LONG SHORT-TERM MEMORY BASED DETECTION OF POTATO LEAF DISEASES FOR ENHANCED CROP MANAGEMENT

Nandhini S[1], S. Thilagavathi [2]*

ABSTRACT

An LSTM-based method for the automated detection of potato leaf diseases is presented in this work. A preprocessed dataset of photos of potato leaves covering a range of diseases such as early and late blight is gathered. The diversity of the dataset is increased by the use of augmentation techniques. The stacked LSTM layers in the LSTM model architecture are succeeded by a softmax output layer for categorization. The program gains accurate illness categorization by learning temporal dependencies in the image sequences through training and validation. Its efficacy in identifying potato leaf diseases is demonstrated by evaluating the performance on an independent test set. This system helps for identifying diseases in potato crops early on, which could help farmers manage their harvests and intervene when necessary.

Keywords: Agricultural Disease Management, Crop Yield, Long Short-Term Memory, potato crops

I. INTRODUCTION

Crop farming plays a crucial role in economics [1]. The Russian agricultural business is changing as a result of a growth in agricultural product production. The Russian government must use creative approaches to boost labor productivity and improve yields, as agriculture is vital to the world's food production. The agricultural industry in the Russian Federation has grown by 5% on average, but developed nations have utilized almost 55% of their potential for innovation in this field. In order to tackle this issue, the Russian Federation must adopt a two-pronged strategy. Firstly, the government should allocate funds for research and development in order to promote innovation, efficiency, and productivity. Secondly, the agricultural sector must concentrate on enhancing its expertise with exceptional planning concerning technology [2]. Modern farming techniques include agricultural disease control as a crucial component to reduce the negative impact of plant diseases on crop quality and productivity. It includes a variety of tactics and methods intended to stop, manage, and lessen the effects of crop-damaging diseases [3]. Maintaining food security, protecting farmers' livelihoods, and increasing agricultural output all depend on effective disease control. Agronomic and cultural techniques, the use of resistant cultivars, early identification and diagnosis, disease surveillance and monitoring, and the prudent use of pesticides and other control methods are all important aspects of managing agricultural diseases.

A key indicator in agriculture is crop yield, which is defined as the amount of harvested produce per unit of land area [4]. It is a crucial factor in determining food security, economic sustainability, and agricultural production. It also plays a major part in providing for the nutritional needs of the world's expanding population. Numerous factors, such as environmental conditions, soil fertility, water availability, pest and disease challenges, and agronomic methods, all have an impact on crop output. One of the main goals for farmers and other agricultural stakeholders globally is to maximize crop output while minimizing input use and environmental effects.

Figure 1 : Potato Leaves

Department of Computer Science and Engineering[1],
Karpagam Academy of Higher Education, Coimbatore, Tamil Nadu, India
nandhini.sivaraj@kahedu.edu.in[1]
Department of Computer Science and Engineering[2],
NGM College
thilagavathibluesky@gmail.com[2]
* Corresponding Author

RNN architectures with LSTM were created expressly to solve the issue that plagues conventional RNNs. Because LSTMs can recognize long-term dependencies in sequential data, they are excellent at applications like as speech recognition, natural language processing, and time series prediction [5].

II. LITERATURE SURVEY

This publication was suggested by Massimo Stella [6] et al. Potato crops are essential to the world's economy and food security, but they are susceptible to a variety of leaf diseases that can have a major negative impact on output and quality. Effective disease control and prevention depend on the timely diagnosis and precise identification of these illnesses. This study provides a thorough analysis and comparison of three cutting-edge CNN models—VGG19, DenseNet121, and ResNet50—for the identification and prediction of potato leaf diseases. The selected CNN models were trained and evaluated using a large dataset of potato leaf images, which included both healthy and diseased specimens. Extensive data augmentation techniques were employed to enhance the diversity and generalization capacities of the dataset.

The most damaging potato diseases are late blight and early blight[7]. For timely prophylaxis, it is important to identify illnesses and the extent of infection on potato leaves. This study looked into a precise recognition technique for identifying the kind of disease and level of infection in potato leaf photos. An automatic approach for the graph-cut algorithm is created in order to efficiently and accurately segment the leaf from the photos. Otsu thresholding was used to extract the seeds from the foreground, and color statistical thresholding on the a* and b* components was used to separate the seeds from the background. When the super pixels next to the leaf outline have entropies that are significantly different from those of the majority of the leaf, they are iteratively removed in order to eliminate backdrops that share the same color as the affected patch.

One of the most important food crops in the world, the sweet potato (Ipomoea balatas), and its leaves provide a nutritional source of nutrients and a range of bioactive compounds [8]. These components of sweet potato leaf (SPL) differ between kinds and are crucial for both disease prevention and treatment. The identification and measurement of bioactive chemicals in SPL, as well as numerous in vitro and in vivo studies, have been prompted by the increased focus on health-promoting properties. Many of these novel compounds have been discovered as the first to have their predominant bioactivities in SPL, according to reports. The current understanding of SPL's bioactive components and health benefits is summed up in this review. Since it may provide vitamins and useful compounds, SPL have the potential to be a sustainable crop for the food and pharmaceutical industries. Flavonoids and polyphenols are two of the primary bioactive ingredients found in sweet potato leaves, which grow in a range of colors including red, yellow, purple, green, and white flesh.

Diseases that harm crops have a negative effect on a country's agricultural productivity and financial resources [9]. Crop disease early identification can reduce farmer losses and increase yield. This study proposes a unique hybrid deep learning model for predicting potato leaf diseases, named PLDPNet, with autonomous capabilities. The PLDPNet framework includes stages of pre-processing, segmentation, feature extraction and fusion, and classification. To generate more powerful features, deep features from two popular models (VGG19 and Inception-V3) are combined using an ensemble method. The hybrid approach incorporates the concept of vision transformers for the final prediction.

One of the principal crops grown in Bangladesh is the potato. In Bangladesh, the past few decades have seen a sharp rise in the popularity of potato fields [10]. However, in the potato industry, a number of illnesses are increasing farmer costs. On the other hand, the majority of crop-related diseases are to blame for the high cost of producing potatoes. The farmer's calendar is going crazy because of that. Automation has been used to upgrade the potato sector and quicken the diagnosis of illnesses. The farmer will not be at risk of suffering substantial financial losses if early diagnosis of such outbreaks and appropriate intervention procedures are implemented.

III. RELATED WORK

The key to preventing crop loss and maintaining the value of agricultural output is early detection of plant diseases. Research on crop diseases entails research on the patterns that can be seen in the plant. Plant disease identification and health monitoring are essential for sustainable agriculture. Accurate observation is a very challenging way to monitor and identify plant diseases. Disease-related crop loss is estimated to account for 15–25% of agricultural production in India. Therefore, in order to address this issue properly, Nation must not only boost productivity but also guarantee food security and nutrition. This work present automated plant disease detection system, which was created by incorporating advanced "Deep Learning" models such as Support Vector Machine (SVM).

IV. MATERIAL AND METHODS

Using an LSTM-based methodology, the suggested system for automated identification of potato leaf diseases provides a fresh way to handle problems with agricultural crop management. The system starts with pre-processing and data collecting, where a variety of datasets spanning different illnesses such as early and late blight are gathered from potato leaf images. In order to ensure uniformity throughout the collection, every image is meticulously labeled with the relevant illness using standard pre-processing techniques. Then, data augmentation methods are used to produce more training samples with different rotation, flipping, and scaling, hence improving the model's resilience. The LSTM model architecture, which is made up of stacked LSTM layers and is intended to capture temporal dependencies in sequential image data, is the central component of the system. With the help of strategies like early stopping, the model is trained on a split dataset in order to avoid overfitting and guarantee peak performance. The model's performance is tracked on a validation set during training in order to adjust hyper parameters and maximize generalization. Ultimately, an independent test set is used to examine the trained LSTM model's performance in properly detecting potato leaf diseases. Metrics including accuracy, precision, recall, and F1-score are computed.

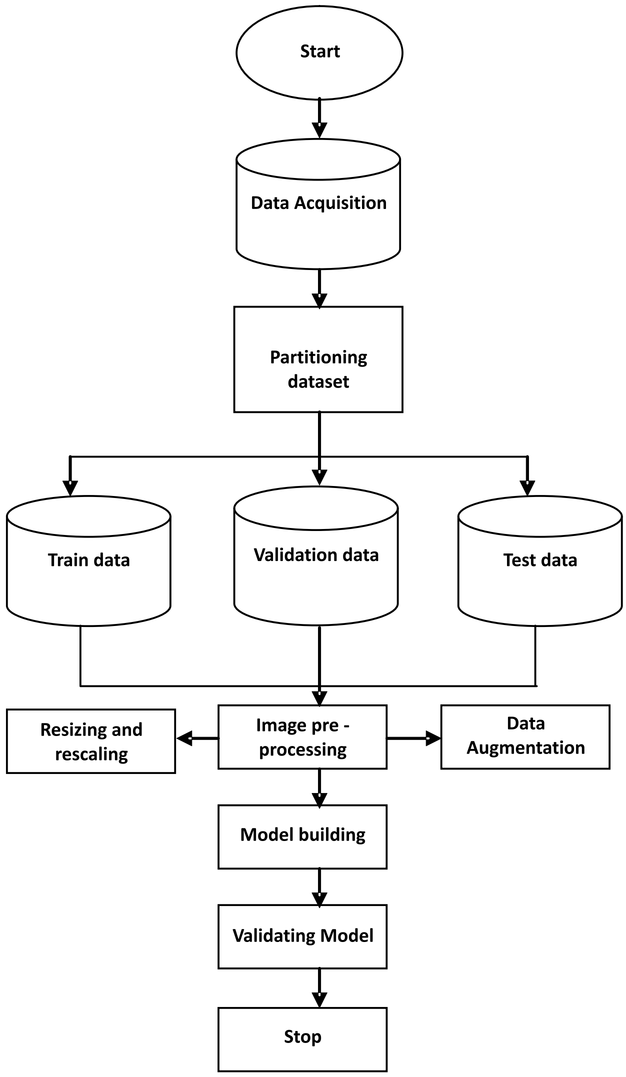

Figure 2: Methodology work flow

4.1. Data Collection and Pre-processing

A large collection of photos of potato leaves is gathered, guaranteeing that different illnesses like early and late blight are represented. The LSTM model is trained and assessed using this dataset as the basis. With careful labeling of each image for the associated ailment, supervised learning is made easier for model training. Techniques for image pre-processing are used to normalize the dataset. This involves resizing the photos to a consistent size, converting them to grayscale, and normalizing the pixel values in order to ensure consistency in the input data format.

Table 1 : Dataset details

Samples	Number
Healthy leaf	150
Early blight	500
Late blight	500
Total	1150

4.2. Data Augmentation

By using data augmentation approaches, the LSTM model's resilience is increased and over fitting is avoided. These techniques—such as rotation, flipping, and scaling—diversify the dataset and improve the model's ability to generalize by introducing variations to the training data.

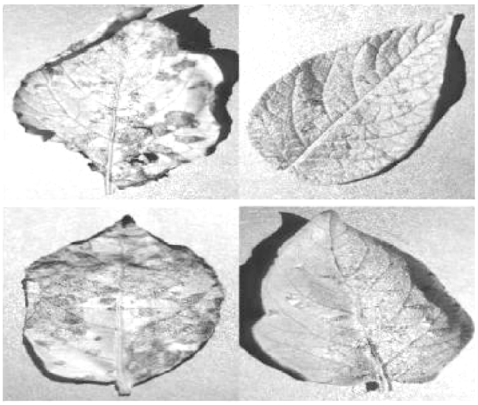

Figure 3.a: Leaf of Potato Early Blight

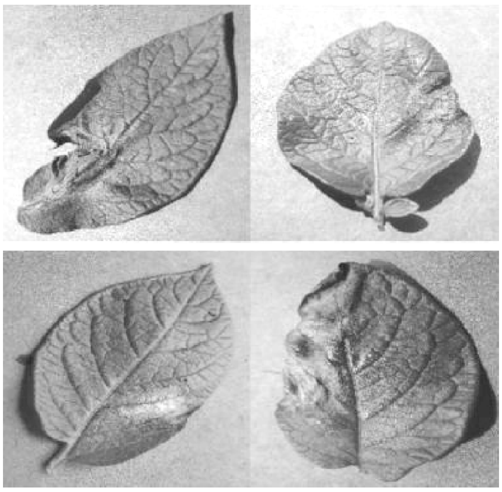

Figure 3.b: Leaf of Potato Late Blight

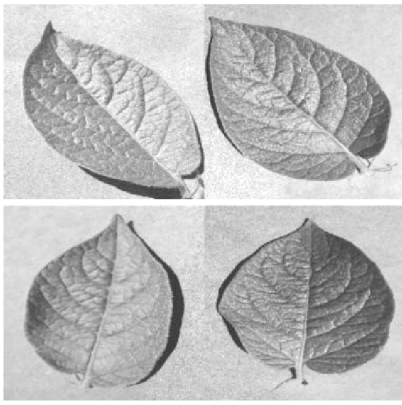

Figure 3.c: Healthy Potato Leaf

4.3. LSTM Model Architecture

The sequences of image data that make up the input to the LSTM model may have been flattened to meet the specifications. In order to capture temporal dependencies in the sequences and allow the model to identify patterns and subtle changes in illness development over time, stacked LSTM layers are employed. For multi-class classification, the output layer uses a softmax activation function, which makes it easier to identify diseases using learned information.

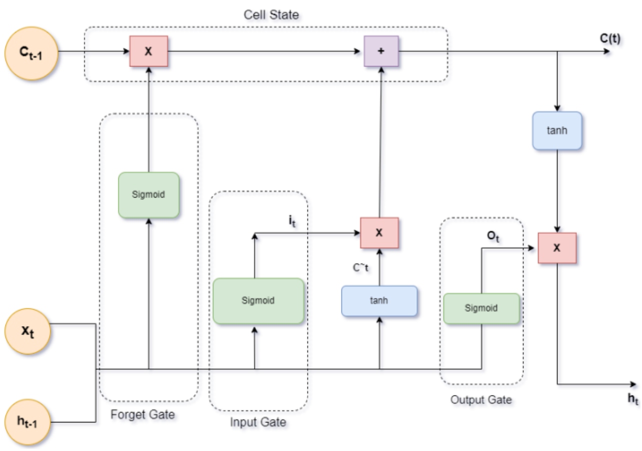

Figure 3: LSTM Architecture

4.4. Training

The dataset is split into training and validation sets to simplify the process of training and analyzing the model. With the appropriate optimization methods and loss functions, the LSTM model is trained on the training set. Early halting is one technique used to minimize overfitting and maximize model performance. To make sure the model generalizes effectively to new data, its performance is tracked throughout training on the validation set.

4.5. Evaluation

To objectively evaluate the trained LSTM model's performance in disease identification, it is tested on a different test set. Accuracy, precision, recall, and F1-score are among the evaluation metrics that are computed to assess how well the model performs in correctly classifying potato leaf diseases. These metrics provide insight into the general efficacy of the model as well as its ability to accurately diagnose certain diseases.

V. RESULT ANALYSIS

The LSTM-based method for automated identification of potato leaf diseases produced encouraging results, according to the findings analysis. On the test dataset, the model showed good performance in correctly identifying a variety of illnesses, such as early and late blight. The obtained metrics precision, recall, accuracy, and F1-score showed how robust the model was in differentiating between various disease classifications. Furthermore, the model's efficient use of stacked LSTM layers demonstrated its capacity to detect temporal dependencies in sequential image data. Data augmentation techniques were incorporated to further improve the model's capacity for generalization and adaptability to changes in input data.

Table 2: Performance of LSTM

Proposed Algorithm	Accuracy	Precision	Recall	*F*1-Score
LSTM	94.20%	0.73	0.8	82.30%

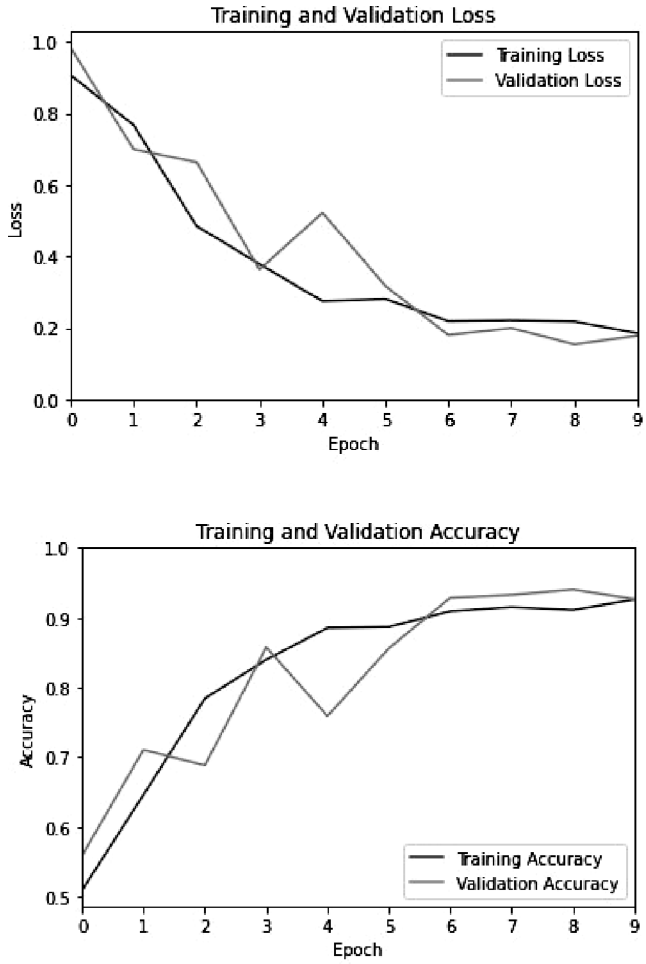

Figure 4: Accuracy vs Data Loss and Epoch graph

5.1. Confusion Matrix

Confusion matrices have become a popular tool for describing the effectiveness of a classification method. Relying solely on classification accuracy can be misleading, especially when dealing with datasets that contain more than two categories or exhibit a clear imbalance in the number of observations in each class. Creating a confusion matrix allows for a deeper understanding of the strengths and weaknesses of a classification model. The confusion matrix serves as an effective visual representation of an algorithm's output, weighing and comparing true and false assumptions. Below are examples of the model equation's correctness and the classification rate equation's precision.

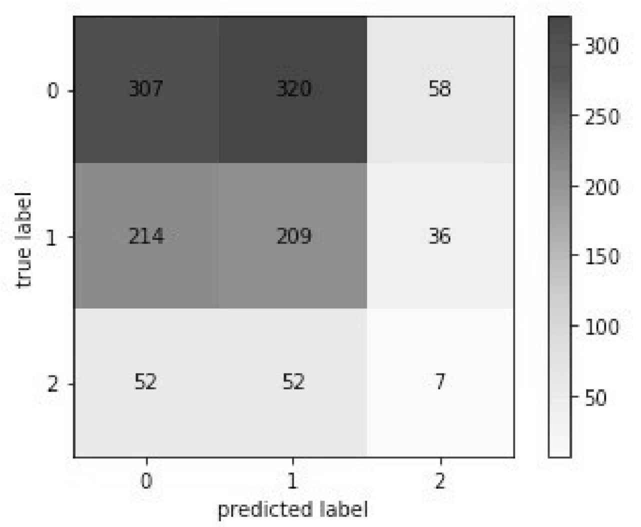

Figure 5: Confusion Matrix

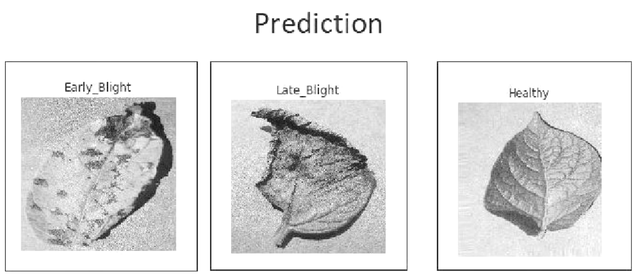

Figure. 6: (a) Early Blight, (b) Late Blight, and (c) Healthy

VI. CONCLUSION

The LSTM-based methodology offers a practical solution for the automatic detection of potato leaf diseases, with significant implications for agricultural crop management. By utilizing sequential image data and stacked LSTM layers to capture temporal relationships, the proposed model exhibits strong performance in accurately diagnosing a variety of diseases, including early and late blight. The system demonstrates effectiveness in early disease identification through rigorous training, validation, and assessment procedures, potentially enabling timely interventions and improving farmers' crop management practices.

VII. FUTURE WORK

To refine the model and develop a website that allows users to view and submit pictures of plant leaves, the platform will also be equipped to offer practical recommendations and remedies for common plant leaf diseases. Additionally, the model will provide contact details for the nearest agricultural center office, enabling access to expert advice in agriculture for more precise outcomes.

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