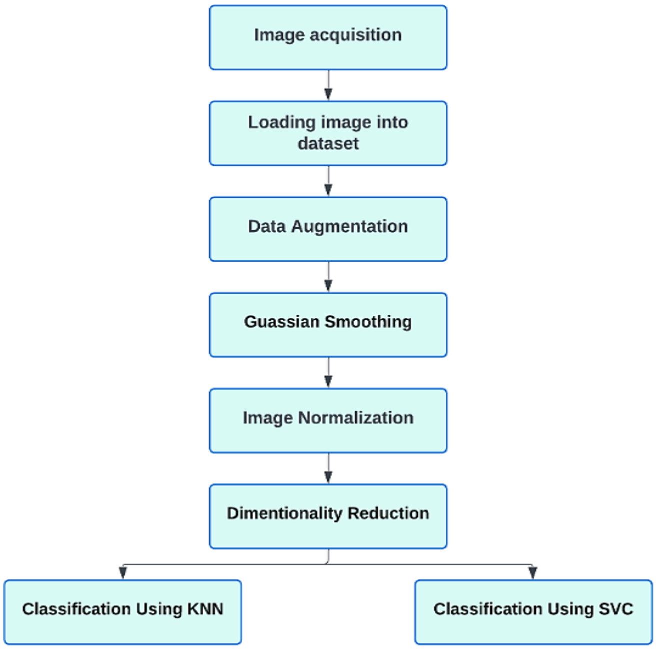

Fig. 2. Flow chart for proposed methodology (KNN, SVC)

3.1. Dataset Description

The dataset was obtained from online. There was not good amount of image in any single dataset. So the authors collected several dataset and merged them to get a big one. The collected dataset consists of both healthy and diseased images of about 2152. The potato leaf images were categorized into three types which are early blight, late blight, and healthy state. About 152 healthy leaves consist in the dataset and about 2000 are disease-affected leaves. The data set was scaled down to have a constant size of 500 by 500 pixels. Two datasets, one of them which is a training set and another is a testing set — were created from the database. 80% of the picture dataset, or 2208 images, are used for training, while the remaining 20%, or 552 images, are used for testing. The dataset training was done carefully and checked multiple time to ensure the reliability. Python was used to implement the framework.

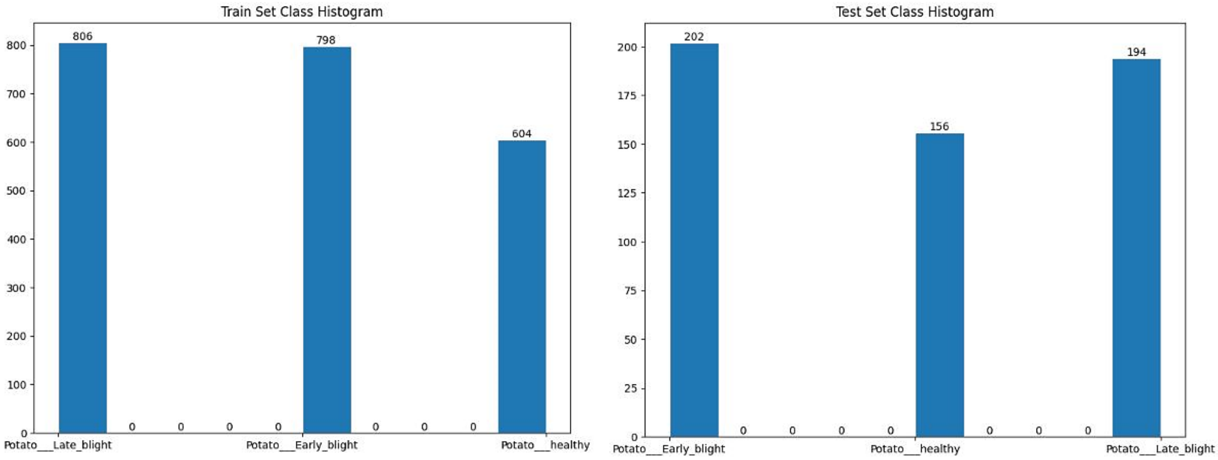

Fig. 3. Histogram of training set and testing set

Image processing consisting of data augmentation, gaussian smoothing, image normalization, dimensionality reduction, one hot encoding, and classification are the main steps in the disease detection process from potato leaves. The next sections will go over each of these stages.

3.2. Image Pre-processing

In our work, we have used three types of classifiers. One is the CNN classifier and the other is KNN and SVC classifier. So, image preprocessing was performed on two types of classifiers. And there are four steps in image processing. The first three steps are the same for both of the classifiers namely, data augmentation, gaussian smoothing, and image normalization but the final steps are different. For CNN classifier the final step is one hot encoding and for KNN and SVC classifiers the final step is dimensionality reduction.

3.3. Data Augmentation

Ref. [7, 8] Data augmentation refers to the process of making minor modifications to current data in order to increase its diversity without collecting new data. It is a strategy for augmenting a dataset. Standard techniques for augmenting data include horizontal and vertical flipping, rotation, cropping, and shearing. Data augmentation may aid in preventing neural networks from acquiring irrelevant properties. The model's performance therefore improves.

Here we will be applying data augmentation techniques to the Potato healthy class only. The operations we will be applying include:

1. Flipping Horizontally
2. Flipping Vertically
3. Slight Rotation Clockwise
4. Slight Rotation Anti-Clockwise

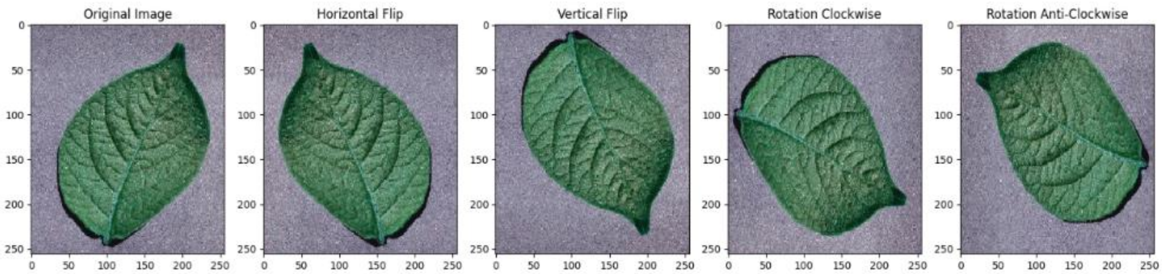

Fig. 4. Different augmented images

After data augmentation was done the total instances were 760 Potato healthy classes. And the total dataset was 2760.

3.4. Gaussian Smoothing

The obtained images were very sharp and noisy, so it would be better to smooth the image to reduce the sharpness. For that, we used gaussian smoothing to reduce the sharpness and noise and blur the images in different regions. [9]

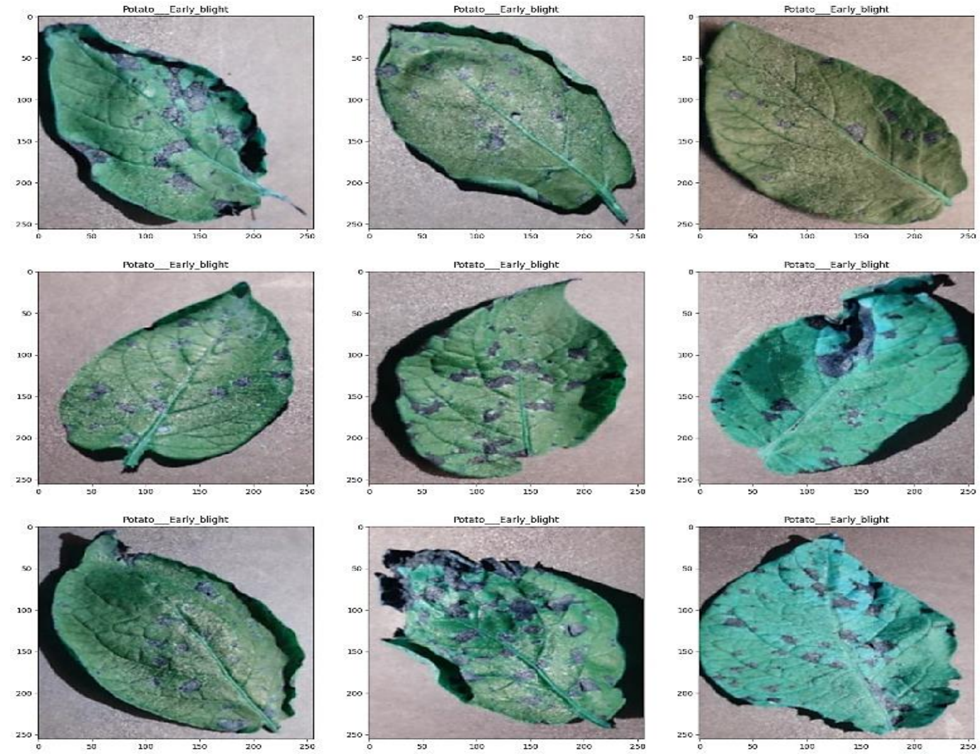

Fig. 5. Reduced sharp and noisy image

3.5. Image Normalization

Data re-scaling refers to the projection of image data pixel (intensity) to a predetermined range, including such (0, 1). This is frequently used for several data kinds; thus, we must standardize them all just so that we may use the same procedures to them.

Frequently, normalization is used to transform the image pixels of an image into a more standard or pleasant appearance. The advantages [10] of it include the following:

- Fairness across all photos - For instance, if all images are scaled to the same range, all photos may contribute equally to the total loss, as opposed to when shots with both high- and low-resolution ranges contribute disproportionately to the loss.
- Re-scaling aids in providing a consistent learning rate for any and all photographs, since high-pixel pictures need a smaller learning rates and reduced images necessitate a high learning rate.

Here, we are normalizing our RGB images which are of data type uint8 and are in the range of **(**0, 255**)**. The new range will be (0, 1**)**.

3.6. One Hot Encoding (CNN classifier)

Now, for CNN classifiers the final step of the pre-processing is one hot encoding [11]. For our work, we will be using a custom CNN model. As we are using SoftMax activation function in the last layer of our custom model, we will need to one hot encode the labels. One Hot Encoding is a powerful data pre-treatment and modification method that improves how well our models comprehend the input.

Based on the number of distinct values in the category feature, the One Hot Encoding approach generates a number of extra features. The category's individual values are all added as features. The method of constructing fake variables is hence known as One Hot Encoding. When paired with a Deep Learning classification model, this method is particularly successful in building stronger classifiers.

3.7. Dimensionality Reduction using Principal Components Analysis (KNN and SVC classifier)

The final step of the pre-processing for KNN and SVC classifier is dimensionality reduction. Scikit-learn Classifiers accept the training features to be in 2D arrays, which means we can't feed RGB images directly into any scikit-learn classifier.[12] To tackle this situation, we need to reshape or flatten the 3d RGB images into a 1D array. But by simply flattening the RGB image of shape 256x256x3, it will become a 1D array of shape 1x196608 which has a lot of features in it.

Due to this complexity, the training time is increased exceedingly and the model will perform poorly. To address this issue, we must utilize the Principal Component Analysis (PCA) dimensionality reduction approach PCA is a method for minimizing the number of dimensions in large data sets by condensing a huge collection of factors into a smaller set that preserves the bulk of the information from the large set.[13]

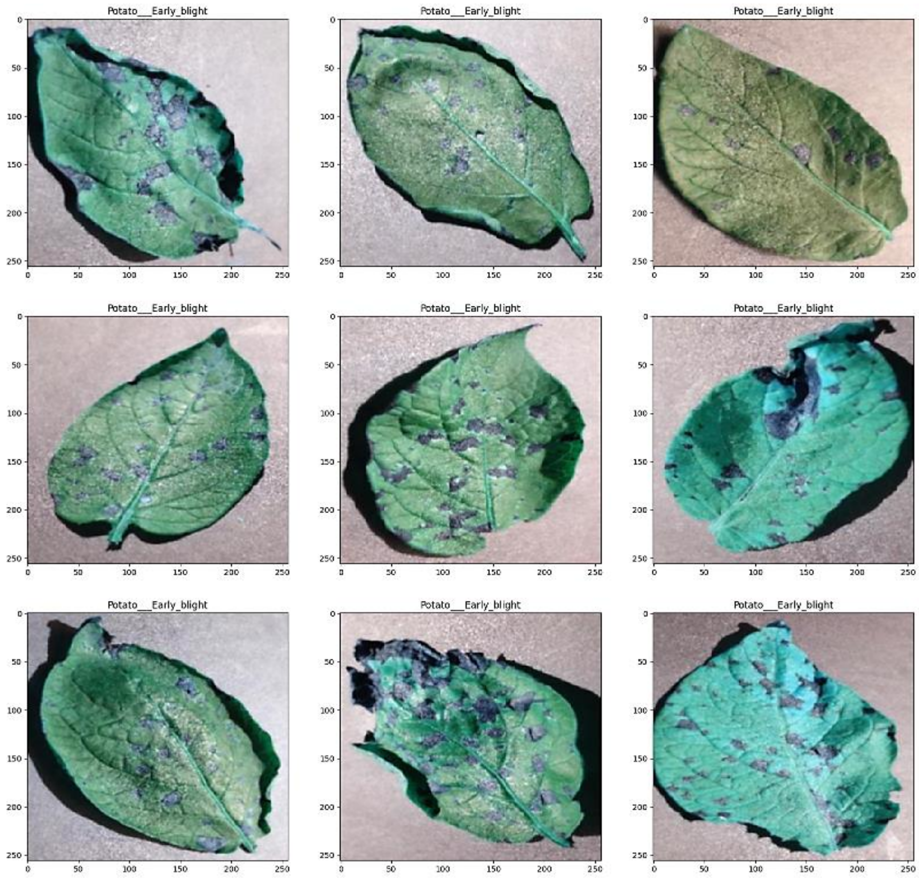

Fig. 6. Different normalized images

As the number of variables in a data collection is decreased, accuracy obviously declines, but the solution to dimensionality reduction is to forgo some precision for simplicity. Smaller data sets facilitate the analysis of data by machine learning algorithms, since there are less superfluous aspects to assess.

We took the first 500 components which cover up to 90% of information when summed up the individual component's variance. This means we have successfully reduced 196608 features to just 500 features by losing only 10% of the information from the dataset.

3.8. Classification

As the dataset has been prepared, now it's time for training different classifiers. In our work, we have employed three classifiers CNN, KNN, and SVC. For CNN we have built a custom CNN model using Keras. For KNN and SVC classifiers we will be training them with hyperparameter tuning. Scikit-learn provides a built-in package named GridSearchCV[14] for performing hyperparameter tuning. We will use KNN Classifier with GridSearchCV and Support Vector Classifier with GridSearchCV as our estimator.

4. Result Analysis and Discussion

In our work, we have used a dataset of 2152 images of potato leaves for the system. Our dataset consists of images of 152 healthy, 1000 early blight affected, and 1000 late blight leaves. The dataset has been split into two phases, the training phase, and the testing phase. The training phase contains 80% dataset and the rest is used for testing. In image pre-processing, we have done data augmentation (To tackle class imbalance), gaussian smoothing (to smooth the image to reduce the sharpness and remove noise), image normalization (Projecting image data pixels (intensity) to a predefined range of (0, 1)), dimensionality reduction (Performing PCA to reduce the complexity of the dataset), and one hot encoding (an effective data transformation technique that helps our model understand the data better). For classification, we used three classifiers namely CNN, KNN, and SVC. Convolutional neural network (CNN) gave the highest overall accuracy of 97.83% among the three classifiers.

For the CNN classifier, we have used a custom CNN model. The model used a total of 20 epochs for training. Overall training progress shows that gradually the training loss decreased and training accuracy increased.

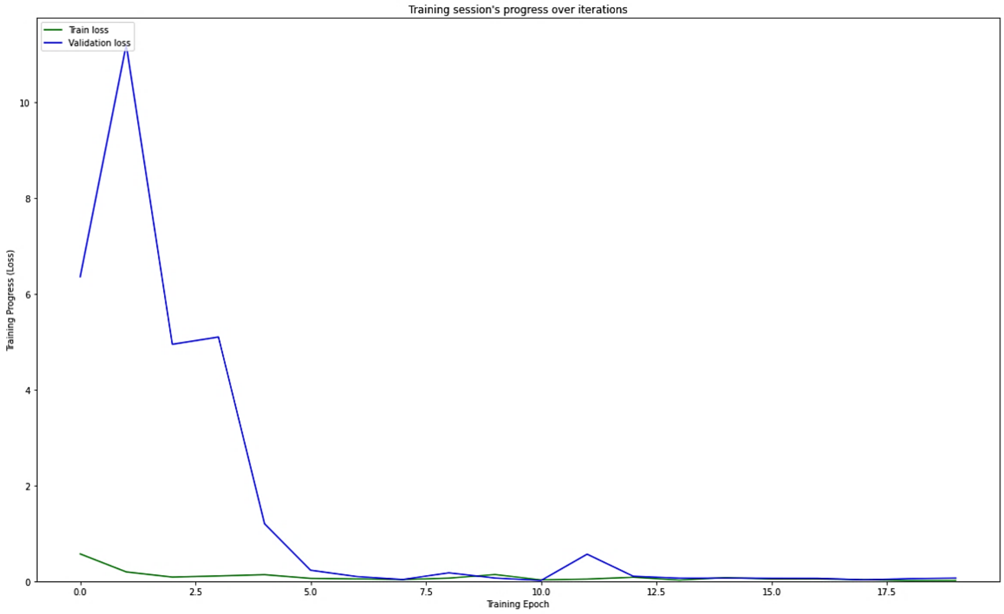

Fig. 7. Training session progress (train and validation loss)

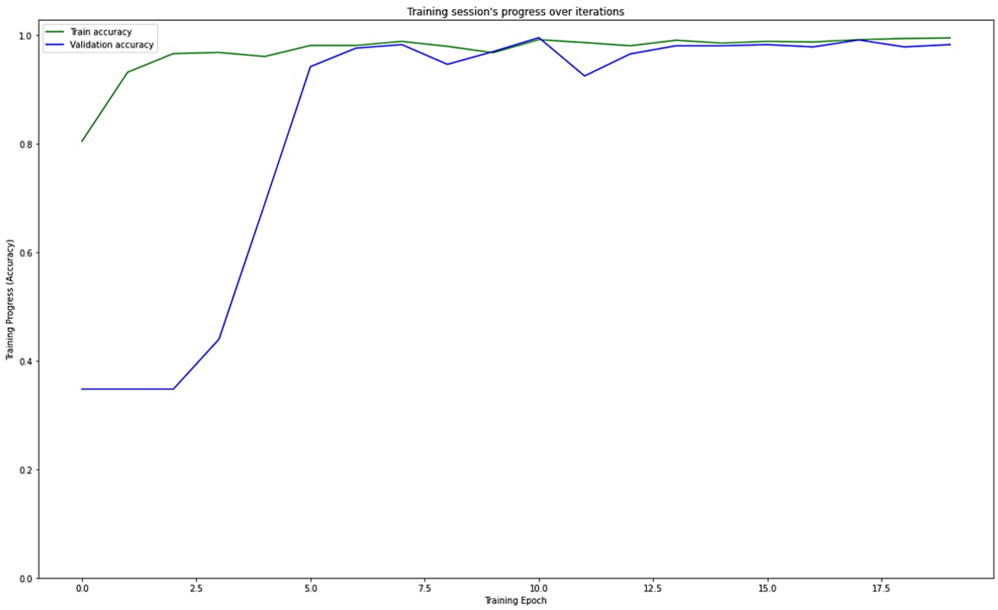

Fig. 8. Training session progress (train and validation accuracy).

For the KNN classifier, the accuracy is 79.35%. We have trained the KNN classifier with hyperparameter tuning. For performing the hyperparameter tuning we have used Scikit-learns built-in package named GridSearchCV . For the hyperparameters, we have used 1, 3,5, 7, and 9 as the parameter of n_neighbors, for algorithm auto, ball_tree, kd_tree, brute parameter has been used, and for leaf_size 20, 30, 40, and 50 has been used as parameters. Among all these parameters the best ones are n_neighbors": [5], "algorithm": ["brute"], "leaf_size": [40] which suits our dataset and gives better accuracy.

GridSearchCV is also used for the SVC classifier and the accuracy is 92.75%. We passed predefined values for C (0.1, 1, 10, 100, 1000), gamma (1, 0.1, 0.01, 0.001, 0.0001), and kernel(rbf) as the hyperparameters for the GridSearchCV function. The best parameters that suit our dataset best are 'C': [10], 'gamma': [0.0001], 'kernel': ['rbf']. As SVMs effectiveness depends on various kernel and kernel parameters we used the radial basis function kernel (RBF).

$$k(x, y) = \exp\left(-\frac{\|x-y\|^2}{2\sigma^2}\right) \tag{1}$$

Where

1. 'σ' is the variance and our hyperparameter
2. $\|x - y\|$ is the Euclidean (L-norm) Distance between two points x and y

RBF Kernel is popular and widely used because it is similar to the KNN algorithm. It has the advantages of the KNN and overcomes the space complexity problem as RBF Kernel just needs to store the support vectors during training and not the entire dataset [9].

Table 1. Comparison between CNN and SVC classifier in terms of precision, recall, f1 score and accuracy.

Classifier	Precision (%)	Recall (%)	F1 score (%)	Accuracy (%)
CNN	97.39	97.39	97.39	97.83
SVC	93.11	93.10	93.08	92.75

Here, potato leaf disease has been detected using image processing. The approach is suitable for the dataset of this study. In the image processing section, data augmentation, gaussian smoothing, image normalization, one-hot encoding, and dimensionality reduction have been used. For classification, supervised learning has been used. From the findings, CNN gave the best result in terms of precision, recall, f1 score, and accuracy. The accuracy is 97.83%. In order to enhance the work further, the same approach can be used to improve the proposed work and make it appropriate for all crops with the necessary accuracy levels. In several instances, the implementation still falls short of accurate results. To more correctly anticipate the disease, additional optimization is required.

The proposed methodology of potato leaf disease detection using CNN can facilitate achieving research objectives by providing a reliable and efficient approach to detecting diseases in potato plants. The use of CNN-based algorithms allows for the automatic and accurate classification of potato leaves into healthy and diseased categories based on image analysis.

The first research objective [15] that can be achieved using this methodology is the accurate identification and classification of potato leaf diseases. By training a CNN model using a dataset of potato leaf images, the model can learn to recognize the unique features associated with various diseases affecting potato plants. This can help in the early detection and diagnosis of diseases, leading to timely intervention and effective management of the disease.

The second research objective that can be achieved is the development of a more efficient and cost-effective method for disease detection. Traditional methods for disease detection, such as manual inspection and laboratory analysis, can be time-consuming and expensive. The use of CNN-based algorithms for disease detection can provide a faster and more cost-effective approach that does not require extensive manual labor or specialized equipment.

The third research objective that can be achieved is the improvement of overall crop yield and productivity. Early detection and effective management of diseases can prevent the spread of the disease to other plants, leading to improved crop yield and productivity. This can help to reduce losses due to disease and increase the overall profitability of potato farming.

In summary, the proposed methodology of potato leaf disease detection using CNN can facilitate achieving research objectives by providing an accurate, efficient, and cost-effective approach to disease detection. This can help to improve overall crop yield and productivity, leading to increased profitability for potato farmers.

However, it is worth noting that these results are based on specific datasets and conditions, and the performance of the algorithms may vary depending on the type of plant, the type of disease, and other environmental factors. Additionally, it is important to consider the limitations of image processing, such as the need for high-quality images and the inability to detect diseases that do not show visible symptoms on the leaves.

5. Conclusions

In this study, early blight and late blight, the two most prevalent leaf diseases of potato plants, are detected and classified using machine learning classifiers with the use of image processing. Additionally, in this procedure, healthy leaves are also recognized and categorized. The use of convolutional neural network (CNN) based image processing techniques for detecting potato leaf diseases represents a significant advancement in the field of plant disease detection. This is because traditional methods of disease diagnosis, such as visual inspection or laboratory analysis, are time-consuming and often require significant expertise.

The CNN-based image processing technique offers a faster, more accurate and cost-effective method for detecting plant diseases. By training the neural network on a large dataset of diseased and healthy plant images, the CNN can learn to identify patterns and features specific to each disease, allowing it to accurately classify new images. This method has the potential to greatly reduce the time and resources required for disease diagnosis, allowing for earlier detection and more effective treatment.

Moreover, the CNN-based image processing technique can overcome the limitations of traditional methods, such as human error and subjectivity in visual inspection. This is particularly important in regions where access to trained professionals or specialized equipment is limited, as it provides a more accessible and reliable means of disease diagnosis.

In summary, the use of CNN-based image processing techniques for potato leaf disease detection represents a significant advancement in the field, offering a faster, more accurate, and cost-effective method for disease diagnosis that has the potential to improve crop yields and food security. The upcoming work's main objective will be to develop a system with a trained model made up of server-side components and an application for smart devices for displaying plant diseases based on leaf images taken by the smartphone camera in different kinds of plants. So that farmers can quickly and simply utilize it to detect the disease.

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References

[1] C. Knaak, J. von Eßen, M. Kröger, F. Schulze, P. Abels, and A. Gillner, “A Spatio-Temporal Ensemble Deep Learning Architecture for Real-Time Defect Detection during Laser Welding on Low Power Embedded Computing Boards,” *Sensors*, vol. 21, no. 12, p. 4205, Jun. 2021, doi: 10.3390/s21124205.

[2] Y. M. Oo and N. C. Htun, “Plant Leaf Disease Detection and Classification using Image Processing,” *International Journal of Research and Engineering*, vol. 5, no. 9, pp. 516–523, Nov. 2018, doi: 10.21276/ijre.2018.5.9.4.

[3] M. A. Jasim and J. M. AL-Tuwaijari, “Plant Leaf Diseases Detection and Classification Using Image Processing and Deep Learning Techniques,” in 2020 International Conference on Computer Science and Software Engineering (CSASE), Apr. 2020, pp. 259–265. doi: 10.1109/CSASE48920.2020.9142097.

[4] G. Shrivastava and H. Patidar, “Rice Plant Disease Identification Decision Support Model Using Machine Learning,” Ictact Journal On Soft Computing, p. 3, 2022, doi: 10.21917/ijsc.2022.0365.

[5] E. A. Abusham, “Image Processing Technique for the Detection of Alberseem Leaves Diseases Based on Soft Computing,” Artificial Intelligence & Robotics Development Journal, pp. 103–115, Jun. 2021, doi: 10.52098/airdj.202127.

[6] Md. A. Iqbal and K. H. Talukder, “Detection of Potato Disease Using Image Segmentation and Machine Learning,” in 2020 International Conference on Wireless Communications Signal Processing and Networking (WiSPNET), Aug. 2020, pp. 43–47. doi: 10.1109/WiSPNET48689.2020.9198563.

[7] C. Shorten and T. M. Khoshgoftaar, “A survey on Image Data Augmentation for Deep Learning,” J Big Data, vol. 6, no. 1, p. 60, Dec. 2019, doi: 10.1186/s40537-019-0197-0.

[8] “Radial basis function kernel - Wikipedia.” https://en.wikipedia.org/wiki/Radial_basis_function_kernel (accessed Oct. 23, 2022).

[9] U. O. Lateef, M. Mohamad, K. Omar and R. C. Muniyandi, “Gaussian smoothing and modified histogram normalization methods to improve neural-biomarker interpretations for dyslexia classification mechanism,” PLOS One, 2021.

[10] X. Zhang, Y. Sugano and A. Bulling, "Revisiting Data Normalization for Appearance-Based Gaze Estimation," Association for Computing Machinery, pp. 1-9, 2018.

[11] L. Jie, C. Jiahao, Z. Xueqin, Z. Yue and L. Jiajun, "One-hot encoding and convolutional neural network based anomaly detection," Journal of Tsinghua University (Science and Technology), vol. 59, no. 7, pp. 523-529, 2019.

[12] B. S. K. Keerthi Vasan, "Dimensionality reduction using Principal Component Analysis for network intrusion detection," ELSEVIER, vol. 8, pp. 510-512, 2016.

[13] K. Sasan , M. A. Shahidan , A. M. Azizah , Z. Mazdak and H. Alireza , "An Overview of Principal Component Analysis," Journal of Signal and Information Processing, vol. 4, pp. 173-175, 2013.

[14] Y. Shuai, Y. Zheng and H. Huang, "Hybrid Software Obsolescence Evaluation Model Based on PCA-SVM-GridSearchCV," in IEEE, Beijing, 2018.

[15] D. Kothari , H. Mishra, V. Pandey, M. Gharat and R. Thakur, "Potato Leaf Disease Detection using Deep Learning," International Journal Of Engineering Research & Technology, vol. 11, no. 11, 2022.

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