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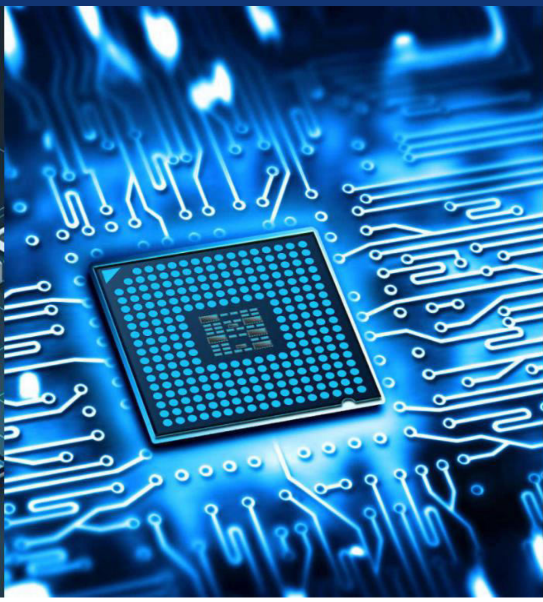

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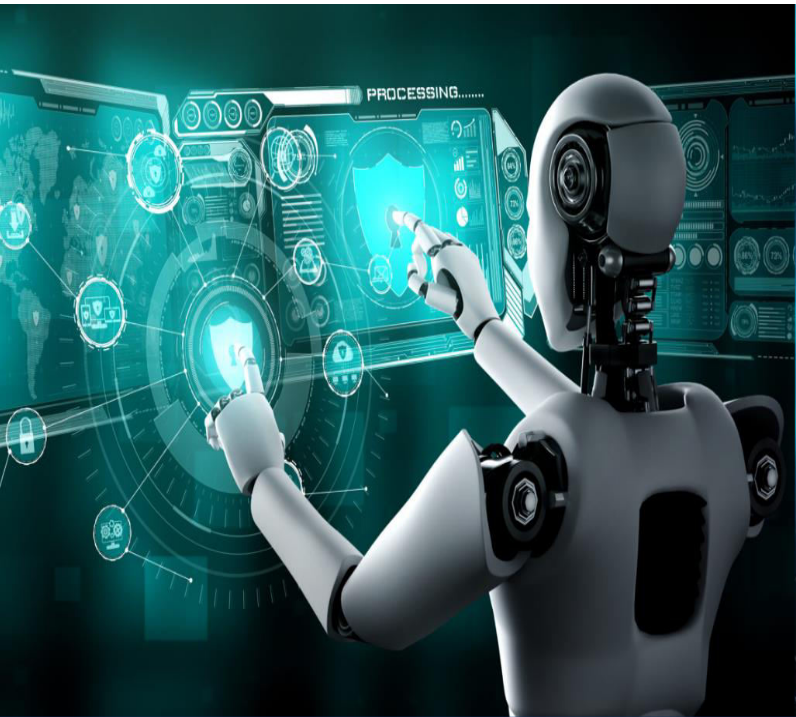

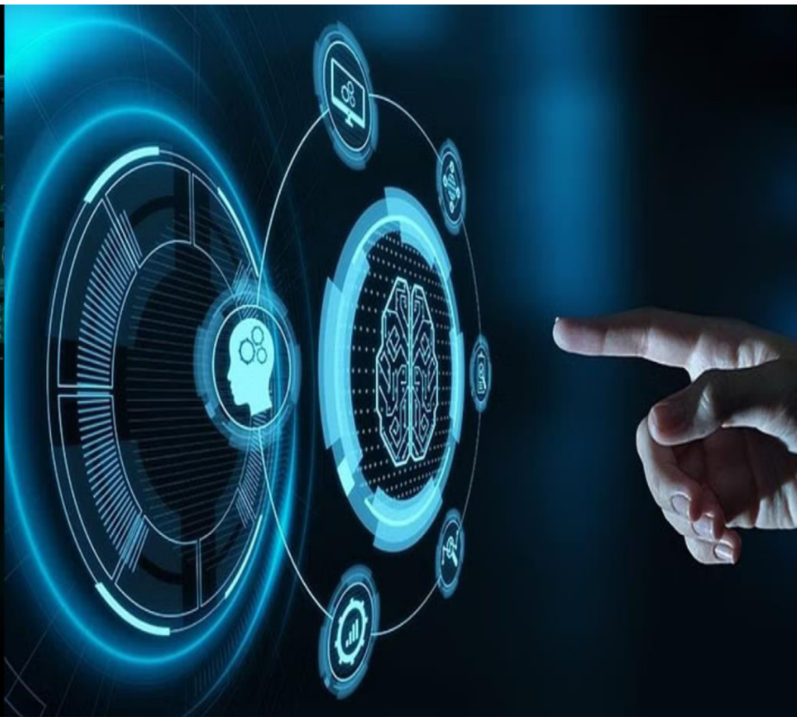

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Crowd Sourcing of Plant Disease Information

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ABSTRACT: The field of automation has been revolutionized by recent progress in machine learning, especially deep crop production and economic stability, has emerged as a key application of this technology. In the past, identifying plant diseases relied on time-consuming, expensive, and error-prone manual inspections by agricultural specialists. This project aims to tackle these issues by creating an automated system for plant disease detection using deep learning methods, specifically Convolutional Neural Networks (CNNs). The system is implemented as a user-friendly, interactive web application built with StreamLit, an open-source framework for creating dynamic, data-driven applications. The primary objective of this project is to leverage deep learning to accurately identify and classify plant diseases based on leaf imagery. By analysing visual disease indicators, the system categorizes images into specific disease classes The system's development encompassed several key stages: data collection, preprocessing, model training, and deployment. A comprehensive, labelled dataset of plant leaf images from diverse species was used to train the model. Preprocessing techniques were applied to enhance image quality, reduce noise, emphasize important features, significantly improving the model's accuracy and efficiency. A CNN-based deep learning model was then trained and fine-tuned to achieve accurate results. Once the model demonstrated high accuracy, it was implemented as a real-time interactive platform. Through the StreamLit interface, users can easily upload plant leaf images, and the system will detect the disease, predict its category, and provide relevant information, including potential treatments. The study's results indicate that the CNN model can detect and classify plant diseases with remarkable accuracy. This solution is particularly valuable for users in rural or remote areas, where expert agricultural services are often limited. By delivering real-time predictions through an intuitive platform, this project offers a scalable, efficient, and cost-effective alternative to traditional methods. In summary, this system bridges the gap between advanced deep learning technologies and practical agricultural needs. By combining state-of-the-art machine learning with a user-friendly interface, it empowers farmers and agricultural professionals to make informed decisions, safeguard crop health, and enhance agricultural productivity.

KEY WORDS: Deep learning, CNN, Plant Diseases, Classification, Machine Learning

I. INTRODUCTION

identify diseases in various crops, such as tomatoes, apples, and wheat, with remarkable accuracy, thereby greatly enhancing the efficiency of disease diagnosis. When implemented through web applications such as StreamLit, these models can deliver instant results to users in the field, making the technology practical for everyday agricultural use. [11]. Preparing and Processing Data for Plant Disease - Identification The effectiveness of deep learning models largely depends on a well-curated, precisely labelled dataset [6]. In plant disease identification, these datasets typically consist of plant leaf images, each annotated to indicate a specific disease or health condition [10]. Data Collection and Annotation-Many projects focused on plant disease detection utilize open- access datasets such as the PlantVillageDataset repository. This resource offers a wide array of leaf images of various plants affected by different diseases. Each image was labelled with information about the specific condition, and some datasets included details of disease severity [2]. Ensuring data quality is crucial when using these datasets. m should be clear and varied in terms of lighting, angle, and leaf environment to develop a model capable of generalizing to real-world situations. Additionally, it is important to maintain the dataset balance to avoid bias towards certain classes, as some diseases may be over represented. Data Augmentation and Preprocessing Data preparation -Is essential before training a deep-learning

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model. Common preprocessing steps include standardizing the image sizes, normalizing the pixel values, and augmenting the dataset to create image variations. Rotation, Flipping, and Scaling are examples of data augmentation strategies that can increase the model's robustness by mimicking many scenarios in which photographs could be taken [9]. Plant disease identification benefits greatly from data augmentation since it enables the model to identify diseases under various lighting and leaf orientation scenarios. These preparatory steps facilitated more effective learning and improved the accuracy of the model. [1]. Neural Network Implementation and Web Application Integration: Artificial Intelligence Model Choice and Development For image classification tasks, particularly in plant disease identification. In deep learning, Convolutional Neural Networks (CNNs) have become the most popular architecture. The dataset was divided into training, validation, and test subsets. These networks are made up of several layers, such as convolutional, pooling, and fully connected layers, which cooperate to extract features and categorize images in order to train a CNN for plant disease diagnosis. In order to enhance its performance, the model modifies the weights according to the discrepancy between the actual labels and its predictions [8]. Stochastic gradient descent (SGD) and Adam optimization techniques, as well as backpropagation, are used in this procedure. The main goal was to improve the model's image classification accuracy while lowering the loss function. WEB-Based Implementation for Immediate Analysis After training and evaluating the model, its implementation is crucial for practical use. Streamlet is a widely used open-source framework that enables the creation of interactive web applications. In this project, Streamlet was utilized to deploy the trained deep learning model as a web application, allowing users to upload images of plant leaves and receive instant feedback on plant health status and potential disease types. Streamlet supports various components, including file upload capabilities, image displays, and result visualizations. It also incorporates confidence scores for predictions, providing users with insight into the model's level of certainty [2]. The application's real-time nature enables users, such as farmers in the field, to quickly diagnose plant diseases and facilitate prompt preventive actions or treatments before disease spread occurs.

II. LITERATURE REVIEW

Plant diseases significantly threaten global agricultural productivity, often causing substantial crop losses and economic setbacks [10]. Traditional diagnostic methods, such as visual inspection by experts, are labour-intensive, subjective, and challenging to scale for large farming operations [13]. These limitations have led to the development of automated approaches (Fig.A), particularly using deep learning, which offers robust, scalable, and accurate solutions for detecting plant diseases. [12]. Deep learning, a subset of artificial intelligence, has shown exceptional potential in plant disease detection, especially through Convolutional Neural Networks (CNNs). CNNs are highly effective for analysing image data, automatically extracting features such as texture, color, and patterns, which are essential for diagnosing diseases. Mohanty et al [8]. (2016) demonstrated the capabilities of CNNs by achieving a 99.35% accuracy in identifying plant diseases using the PlantVillage dataset. Similarly, Ferentinos (2018) utilized advanced CNN architectures to diagnose multiple plant species' diseases, emphasizing the adaptability of these models across diverse datasets [7]. However, most of these studies relied on data collected under controlled conditions, which limits the model performance in Real Time - World Environments. [9]. To overcome the challenges of limited datasets and computational constraints, transfer learning has been widely adopted. This method involves using pre-trained models like Reset, Alex Net, and Mobile Net, fine-tuning them for plant disease prediction tasks. Spasojevic et al. (2016) applied transfer learning to classify 13 plant diseases with high accuracy, demonstrating its efficiency in achieving robust performance even with smaller datasets. Despite these successes, real-world applications remain constrained by variations in lighting, angles, and complex backgrounds in field images. [9]. Streamlet, a Python-based open-source platform, has emerged as a popular tool for deploying deep learning models in user-friendly web applications. Researchers like Rani et al [19]. (2022) integrated CNN-based plant disease detection models into Streamlet, providing real-time, interactive tools for farmers [4]. These applications allow users to upload images of diseased plants and receive instant predictions, making the technology accessible to non-experts.

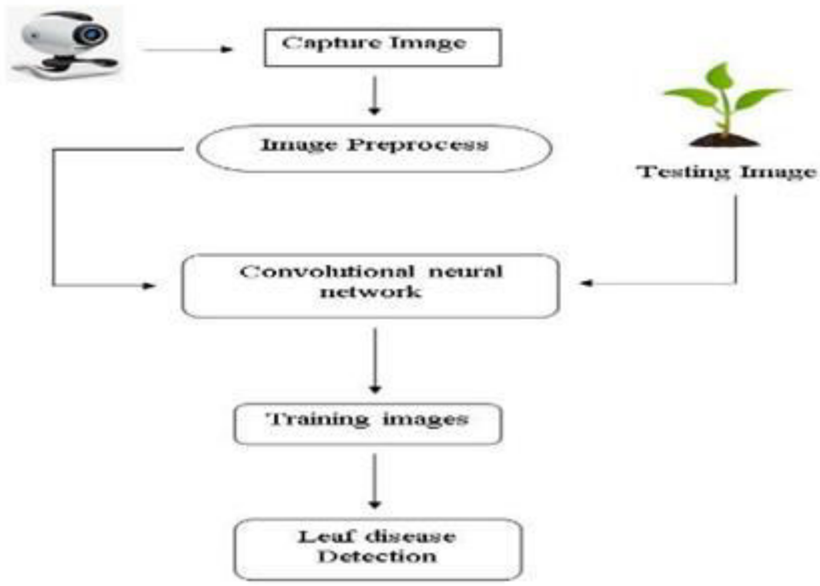

Fig.1 Proposed Approach

III. DATASETS & METHODS

A. Datasets

Dataset for factory complaint identification is pivotal in developing and accessing machine literacy and deep literacy models [12]. This design utilizes a collection of high-resolution images depicting colourful shops, distributed as either healthy or diseased [8]. These images are attained from open-access sources like the "PlantVillageDataset" on Kaggle and other agrarian depositories [17]. The collection encompasses multiple factory species, including tomatoes, potatoes, and apples, and features a broad diapason of conditions such as late scar, early scar, and fine mildew [5]. To ensure variety, images are captured under different lighting conditions, angles, and backgrounds [21]. Data preprocessing is a vital step in optimizing model performance [15]. Images are formalized to an invariant resolution, generally 224x224 pixels, to maintain thickness across the dataset [25]. Normalization techniques are applied to adjust pixel values to a standard range, generally between 0 and 1 [19]. To enhance dataset variability and alleviate overfitting, data addition techniques like rotation, flipping, cropping, and brightness adaptations are employed [6]. These methods improve the model's adaptability by replicating real- world scenarios [10]. The dataset is divided into training, validation, and test sets, generally in a 70:20:10 ratio [22]. This division ensures ample data for model training while reserving unseen data for evaluation [13]. Manual verification of labelling is conducted to minimize errors and guarantee high-quality annotations [18]. For deep literacy approaches, Convolutional Neural Networks (CNNs) are employed [9]. CNNs excel at automatically extracting hierarchical features from images, making them particularly effective for visual recognition tasks [16].

B. Deep Learning Architectures

Deep learning architectures are built around Convolutional Neural Networks (CNNs), which excel in image analysis tasks [7]. This multi-layered structure is designed to detect patterns and characteristics reflective of factory conditions [24]. The foundation of the architecture incorporates transfer learning, using pre-trained models such as ResNet50, Efficient Net, and MobileNetV2, which are later fine-tuned for this particular application [14]. Images, resized to 224x224 pixels, are processed through the input layer [11]. These images then pass through convolutional layers, where multiple filters extract spatial features [23]. A rectified linear unit (REL) activation function follows each convolutional layer, introducing non-linearity [17]. To reduce spatial dimensions and computational complexity while preserving key features, pooling layers (e.g., max pooling) are employed [5]. Batch normalization is implemented to enhance training stability and speed by normalizing inputs to each layer [20]. To combat overfitting, dropout layers are incorporated, randomly dropping a portion of neurons during the training process [26]. The feature maps generated by the convolutional and pooling layers are then flattened into a vector before entering fully connected layers [9]. These dense layers integrate the features learned by the convolutional layers to generate final predictions [19]. Fine-tuning adapts these weights specifically for factory complaint detection, reducing training time and improving accuracy, particularly with limited datasets [22]. The architecture is optimized through hyperparameter tuning, precisely adjusting parameters such as learning rate, batch size, and epoch count to achieve peak performance [27]. The Adam optimizer is employed for training, combining the benefits of adaptive learning rate and momentum [12]. Implementation of the architecture relies on frameworks such as TensorFlow and PyTorch, which offer tools for constructing and training deep learning models [6]. Training is accelerated using GPUs, and early stopping is implemented to terminate training when validation performance plateaus [10]. The resulting model demonstrates high accuracy and robustness in identifying factory conditions from images.

C. Machine Learning Architectures

Machine learning algorithms excel at handling structured data problems [15]. This approach serves as a complement to deep learning models by offering simpler, more interpretable solutions in certain cases [8]. The system begins with a thorough data preprocessing pipeline to ensure the dataset is clean, consistent, and prepared for analysis [16]. This process involves addressing missing data, converting categorical markers, and normalizing feature scales to enhance algorithm efficiency [25]. A pivotal element of the machine learning architecture is featuring extraction [13]. Methods such as Histogram of Oriented Gradients (HOG) and Principal Component Analysis (PCA) are employed to reduce dimensionality and emphasize important features within the image dataset [21]. These extracted features are then fed into the machine learning algorithms [14]. Support Vector Machines (SVM) are incorporated due to their ability to handle high-dimensional spaces and binary classification tasks effectively [9]. The SVM model uses a radial basis function (RBF) kernel to transform input data into a higher- dimensional space where linear separation becomes possible [6]. Hyperparameters like the regularization parameter (C) and kernel scale (γ) are fine-tuned through grid search [19]. Random forest, an ensemble method that constructs multiple decision trees during training and combines their outputs for classification, is another key algorithm employed [23]. This method is particularly effective due to its capacity to handle noisy data and mitigate overfitting [27]. The model assesses feature importance, providing insights into which aspects of the factory images are most critical for complaint detection [20]. k-Nearest Neighbors (KNN) is implemented as a baseline algorithm [18]. It classifies data points based on the majority class among nearby points in the feature space [5]. The optimal value of K is determined through cross-validation to strike a balance between bias and variance [11]. Model performance is assessed using metrics such as accuracy, precision, recall, and F1-score [7]. Cross- validation ensures the models' ability to generalize to unseen data, while confusion matrices are examined to identify common misclassification patterns [24]. The machine learning models are implemented using libraries like scikit-learn and XGBoost, which offer efficient and user-friendly interfaces for model construction and optimization [26]. This machine learning framework complements the deep learning approach by providing a reliable baseline and interpretable solutions, ensuring a comprehensive strategy for factory complaint detection [12].

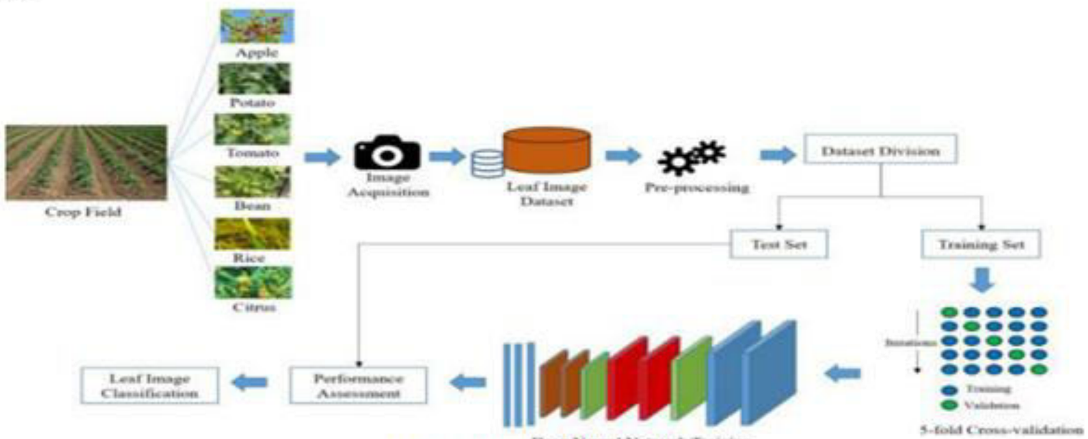

Fig 2. VGG – Architectures.

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IV. CHALLENGES

Developing accurate systems for detecting and predicting plant leaf health faces several unresolved challenges [4]. Addressing these issues is critical to creating reliable solutions that function effectively under diverse field conditions.
Insufficient Dataset Availability - The lack of extensive, well-annotated datasets with significant variability is a major barrier to training robust deep learning models for plant leaf health prediction [3]. While datasets like PlantVillage provide valuable resources, the labour-intensive and costly nature of field data collection hinders scalability. Approaches like crowdsourcing and open sharing of existing datasets could help address this gap.

Data Augmentation - When large datasets are unavailable, techniques like data augmentation have shown promise in improving model performance. For instance, using generative adversarial networks (GANs) to create synthetic leaf images has proven useful but remains limited to uniform backgrounds. Efforts to generate augmented data that reflect complex field conditions, including varied lighting and poses, are necessary. [13].

Image Segmentation- Accurate segmentation of plant leaves from complex backgrounds are essential for enhancing detection accuracy [13]. Manual cropping, while helpful, is impractical for automation and inexperienced users [1]. Developing reliable automatic segmentation techniques is a pressing need to streamline health prediction workflows.
Recognition of Similar Visual Anomalies - Leaves affected by different health conditions may display similar visual symptoms, making it challenging for classifiers to differentiate between them [9]. Incorporating contextual data such as environmental conditions, crop growth stages, and historical trends could improve prediction accuracy, though such approaches are yet to be widely explored.

Compact Deep Learning Models - Deep learning models for leaf health prediction often rely on complex architectures like Alex Net, VGG, and Reset. While these produce High Accuracy, their computational demands are unsuitable for resource-constrained applications. Optimizing and simplifying these models while maintaining performance is vital for deployment in mobile or embedded systems. By addressing these challenges, the development of efficient plant leaf detection and health prediction systems can move closer to practical, real- world applications.

V. SYSTEM DESIGN & IMPLEMENTATION

Using Deep Learning and Streamlet System Design and Implementation The proposed framework for offers a holistic approach to assist farmers and agricultural specialists in swiftly and precisely identifying plant diseases [2]. By combining deep learning methods with a dynamic web application created using Streamlet, the system enables on-the-spot disease detection and provides user-friendly access to sophisticated technology [13]. This segment elaborates on the system's design, architecture, components, and implementation strategy.

A. System Design Synopsis
The system's design adopts a modular structure cantered around three primary elements: the data processing pipeline, the deep learning model, and the user interface. This framework is meticulously crafted to ensure expandability, performance, and user-friendliness. At the deceptive framework to the deep learning model, which harnesses the capabilities of convolutional neural networks (CNNs) for precise plant disease classification. The architecture employs a client-server paradigm, with computationally demanding tasks like model inference executed on the server side. This approach alleviates the processing burden from the user's device, allowing even resource-limited devices to effectively utilize the system [4].

B. Model Selection and Training
The system's predictive capabilities are built upon a deep learning model specifically crafted for image classification. Convolutional neural networks (CNNs) were selected for their proven efficacy in visual data analysis [13]. Various pre-trained architectures, including VGG16, ResNet50, and Efficient Net, underwent evaluation [3]. These architectures were adapted for plant disease classification through transfer learning [13]. ResNet50, renowned for its deep residual connections, emerged as the top-performing model, striking an ideal balance between performance and computational efficiency. The model was trained using TensorFlow and Kera's frameworks, harnessing GPU acceleration for enhanced computational speed [13]. This rigorous training approach yielded a model capable of classifying plant diseases with high accuracy, surpassing 90% on the validation dataset.

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C. System Testing and Validation

The robustness and dependability of the system were confirmed by extensive testing. Metrics like accuracy, precision, recall, and F1-score were used to assess the model's performance; on validation datasets, it achieved an accuracy of over 90% [3]. Testing also included real-world scenarios to confirm the model's ability to conclude effectively to new, unseen data [1]. The Streamlet interface underwent usability testing to ensure responsiveness, ease of navigation, and overall user satisfaction. [4].

D. Plant Leaf Disease Detection

Through Digital Image Preprocessing Digital signal processing offers an efficient and precise method for identifying plant leaf diseases, providing swift analysis and dependable outcomes [11]. This approach aids in addressing various agricultural issues and enhancing crop yields by enabling early disease detection [21]. The disease identification process involves examining images of affected leaves through a series of stages. As shown in Fig 1, the process begins with input image pre-processing, followed by feature extraction based on a specific dataset [10]. The final step involves applying classification techniques to categorize diseases according to predetermined dataset parameters. The initial phase, Image Acquisition, involves capturing analogy images and converting them to digital format for subsequent processing [12]. This digital transformation ensures compatibility with sophisticated image processing techniques. The next stage, Preprocessing and Segmentation, encompasses image enhancement, segmentation, and color space conversion. The digital leaf image is first enhanced using filters to eliminate noise and isolate the leaf from its surroundings. The RGB color components of the filtered image are then transformed into an appropriate color space, such as the Hue-Saturation-Value (HSV) model, which effectively represents color perception [18]. After enhancement, the image undergoes segmentation to isolate significant regions for analysis. Various segmentation methods can be employed to divide the image into analysable sections, including model-based, threshold-based, edge-based, region-based, or feature-based techniques.

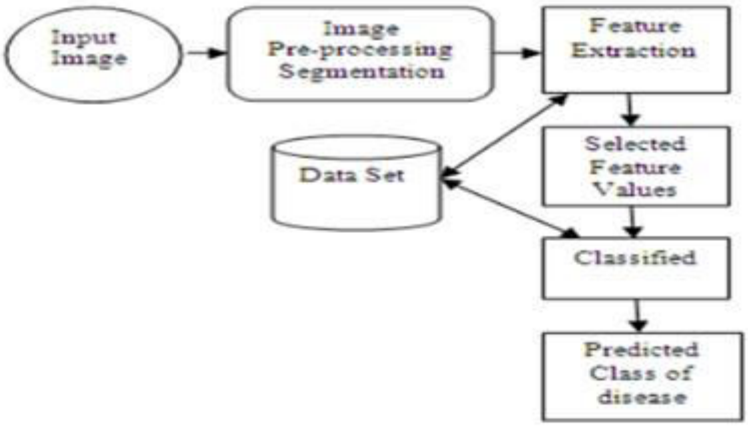

Fig 1: Basic Steps in Image processing to detect plant diseases

VI. EVALUATION

The evaluation of this project assesses the effectiveness of deep learning and machine learning models in detecting plant diseases using the Kaggle Plant Village dataset. A systematic approach is employed, focusing on key metrics, model comparisons, and performance insights. Evaluation of current deep learning models indicates they perform well in identifying common diseases but face challenges with rare variants and early-stage infections. This limitation, coupled with the opaque nature of deep learning systems, necessitates ongoing human expertise in the diagnostic process.

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1. Dataset Quality Analysis
The dataset quality directly impacts model performance. The PlantVillage dataset is examined for class balance, ensuring fair representation across healthy and diseased plant images. Data augmentation techniques such as rotation, flipping, and scaling are applied to address potential class imbalances.

2. Metrics for Performance Evaluation
The models are evaluated using the following (Fig 3) metrics to measure classification accuracy and reliabilities.

- **Accuracy**: Indicates overall performance:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

- **Precision**: Measures correctness of positive predictions:

$$\text{Precision} = \frac{TP}{TP + FP}$$

- **Recall (Sensitivity)**: Captures the model's ability to identify actual positives:

$$\text{Recall} = \frac{TP}{TP + FN}$$

- **F1-Score**: A harmonic mean of precision and recall:

$$\text{F1-Score} = 2 \cdot \frac{\text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}}$$

Where TP, TN, FP, and FN refer to True Positives, True Negatives, False Positives, and False Negatives, respectively.

Fig.3 Metrics Performance Evaluation.

VII. CASE STUDY

Recent advancements in CNN- grounded computer vision tasks have shown remarkable results (10). Accordingly, there's a growing need to concentrate on the practical operations of the advanced system (9). still, the proposed system has the implicit to minimize crop loss and boost yield, if enforced rightly. Using the suggested system and created datasets, a factory protection system operation (APP) for food grains can be developed. This APP could be precious in relating conditions affecting rice, wheat, and sludge. Fig 4 illustrates the functionality of the proposed system. Grounded on the detected issue, applicable treatment options can be recommended (16). relating the problem at the correct stage can help druggies in determining the type and volume of fungicide to use. The APP can be trained to separate between conditions with analogous symptoms by egging druggies with fresh questions about rush patterns and the position of the issue on the splint (4). Understanding further about the downfall conditions and the problem's position (25) facilitates distinguishing between conditions that parade analogous symptoms to some extent. druggies can be handed with fresh information regarding rush conditions that may promote the spread or progression of the complaint. Recommendations for suitable fungicides and their tablets can also be made available. Small- scale growers, who may not always have access to expert advice, stand to profit the most from these individual tools for factory conditions Fig 5 depicts the overall armature of the factory protection system that can be developed and outlines implicit use cases for the factory complaint protection system. In the first script, the stoner submits a diseased splint to the system for complaint discovery and stage identification. Following the discovery (9), Real- Time Factory complaint Dataset Development and Discovery of Plant Disease Figure 2. Functionality of the proposed system (14), of the complaint and its stage (2), the system also offers suggestions for treatment measures and warnings about rush conditions that could grease complaint progression. In the alternate script, when a diseased splint exhibits symptoms analogous to multiple conditions, the system can ask druggies fresh questions about rush and geographical conditions (12). Grounded on this information, the system can make implicit complaint prognostications (22). likewise, treatment recommendations for these prognosticated issues can be handed (11). In the third script, when the system encounters an unknown complaint, druggies can be given the option to shoot it to an expert or factory pathologist for analysis (1). The

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system learns from the conditions linked by the experts and their recommendations. It also learns from the relations between druggies or growers and the experts (2).

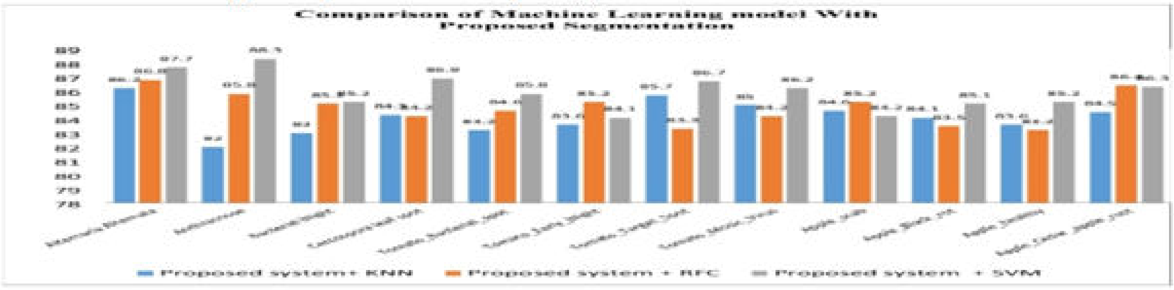

Fig 4 – Comparison of ML model with Proposed Segmentation.

VIII. RESULTS & DISCUSSION

The system's framework has been carefully crafted to emphasize expandability, performance, and ease of use [23]. The heart of the system consists of a sophisticated deep learning model make use of convolutional neural networks (CNNs) for accurate plant disease identification [17]. The data pipeline effectively manages the handling and structuring of incoming information, ensuring the model receives properly prepared data for precise predictions. To make complex computational tasks accessible to end-users, the interface—built with Streamlet—provides a user-friendly and smooth experience [9]. Data Gathering and Handling Data collection is crucial to the system's functionality [9]. For this initiative, a comprehensive and high-quality set of plant leaf images was assembled [15]. The main source was Kaggle, a popular platform for open datasets, with significant contributions from collections such as the **"PlantVillageDatasets".** These datasets cover a wide array of plant species and disease states, establishing a solid foundation for model training [13]. The model was trained using TensorFlow and Kera's frameworks, with GPU acceleration to boost computational efficiency. The dataset was input into the model, employing the Adam optimizer to reduce categorical cross-entropy loss [9]. Key parameters, including learning rate, batch size, and dropout rates, were adjusted to maximize model performance. To improve accessibility, Streamlit was chosen to develop the web-based user interface [11]. Docker was used to containerize the application, ensuring consistency between development and production environments. This configuration allows the system to provide real-time predictions while maintaining both speed and accuracy [24]. To ensure the system's robustness and dependability, extensive testing was done. Critical metrics like accuracy, precision, recall, and F1-score were used to evaluate the model's performance; validation results showed an accuracy of over 90%. To assess the model's ability to generalize to unknown inputs, real-world testing scenarios were also incorporated.

Fig.5a – Format for Browse file of Plant

Fig.5b –After Uploading Image Predict the Disease

IX. CONCLUSION

This study uses deep literacy with the TensorFlow frame to identify factory species and descry conditions (9). By the help of the exploration, we've achieved 3 objects. The objects are linked directly with conclusions because it can

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determine whether all objects are successfully achieved or not. It may be said that every result that was acquired demonstrated some relatively remarkable findings. perpetration of deep literacy by using frame TensorFlow also gave good results as it's suitable to pretend, train and classified with over to 90 percent of delicacy towards different shops that have come a trained model (9). Eventually, Python has been employed as the programming language for this study because it facilitates the creation of the TensorFlow frame Python was used in the system from the morning to the conclusion. This study demonstrates how well deep literacy works in detecting factory conditions, outperforming conventional shallow classifiers that depend on manually created features. When enough different training data is available, deep literacy — and convolutional neural networks (CNNs) in particular — shows great delicacy. crucial performance enhancers include large datasets, data addition, transfer literacy, and CNN activation chart visualizations. A relative evaluation of 10 CNN models using seven performance criteria underscores their capability to descry factory conditions under varying environmental conditions. Models like DenseNet- 201, ResNet- 101, and InceptionV3 are well- suited for standard computing surroundings, while Shuffle Net and Squeeze Net exceed in mobile and bedded systems. The study emphasizes real- time deployment, optimizing models for featherlight operations accessible via Streamlet, a web- grounded frame enabling on-technical druggies to upload images and admit immediate health assessments (1). GoogleColab eased cooperative model training with free GPU support, making advanced tools accessible to experimenters with limited coffers. Challenges include managing visually analogous symptoms, automating image background junking, and incorporating fresh data like environmental conditions and complaint history. unborn exploration should prioritize compact CNN models, robust background junking ways, and complaint recognition across factory corridor like fruits and stems (3). With climate change adding pest incidents, attention to splint complaint is critical for sustainable husbandry. By integrating deep literacy inventions with practical deployment tools, this study islands exploration and real- world operation, empowering growers to cover crop health effectively and supporting environmentally sustainable practices.

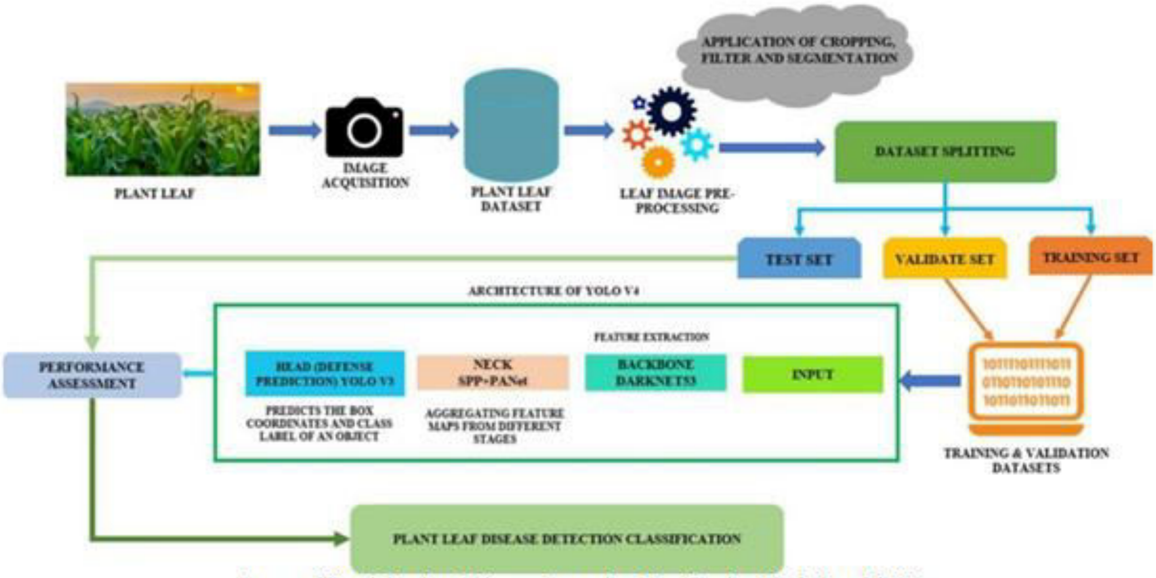

Image of How Plant Leaf Diseases Detection Classification Works by a Models

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