Image-Based Potato leaf Disease Detection using Deep Convolutional Neural Networks

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Introduction

Agriculture is a long-standing source of food and is still a fundamental source of livelihood all over the world. Plants are necessary for both human beings and animals, giving them oxygen, food and other essentials. The agricultural specialists and the government are constantly trying to boost production of food through new methods. However, plant illnesses, caused by bacterial, fungal, and other pathogens, impact crop yields and all living organisms in the ecosystem. The diseases can occur on any part of the plant, including leaves, stems, and branches, and the severity will depend on climatic conditions. Low food yield by diseases and climate change has resulted in food shortages globally. Early detection of plant disease is essential to prevent loss of crops on a large scale, and the correct application of pesticides, under expert advice, is necessary to help avoid the negative effects on crops and land.

Disease detection equipment has revolutionized agriculture with precise and timely results for large- and small-scale farming. Neural network and Deep learning, particularly CNN are central in these technologies. CNNs are used to detect diseased and healthy leaves through image assessment, allowing disease detection and management earlier. This boosts agricultural productivity at the expense of crop quality.

Precision farming is a new age technology that involves utilizing sophisticated tools in order to increase crop yields and maximize farm management. It targets such parameters as water, stress in land, pesticides, and fertilizers, by applying image assessment to analyze agronomic hurdles efficiently and accurately. Through these new techniques, farmers are able to attain more yields and sustainable farming practices.

Machine learning techniques and image processing were employed to detect plant diseases prior to deep learning. In order to process images for subsequent steps, image processing techniques like image enhancement, segmentation, color space conversion, and changing are employed. The major features of the image are obtained and utilized as input to the classifier. The accuracy of overall classification depends on the image processing and feature extraction methods.

Literature Review

- Konstantinos P. Ferentinos [1] proposed a method deep learning models for plant disease detection and diagnosis. This paper discusses how deep learning techniques, are applied to plant disease detection, enhancing traditional symptom-based detection with automated analysis. It combines visual inspections with machine learning for faster and more accurate detection. It requires a large dataset for training, which might not always be available for every disease.

- Sharma A and Kumar M demonstrated that Potato diseases detection with machine learning methods. The paper discusses incorporating conventional methods of disease detection of potato plants as well as machine learning models in order to enable the automation process of disease classification. Automates and accelerates the process of disease detection. Machine learning models rely greatly upon high-quality as well as tagged data [2].

- Saha S and Kundu S introduced a method Potato plant disease detection using machine learning techniques. This research [3] utilizes traditional plant disease symptoms combined with machine learning algorithms to improve accuracy in potato disease classification. It enhances traditional disease detection with automated analysis, reducing human error. Needs a diverse dataset to handle multiple disease types effectively.

- Singh A and Kaur H suggested concept Potato plant leaf disease detection and classification with machine learning techniques [4]. The paper integrates classical methods for detection of plant diseases, such as symptom observation, and machine learning classifiers to identify potato diseases in a better manner. Enhances disease detection and management using advanced models for more accurate results. Data preprocessing and collection may be time-consuming.

- Singh M and Agarwal A[16] explored a method Potato crop disease prediction using machine learning: A case study. Provides a comprehensive look at how traditional methods have evolved and highlights the importance of visual diagnostics in disease management. The reliance on visible symptoms for disease identification means some diseases can be misidentified or not detected until later stages, affecting yield.

Literature Review

- Ghosh A and Saha S designed a system Real-time potato leaf disease classification using CNN. The system [22] discussed in this work investigates the use of CNN for the classification of various potato diseases from images using a dataset of images of diseased potato plants. CNN's performance is far superior to the traditional methods when it comes to speed and accuracy in the classification of potato diseases. The performance of the model greatly relies upon the quality of the image dataset; incorrect acquisition of images results in poor output.

- Singh R and Verma S suggested a technique [23] Potato disease detection using convolutional neural networks. Describes applying CNNs to identify potato diseases such as late blight, early blight, and bacterial wilt. Automatic detection minimizes human error and yields more accurate and consistent results in disease classification. The model could perform poorly with unforeseen disease classes or intricate symptoms, especially when the training dataset is not diversified.

- Patel S and Patel N discussed a technique Potato leaf disease prediction using convolutional neural networks. This work emphasizes the application of CNNs to image analysis of potato leaves for disease detection. CNNs provide an end-to-end solution for disease detection without the need for manual extraction of features from images. Needs a large quantity of labeled data for training, which might not always be available, particularly for uncommon diseases [24].

- Kumar V and Verma A developed a system [25] Potato disease identification using CNN-based model. Investigates the real-time application of CNNs for detecting potato diseases during field inspections using smartphones or cameras. Real-time detection allows farmers to quickly identify and address diseases before they spread significantly. Real-time processing may be slower on low-powered devices and may require high-performance hardware.

- Ravi P and Deshmukh A suggested a method Convolutional neural network-based model for real-time potato disease prediction. This research [20] investigates the use of pre-trained CNN models fine-tuned on potato disease datasets to enhance disease detection accuracy. Fine-tuning reduces the amount of data needed for training and can improve performance, especially with limited disease images. Fine-tuning still requires computational resources and may not work well if the dataset is too small or unbalanced.

Existing method Drawback

Entering the market can be challenging, and some drawbacks to consider include:

- High Initial Investment
- Complexity in Deployment
- Lack of Trust and Skepticism
- Data Privacy and Security Concerns
- Market Fragmentation
- Dependence on High-Quality Data
- Lack of Standardization

Additionally, regulatory hurdles and certification requirements may pose significant barriers to market entry, particularly in regions with healthy and quality standards.

Proposed Method

We have proposed a system to predict different types of diseases in potato plant using CNN. The methodology involves collecting a dataset of potato leaf images, preprocessing them through resizing and normalization, and then training a CNN model to classify diseases. The CNN extracts feature(s) from the images, learns patterns, and predicts diseases based on trained weights, with evaluation metrics like accuracy and loss guiding model optimization.

To accomplish this, we employ CNN based model that has been trained on a labeled data set of potato plant leaf images obtained from Kaggle. The approach starts with image acquisition, followed by preprocessing activities including resizing every image to 224×224 pixels, pixel value normalization to [0, 1], and data augmentation for enhancing model robustness. The architecture of CNN consists of three convolutional layers with 3×3 kernels, ReLU activation, max pooling layers, and a fully connected layer. Softmax activation is applied in the output layer to perform multiclass classification. Such a configuration helps the model extract disease-specific features such as shape, texture, and color patterns from leaf images and assign them to their respective class with a high confidence level. Utilization of CNN provides automatic, precise, and effective detection of potato leaf diseases from real-time images to enable farmers to make timely and informed decisions in crop health management.

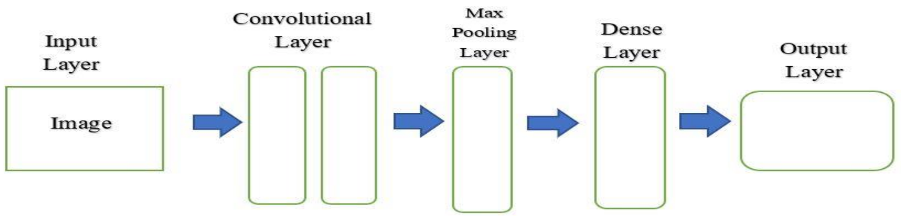

Fig. 1. Architecture of CNN

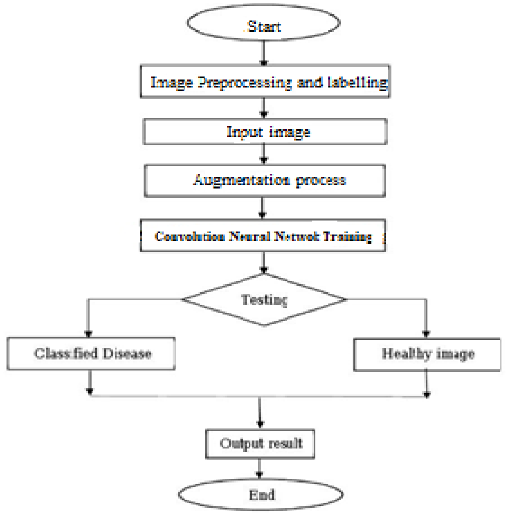

Fig. 2. Flowchart of proposed system

Objectives

MAJOR OBJECTIVES

- The major objectives are listed below:
- Detecting Early blight in potato plant leaf
- Detecting Late blight in potato plant leaf
- Detecting Healthy plant in potato plant leaf

MINOR OBJECTIVES

- The minor objectives are listed below:
- Restricted Dataset Variability
- Domain Shift under Actual Conditions
- Lack of Explainability in Model Decisions
- Single-Disease Focus in Classification
- Limited Ability in Early Disease Detection
- Computational Complexity for Field Deployment
- Ambiguity Among Similar Visual Symptoms
- Inadequate Integration with Farm Management Systems
- Cultivar and Geographic Specificity
- Lack of Standardized Benchmarks and Evaluation
- Quality and Consistency of Data Annotation
- Modeling Temporal Progression
- Sensitivity to Environmental Noise
- Multimodal Data Fusion Deficiency

Methodology/Modules

The simulation platform for the deployment of the potato plant leaf disease detection model is set up with Python 3.12.9 as the main programming language because it supports machine learning and deep learning libraries extensively. Model building utilizes important libraries such as Keras for building and training the CNN architecture, NumPy for numerical computations, OpenCV for image pre-processing and handling, Matplotlib for monitoring training process and evaluation metrics, and Scikit-learn for more data pre-processing, model evaluation, and performance metrics analysis. Training process is speeded up on an NVIDIA CUDA GPU system for optimum computational performance while processing big data and convergence rates for the models. Development of models, simulations, and testing are carried out on Google Colab workspaces for facilitating interactive development processes, onboard access to GPU processors, and quick visualization capabilities.

Implementation of potato plant leaf disease detection with CNN includes three major steps.In first stage, you will have to collect a comprehensive dataset of potato plant leaf images covering various growth stages and possible diseases. In second stage, images were pre-processed by resizing and normalizing them.In the final stage, CNN model is trained, in which model learns about leaf by extracting its features.

To measure the performance of the model, accuracy, precision, recall, and F1-score are used to test the model.

In Prediction of Potato Plant Leaf Disease Detection using CNN, we worked on a publically available data set from Kaggle. It has around 2783 images which are categorized into three categories: Early blight: 1000 images, Late blight: 1067 images, Healthy leaves: 716 images. Based on the data set, we used 80% data set for training and 20% data set for testing. This systematic dataset split guarantees an optimal balance between training, validation, and testing, resulting in a well-generalized CNN model

Architecture

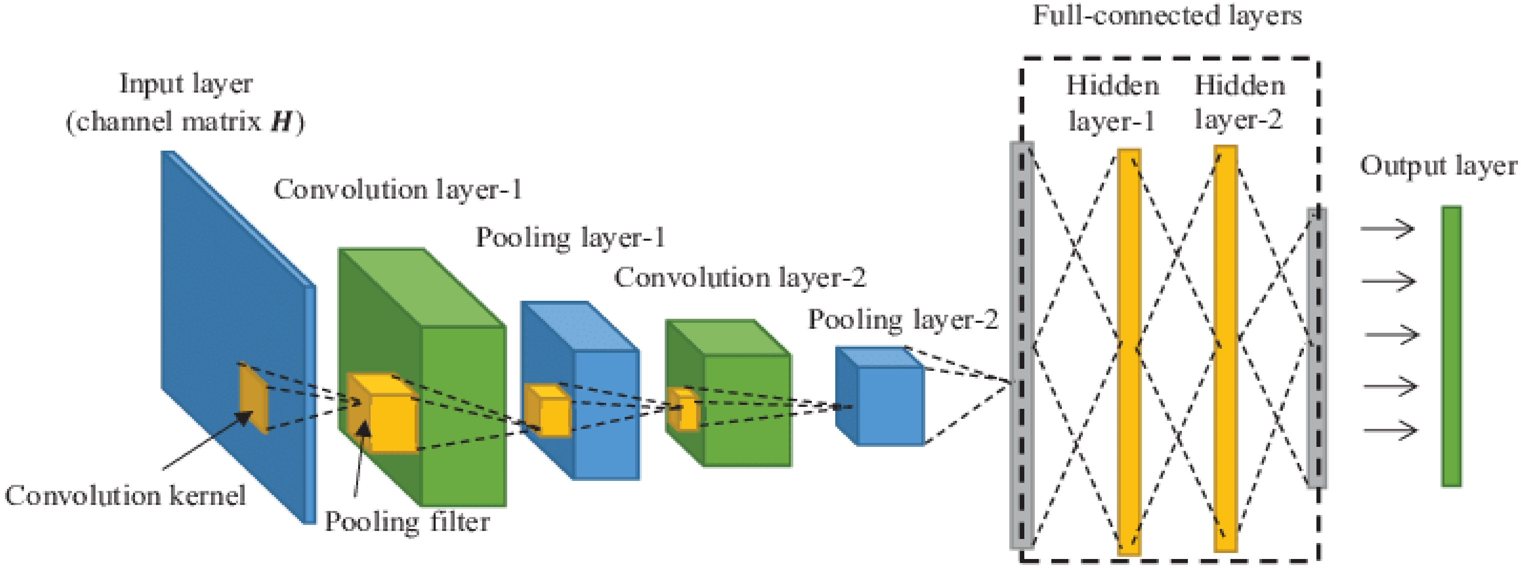

Fig 3. Architecture diagram of CNN

Expected Outcomes

The "Image-Based Potato leaf Disease Detection using Deep Convolutional Neural Networks" project aims to deliver several key outcomes that will enhance crop safety and early disease detection. Here are the expected outcomes of the project:

- Improved Accuracy and Early Detection
- Automation of Disease Monitoring
- Increased Crop Yields and Reduced Losses
- Environmental Sustainability
- Data-Driven Insights for Farmers
- Increased Decision-Making Confidence

GitHub

The Github link provided should have public access permission.

Github Link : [**https://github.com/Adarsha-sg/Image-Based-Potato-leaf-Disease-Detection-using-Deep-Convolutional-Neural-Networks**](https://github.com/Adarsha-sg/Image-Based-Potato-leaf-Disease-Detection-using-Deep-Convolutional-Neural-Networks)

Conclusion

Despite the existence of multiple approaches to automatic or computer vision detection and classification of potato plant leaf diseases, research on this topic has been scarce. Moreover, commercial alternatives are few, except those targeting plant species identification through images. A new way of automatically identifying and detecting leaf diseases of plants from images of leaves was researched through this project using deep learning methods. To a precision level of 90%, the built model was able to identify healthy leaves from three diseases that may be seen by the eye. Based on the great performance level from which it developed, it is now apparent that CNN are suitable for automatic detection and plant identification.

The primary objective of the upcoming project is to design an entire system on the server with a trained model. On top of this, an application on mobile phones displaying detected diseases in potato plant leaf based on images captured in mobile phone. This program will benefit farmers by enabling them to identify and treat plant diseases in time and assist them in making the right decisions while using chemical pesticides, And lastly, work in the future will also focus on extending the application of the model over more land to identify diseases in plants based on aerial shots with drones, alongside CNN used for recognition of object. A potential option for agriculturalist based at rural sites may be to develop an automatic system for prescribing pesticides that would need the stamp of approval from an automated system of disease diagnosis in order to enable the farmers to buy suitable pesticides. Therefore, uncontrolled pesticide availability could be highly limited and lead to their overuse can cause deadly consequences on the environment.

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Project work mapping with SDG

SDG 2: Zero Hunger
Early disease detection of potato leaf infections by using images enhances the potential for early intervention and reducing losses in crops. This leads to improved yields, contributes to food security, and increases agricultural productivity, particularly among smallholder farmers. It contributes to sustainable food systems and fighting hunger through precision agriculture based on deep learning.

SDG 3: Good Health and Well-being
Focused disease control minimizes overuse of pesticides, decreasing farmers', consumers', and the environment's exposure risk to chemicals. This leads to healthier working environments, safer food, and better environmental health. The technology indirectly contributes to well-being by reducing health risks associated with conventional, chemical-based agriculture.

Project work mapping with SDG

SDG 9: Industry, Innovation, and Infrastructure

The integration of deep learning into agriculture revolutionizes conventional practices, encouraging innovation and technological development in rural economies. It encourages digital tool development and smart farm infrastructure. This boosts productivity, aids agritech entrepreneurship, and bridges the digital divide in agricultural enterprises, ensuring sustainable industrial growth.

SDG 12: Responsible Consumption and Production

Application of CNNs for disease detection decreases reliance on indiscriminate use of pesticides through the provision of selective treatment. This decreases chemical runoff and environmental degradation, promoting responsive farm inputs. It facilitates sustainable production systems and optimizes the use of agricultural inputs, in line with the objective of reducing waste and environmental degradation.

SDG 13: Climate Action

Through enhanced crop health and loss minimization, AI-based disease detection minimizes repeated planting and input-driven interventions. This saves water, energy, and fertilizers, reducing agriculture's carbon footprint. It makes climate resilience possible and enables climate-smart agricultural practices that cope with and counter climate change effects.

SDG 15: Life on Land

Precise disease detection reduces infection spreading and minimizes land-clearance demand because of crop loss. It ensures minimal use of chemicals, promotes sustainable land use, and conserves soil diversity and ecosystem balance. The system ensures long-term land health and biodiversity preservation.

Thank You