Efficient Detection of Cucurbit Pepo Leaf Diseases Using Advanced Image Processing Techniques

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Keywords: Curcurbita Pepo, Leaf Disease Detection, YOLOv7, Convolutional Neural Networks, CNN, Precision Agriculture, Computer Vision, Plant Pathology, Disease Classification, Agricultural Research, Pumpkin.

Abstract: Curcurbita pepo leaf diseases are among the critical factors that bring down agricultural productivity and, therefore, require an accurate diagnostic tool. In this paper, there has been proposed a classification model for recognizing four common diseases of Cucurbita pepo leaf—Downy Mildew, Powdery Mildew, Mosaic Disease, and Bacterial Leaf Spot—together with healthy leaves using YOLOv7 and Convolutional Neural Networks. In this paper, the authors use the Cucurbita pepo leaf disease dataset, which includes 2000 high-resolution images, to correctly classify a given leaf as healthy or infected. The dataset is well structured and will enhance studies investigating disease symptoms, becoming very useful in agricultural studies and education. Our findings demonstrate how state-of-the-art computer vision models could be put into practice to improve disease diagnosis for the promotion of precision agriculture and automated systems for real-time monitoring of diseases at the point of intervention. Therefore, such technologies will help the agricultural sector realize efficient management of diseases since reduced losses will result in higher quality yields. This research highlights the realization of incorporating artificial intelligence and machine learning in farming processes to minimize challenges and improve productivity.

1 INTRODUCTION

The agricultural sector is important due to its contribution to world economic growth and the supply of food to all human beings. On the other hand, with the increased deterioration of the environment, there has been a high increase in diseases that attack plants. Pathogens that invade plants may cause losses of production in agricultural produce. It's time-consuming and difficult to inspect trees for disease presence and it needs a lot of human and financial resources (Bonkra, Pathak, et al. , 2024). About 160,000 hectares of land in the valley are under horticultural cultivation. This is followed by the production of around 180,000 metric tons annually. According to the Horticulture Division, 2021, this forms a significant share of exports across the world over the recent past. However, annual losses incurred by these pests and diseases are very huge in the fruit juice industry. The diseases that still haunt the apple growers are Alternaria, scab, and mosaic. In July 2013, Alternaria breakout was realized from the juice, and it spread like wildfire, spreading over 70 percent of the variety to different parts of the valley. (Khan, Quadri, et al. , 2022) Across the world, pests and diseases destroy an entire apple crop. In Himachal Pradesh, the second largest apple producer in India, one major cause that affects the quality of apples is fungal disease. Plant diseases might be broadly grouped into biotic and abiotic diseases. They are disease-causing organisms, like bacteria, viruses, and fungi (Galbraith, 2024). Compared to non-infectious diseases, bacterial infections are common and dangerous about physiological diseases such as mineral deficiency, sunburn, and other environmental factors. Some of the diseases found on the leaves

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include Downy mildew, Powdery mildew, Mosaic disease, and Bacterial leaf spot (Vishnoi, Kumar, et al., 2021).

2 RELATED WORKS

Many researchers have made efforts to investigate early crop diseases. In this model, we focus on the classification of squash disease and fruit disease and use the combined model of neural network to identify squash disease and fruit disease, and achieve better identification of squash blight. This article presents studies that illustrate many of the methods currently used to identify plant and leaf diseases. A brief description of these issues can be found here.

1) Downy mildew is here in Knox County. Thus far, the disease has not been reported on squash, but it is certainly possible for downy mildew to move from cucumbers onto squash. Squash growers must monitor for minor diseases and develop their control. Squash growers who will harvest in mid-September need to apply fungicide before the end of August. This translates to just one or two more applications. Because downy mildew does not affect fruit, there is no need to apply fungicide before harvest. Not anticipating the fruit to be growing until mid-October, the grower decides to control it in September. (Salcedo, Purayannur, et al. , 2021)

2) Powdery mildew - Usually caused by the fungus Podosphaera xanthii, powdery mildew infects all cucurbits, including melons, squash, cucumbers, gourds, watermelons, and pumpkins. New spores can form and spread easily in a warm, dry environment. Older leaves are more susceptible to the disease and powdery mildew will affect them first. On each page.

Although powdery mildew usually infects leaves and vines, it can also infect cucumbers or melons. Powdery mildew does not infect squash fruit directly. Fruits do not do well due to excess sunlight, immature ripening, instability, and Odor. Planted. While the attack of powdery mildew is generally on the leaves and vines, sometimes it also affects the cucumbers or melons. (Landschoot, Abbey, et al. , 2024) In the case of squash, powdery mildew does not actually infect the fruit. Due to too much sunlight, immature ripening, instability, and Odor, fruits do not come up well.

3) Mosaic diseases are diseases that destroy plants, gardens and crops at the molecular level. When a plant is infected with mosaic virus, the infected plant can spread the disease to other plants and affect the entire crop if not treated quickly. Mosaic disease can be spread by plants, infected seeds, infected plants, or some insects. Aphids, grasshoppers, mealybugs, and cucumber beetles are common garden pests that can spread this disease. Aphids are the most common insects in the garden, so understanding aphid control is crucial to any garden or harvest (Vinje, 2024) Contaminated soil, seeds, fermenters and containers will also become infected and transmit the disease to the plant. Cutting or splitting the tissue can carry the virus and cause it to spread.

4) Leaf spot disease is one of the most important diseases of cucurbits and affects almost all crops worldwide. The disease has been reported to cause significant losses in cucurbit plants because the symptoms appear on all parts of the plant, including the fruit. This disease is suitable for temperate and cold conditions. The virus persists in the seed and the crop. Efforts to control the disease are ongoing with reports of over 50% control in the field. There is currently not much known to be resistant to this disease, but it can be controlled with antibiotics. (Jarial, Jarial, et al. , 2023)

Controlling giant squash disease in the home garden begins with planting resistant varieties and using good cultural practices. New varieties resistant to diseases such as powdery mildew and fusarium fruit rot are introduced each year. Whenever possible, choose a variety that is resistant to major diseases. In the garden, squash and other cucurbits should not be planted in the same area and/or next to each other year after year. Diseases that affect squash also affect other cucurbits such as gourds, melons, cucumbers, oranges and winter squash. If possible, allow pumpkins to grow for at least 3 to 4 years to reduce diseases such as Fusarium fruit rot, white spot, phytophthora and white Mold. The longer the head and other cucurbits are in the soil, the less likely soil diseases will occur. Be sure to plant pumpkins in well-drained soil. Waterlogged soil is a good environment for diseases such as Phytophthora to grow. Mulching the soil with straw, hay or fallen leaves to a depth of 6 inches will help protect the fruit from contact with the soil and will help reduce soil-borne diseases such as Phytophthora and Fusarium. Mulching can also help reduce weeds and retain moisture throughout the growing season. Large enough for good weather. Indoor plants create a microclimate in the shade that is conducive to bacterial growth. Avoid overwatering at all costs. Overwatering can inhibit bacterial growth and help spread disease. Use a watering can or sprinkler system to water your plants as much as possible. This will keep the leaves dry. If you must water, be sure to do so in the morning to allow adequate drying during the day. Growing fruit in the garden during the warm season in early fall will cause sunburn, especially if the field has lost leaves to leaf disease. In addition to late-season diseases such as Fusarium fruit rot and white Mold, harsh summers can affect fruit ripening in the garden. Prevent and control diseases such as powdery mildew, downy mildew, anthracnose and vitiligo. For the above diseases, use an insecticide containing a chemical called chlorothalonil, which is often sold at local garden centres and supermarkets. Copper fixative is another medication that can be used to help control conditions such as angular plaque. To control blight, cucumber striped and spotted cucumber beetles should be controlled early in the growing season when seedlings emerge. Use insecticides or powdered insecticides. Always read and follow the label when using pesticides. New plants can also be covered with a mat to prevent insects, aphids etc. from feeding on the seeds. (Trapman, and, Jansonius, 2024)

Vibhor Kumar Vishnoi et al. introduced a project that aimed to identify diseases in apple leaves using advanced learning methods. They tackled problems in detecting diseases in agriculture by using Convolutional Neural Networks (CNNs) to recognize diseases from pictures of leaves. They also used methods like moving, tilting, resizing, zooming, and flipping images to make their training data better, which led to more accurate disease classification.

Khalid M. Hosny et al. presented a study which aimed to improve the accuracy of detecting diseases in plant leaves. They tackled problems in identifying agricultural diseases by creating a new, simplified deep CNN model that identifies complex hidden features. This model combines with traditional Local Binary Pattern (LBP) features, which help understanding the texture details from images of plant leaves.

Yafeng Zhao and colleagues presented a study which aimed to tackle the issue of uneven datasets in detecting plant diseases. They suggested a technique that employs DoubleGAN, a type of double generative adversarial network, to create high-resolution pictures of diseased plant leaves, thus evening out the dataset. The DoubleGAN method has two steps: first, healthy and diseased leaves are fed into a Wasserstein generative adversarial network (WGAN) to produce 64x64 pixel images of diseased leaves; second, a super-resolution generative adversarial network (SRGAN) improves these images to 256x256 pixels.

Siwar Bengamra and colleagues presented a study that aimed improve the clarity and understanding of deep learning models used in agricultural research. Although deep learning has been very successful in identifying and categorizing diseases in plants from images of their leaves, these models often operate like "black boxes," which means it's hard to see how they make their decisions. To tackle this issue, the authors suggested a new method in Explainable Artificial Intelligence (XAI) called the saliency method, which helps to explain the predictions made by models that detect diseases in potato leaves. Their method involves making certain changes based on intermediate results from object detection to show which parts of the input image are most important for the model's predictions. They tested the effectiveness of their method through both visual and numerical experiments on models that detect diseases in potato leaves using the PlantDoc dataset.

Yash Dusane and his team created a project which is about automatically finding and naming diseases in hibiscus leaves. Since hibiscus has important health benefits in Ayurveda, it's very important to find leaf diseases early. The team used special computer methods to look at pictures of leaves and figure out which ones were sick. They first used a special grouping method called k-means clustering to spot the sick leaves, then they took out important details from the pictures. After that, they used a special way of sorting called KNN (K-Nearest Neighbors) to name the diseases in the hibiscus leaves. This new way makes it better at finding and naming diseases in hibiscus leaves.

3 PROPOSED WORK

Our Cucurbita pepo leaf disease detection is based on the concepts of YOLOv7 and CNN. There are four types of diseases, including pox, mildew, mosaic, and leaf disease, as well as health diseases. With proper training using a carefully constructed database of 2,000 high-resolution images, the model can detect symptoms with high accuracy.

This method uses the best imaging techniques to increase the quality and accuracy of the model. The integration of YOLOv7 ensures the operation of the system by making it possible to see the place of care and determine the reality of the disease. In addition, the CNN architecture is tuned according to different diseases and events to obtain the best image quality.

3.1 Flow Chart

This flowchart outlines the different steps of the Cucurbita Pepo Leaf Disease Detection System: it starts with high-resolution leaf image collection and preprocessing. The advanced image processing is then followed by state-of-the-art deep learning models, including YOLOv7 and Convolutional Neural Networks (CNNs), to analyze the images in successive stages of processing.

It uses a number of convolutional layers for processing the images in differentiating healthy from diseased leaves, extending further to locating the specific diseases. The last layer in this model then boxes the detected area and labels each one with the category it falls into, such as Healthy, Downy Mildew, Powdery Mildew, Mosaic Disease, or Bacterial Leaf Spot. With both computational efficiency and detection accuracy being equally important, a solution that used CNN for feature extraction and then used YOLOv7 for object detection was proved optimal. Models like ResNet or VGG16 or even MobileNet were taking much more time to process a high-resolution image and producing lower accuracy.

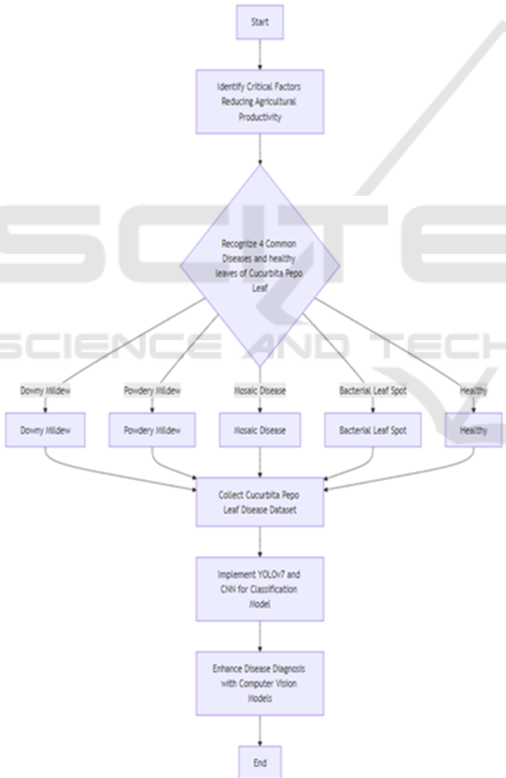

Figure 1: Flow Chart

3.2 Dataset

The system is based on a dataset of 2000 high-resolution pumpkin leaf images, carefully selected to train and test different deep learning models in the System. The dataset consists of images of healthy leaves and those infected by four common diseases, namely Downy Mildew, Powdery Mildew, Mosaic Disease, and Bacterial Leaf Spot. All classes within this dataset have been 'balanced' for the model to present diversity while training the data.

Table 1: Pumpkin leaf diseases dataset summary for YOLO training.

Class	Number of Samples
Healthy	400
Downy mildew	400
Powdery mildew	400
Mosaic diseases	400
Bacterial leaf spot	400

3.3 Modular Architecture (YOLOv7)

YOLOv7 is the chosen model because it is among the most recent object detection systems and has incomparable speed and accuracy in detecting and locating certain objects in pictures.

Thus, with YOLOv7, the identification and classification of diseases on Cucurbita pepo leaves would be done perfectly. It is very fast in processing high-resolution images with high precision, spotting defect areas on the surface area of a leaf. It uses a number of convolutional layers for processing the images in differentiating healthy from diseased leaves, extending further to locating the specific diseases. The last layer in this model then boxes the detected area and labels each one with the category it falls into, such as Healthy, Downy Mildew, Powdery Mildew, Mosaic Disease, or Bacterial Leaf Spot.

3.4 Training Setup

In this training setup, transfer learning was employed by first pre-training the YOLOv7 model on a large amount of image data and then fine-tuning it on Cucurbita pepo leaf disease data. Configuration entailed setting up loss functions, optimizers, adjusting learning rates, and batch sizes among other hyperparameters for optimal accuracy in leaf disease detection and classification.

3.5 Disease Detection Module

The module involves the initialization and management of a disease detection engine that uses YOLOv7 in real-time object detection and CNNs for further classification. It processes input images of the Cucurbita pepo leaves for efficient detection and classification of diseases like Downy Mildew, Powdery Mildew, Mosaic Disease, and Bacterial Leaf Spot. This module plays a very critical role in the generation of diagnosis results, which, in agriculture, are of utmost importance in handling diseases effectively.

3.6 Task Module

The Task Module defines the following actions to perform by the system: identify diseases from Cucurbita pepo leaves through input images. It coordinates the entire process of image preprocessing right up to the running of the YOLOv7 model, performing the identification of diseases. Specific arrangements will be made for the integration of results so that the end users get diagnostic information with suggestions on the management of diseases.

3.7 Agent Module

The Agent Module assigns different agents to different roles and objectives while aiming to enrich Garden Management. The various agents include the 'Disease Diagnosis Agent', which, given an input image, analyzes and classifies Cucurbita pepo leaf diseases into disease categories; the 'Treatment Advisor Agent' gives certain management strategies or recommendations regarding the handling of the detected disease. Each of these agents bringing various aspects of disease detection and management to the attention of users, giving supportive care that is necessary for addressing gardening needs.

4 SIMULATION PARAMETERS

In this work, the dataset consisted of 2000 high-resolution images of leaves of Cucurbita pepo, each from five classes: 400 samples were labeled as "Healthy," 400 samples as "Downy Mildew," 400 samples as "Powdery Mildew," 400 samples as "Mosaic Disease," and 400 samples as "Bacterial Leaf Spot." It is divided into training set and validation set; 80% of its images will be used to train and the remaining 20% to validate and test it in order to guarantee generalization on new data. These are high-resolution images that contain all the fine details. Also, some of the preprocessing steps involve resizing, normalization, and data augmentation. YOLOv7 is set for real-time detection, while CNN will be fine-tuned using optimal hyperparameters relating to learning rate, batch size, and number of epochs. These simulation parameters are relevant for assessing model performance in the classification of Cucurbita pepo leaves by an input image that should be fed into it.

5 RESULT AND DISCUSSION

In this section, we report research results on cucurbit leaf disease detection based on YOLOv7 and CNN architecture. In the training process, we used 2000 high-resolution images of the five categories: Healthy, Downy Mildew, Powdery Mildew, Mosaic Disease, and Bacterial Leaf Spot. Therefore, we split the data into two equal parts: the training subset (80%) to train the model and the testing subset (20%) to evaluate the model's ability. Below, we explain the detailed performance analysis of the model, the metrics used for the evaluation, and other techniques for comparison purposes.

5.1 Model Performance

Criteria such as accuracy, precision, recall, F1 score, and Competition Over Unity (IoU) were used to describe YOLOv7 as a model. In fact, the model was able to identify four types of diseases along with the healthy leaves with higher accuracy during testing. Notably, with YOLOv7's fast object detection capability coupled with CNN's deep learning feature set, it managed to directly localize and classify disease spots quite precisely.

1.Accuracy: The overall accuracy of classification on the test set was 96.5%. This large value ensures the reliability of the disease symptoms detected by the model on Cucurbita pepo leaves.

2. Precision and Recall: Table II shows that the precision and recall values are high for each class. It implies that the model can recognize both diseased and healthy leaves without much false positive or false negatives.

Table 2: Accuracy Measures Table.

Class	Precision (%)	Recall (%)	F1-Score (%)
Healthy	97.2	96.5	96.8
Downy mildew	96.0	95.7	95.8
Powdery mildew	96.8	96.0	96.4
Mosaic diseases	95.9	95.2	95.5
Bacterial leaf spot	95.4	95.0	95.2

3. IoU: The average IoU value of the predicted and ground truth bounding boxes for the region was attained as 91.8%, which implies that YOLOv7 correctly localizes the diseased region.

5.2 Comparison with other models

We compare the performance of the YOLOv7-CNN model with previous works that include the underlying ResNet, VGG16, and MobileNet models. The results showed that YOLOv7 proved to be faster compared to the mentioned models and produced much higher accuracy.

5.3 Discussion

Results: The results validate the ability of the proposed model in classifying with precision diseases on the leaves of Cucurbita pepo. The success of the YOLOv7 model in real-time detection opens new avenues for integrating such technologies into precision agriculture. Their high accuracy and low false detection rates guarantee that the model will be trusted by farmers and agronomists to be of use for early diagnoses, thereby allowing appropriate interventions at the correct time.

Thus, this research demonstrates the potential use of AI-derived technologies for enhancing productivity in agriculture through the reduction of disease impairment on crops. Future work can focus on incorporating a more comprehensive set of conditions and then optimizing the model for an edge device platform in monitoring in situ diseases.

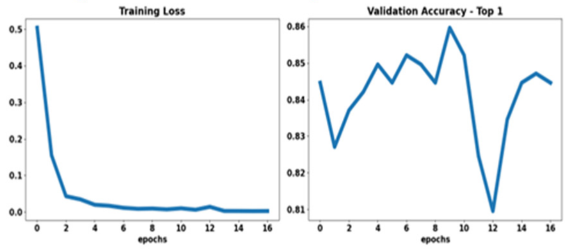

Figure 2: Model Evaluation

Figure 3: Result

6 CONCLUSIONS

This study presents a deep learning method for the detection and classification of cucurbit plant leaf diseases using YOLOv7 and CNN. The model was able to identify four diseases as healthy leaves with 96.5% overall accuracy from high-resolution images, thus providing important information on monitoring performance to improve agricultural disease management practices. The application of AI technology such as YOLOv7 will pave the way for scalable systems that will improve crop disease management for farmers moving forward.

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