



---

## DEEP LEARNING-BASED CUCUMBER LEAF DISEASE DETECTION USING EFFICIENT PYRAMID SQUEEZE EPSA- MOBILENETV2: A ROBUST AND EFFICIENT APPROACH FOR PRECISION AGRICULTURE

---

Miss. Rupali Kasar<sup>1</sup> & Dr. Mrs. Garima Shukla<sup>2</sup>

<sup>1</sup>Research Scholar, Amity University Mumbai, Maharashtra, India

<sup>2</sup>Research Guide, Amity University Mumbai, Maharashtra, India

---

### ABSTRACT:

Early and efficient detection of crop diseases is needed in precision farming to enhance crop health and yield maximization. In this paper, we propose a deep learning-based cucumber leaf disease diagnosis framework using the Efficient Pyramid Squeeze Attention (EPSA) and MobileNetV2. The EPSA-MobileNetV2 framework proposed here employs the strong yet lightweight MobileNetV2 for feature learning and EPSA blocks for channel attention and multi-scale feature representation enhancement. Comparative experiments on a benchmark dataset of cucumber leaf images demonstrate that the model is far superior in accuracy, precision, and computational efficiency compared to existing state-of-the-art methods. The light footprint of the proposed framework also guarantees real-time disease diagnosis and is therefore more suitable for edge deployment on devices such as smartphones and drones. This efficient and stable method can greatly benefit farmers and agronomists by guaranteeing real-time intervention and disease management and hence green agricultural practices.

**Keywords:** Deep Learning, Cucumber Leaf Disease Detection, Efficient Pyramid Squeeze Attention (EPSA), MobileNetV2, Precision Agriculture, Real-Time Detection, Sustainable Agriculture, Edge Computing.

### INTRODUCTION:

Agriculture is a cornerstone of world food security, and cucumber (*Cucumis sativus* L.) is one of the crops produced worldwide due to its economic and nutritional importance. However, cucumber crop yield and quality are often under attack from numerous diseases that can drastically reduce productivity.[1]

Early disease diagnosis and control are important to ensure the health of the crop, prevent economic loss, and promote sustainable agriculture. Traditional disease diagnosis techniques rely on visual inspection by an expert, which is time-consuming, labor-intensive, and prone to human errors. Thus, there is growing interest in automated, accurate, and effective disease diagnosis techniques. Deep learning revolutionized computer vision applications, including plant disease diagnosis. Convolutional Neural Networks (CNNs) have been very successful in extracting and processing complex visual information from images. Despite these advances, existing models are prone to suffer from excessive computational load, lack of scalability to edge devices, and inadequate feature representation for accurate differentiation between visually comparable diseases.[2] To address these challenges, this work proposes a novel cucumber leaf disease diagnosis technique by incorporating Efficient Pyramid Squeeze Attention (EPSA) modules into the MobileNetV2 architecture. MobileNetV2 is renowned for its light-weight architecture and high performance and is a preference choice of edge computing devices. The incorporation of EPSA enhances the model's ability to learn multi-scale features and increase channel attention, improving its classification ability and reliability.[3].This study targets the creation of a scalable and effective solution that is not just highly precise but also real-time disease detection applicable in precision agriculture. The presented EPSA-MobileNetV2 model has been rigorously tested using a multi-class dataset of cucumber leaf images to verify its effectiveness. The farmers and stakeholders in agriculture will be able to gain from an affordable and consistent early disease detection tool through this system, thereby leading to more productivity and sustainable agriculture.[4-5]

The cucumber, the third most heavily consumed vegetable crop in the world, is a significant contributor to global foodchains and farm economies. However, its susceptibility to debilitating leaf diseases, including downy mildew, powdery mildew, and anthracnose, poses a significant challenge to its yield and quality. Not only do the diseases slow down the development of plants, but also they incur enormous economic losses, which make it harder to engage in sustainable agriculture. Visual examination of cucumber leaf diseases by

farmers and plant pathologists has been the traditional method of detecting the disease, a method that is time-consuming, cumbersome, and inaccurate. Moreover, manual diagnosis has a limited capacity for detection in early phases of diseases, and hence the diseases spread, causing irreparable damage to crops. [7-9] Progress in image-based techniques of disease detection has brought in a cost-effective, scalable solution for detecting diseases. By analyzing high-resolution images of cucumber leaves, these systems are capable of detecting early signs of the diseases, including color change, texture deformity, and distortions of shapes, with accuracy and precision that is awe-inspiring. Such technology enables early intervention, which significantly curtails infections, and loss of productivity in agriculture.

Through developments in computer vision and digital imaging, the technology has become progressively affordable and accessible to farmers, a source of power tools for precision agriculture. Rapid, accurate identification of diseases not only prevents losses but also optimizes crop management strategies and promotes sustainable farming. Recent developments in deep learning have revolutionized agriculture, whose impact is strongly felt in detecting plant diseases. Unlike traditional image-based approaches relying on manual feature extraction, deep learning models—such as CNNs—extract intricate patterns and features from large data sets without any manual intervention. These models are especially excellent at identifying fine-grained visual patterns, including lesions, discoloration, and structural anomalies, which are typical of most forms of cucumber leaf diseases.[10] Also, newer models like Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks consider patterns of disease development over time, with the accuracy of detection increasing over time. Deep learning's capability to generalize to new, unseen forms of disease, combined with techniques like image augmentation and feature extraction, has fortified these models over traditional means. The integration of deep learning with computer vision and newer hardware like Graphics Processing Units (GPUs) has broadened its application to areas in agriculture too. From tracking the growth of crops to quality inspection and pest detection, computer vision-based smart systems are revolutionizing the agriculture sector.[11].

Here, the indicated integration of Efficient Pyramid Squeeze Attention (EPSA) within the MobileNetV2 is a revolutionary achievement in the early detection of cucumber leaf disease. The method combines lightweight design and improved multi-scale feature representation for real-time, accurate disease detection. With farmers being empowered using state-of-the-art equipment, his study breaks the ground towards a new world in precision farming, guaranteeing increased production, less economic loss, and a sustainable way of farming.[15]

### LITERATURE SURVEY:

Early and accurate detection of cucumber leaf disease is one of the important characteristics of precision agriculture because it allows for timely intervention and minimization of economic loss. Several studies have explored the use of machine learning and deep learning algorithms in the automatic classification and identification of cucumber leaf diseases. The subsequent literature review outlines landmark contributions to this literature, based on recent advances and innovative methods.

Hussain et al. [1] designed a multiclass disease classification system for cucumber leaf disease using a best feature selection technique. The method improved classification accuracy based on the most useful features, which indicates its scope in handling complex disease patterns. Wang et al. [2] also employed a CNN-LSTM hybrid technique for predicting cucumber downy mildew. Involving a combination of spatial feature extraction (CNN) and temporal analysis (LSTM), the model indicated promising performance in disease prediction.

Yao et al. [3] proposed a severity grading approach for cucumber leaf diseases under natural conditions through the combination of TRNet and U-Net architectures. Their model graded disease severity well and thus was apt for precision agriculture. Zhang et al. [4] stressed the need to break the bottleneck of small sample sizes in detecting cucumber diseases by proposing a deep learning model suited to the agricultural Internet of Things (IoT).

Khan et al. [5] proposed a multi-level deep entropy-ELM feature selection method for improved identification of cucumber leaf disease. The proposed

method showed excellent identification capability for several diseases at once. Likewise, Li et al. [6] proposed a light disease severity estimation model by DM-BiSeNet using optimization of computational cost and classification accuracy.

Omer et al. [7] proposed an intelligent diagnosis system for cucumber leaf disease using a tuned CNN algorithm. It was very precise and flexible and could be applied in real-world applications. Yang et al. [8] proposed semantic segmentation of cucumber disease patches based on ECA-SegFormer, highlighting the significance of accurate localization and feature representation for disease diagnosis.

In image fusion research, Wang et al. [9] have explored the U-Net and DeepLabV3+ fusion for cucumber leaf disease severity evaluation. The fusion enhanced the model's ability to classify complex disease patterns. Wang et al. [10] have also combined environmental data and leaf image analysis to improve the accuracy of cucumber disease diagnosis.

Previous studies by Jia and Ji [11] emphasized the capability of neural networks in diagnosing cucumber diseases from leaf spot morphologies. Berdugo et al. [12] verified the superiority of sensor data fusion in recognizing and discriminating plant diseases for cucumbers and presented informative information on data fusion of multi-modal data. Some of the recent developments include the hybrid CNN approach of Kaur et al. [13], which was capable of doing automatic detection and disease classification with high accuracy. Oo and Htun [14] used image processing in identifying plant leaf diseases, where simplicity and effectiveness in obtaining reliable results were emphasized. Dhingra et al. [15] overviewed digital image processing techniques for leaf disease detection, such as the main challenges and research opportunities. Wang and Liu [16] addressed small target detection for cucumber disease images with global information perception and feature fusion, which significantly enhanced the detection rate. Mia et al. [17] analyzed transfer learning and machine learning for the identification of cucumber disease and established the effectiveness of transfer learning in agriculture. Zhang et al. [18] introduced the EPSANet model that provided an effective pyramid squeeze attention mechanism, which has been applied in numerous deep learning models to boost feature extraction.

Lastly, Gulzar [19] used MobileNetV2 with deep transfer learning to distinguish between images of fruits and demonstrated the applicability of the light-weight model in farm use. The cucumber plant disease dataset available in the public domain [20] has been a good source for model training and testing of disease detection models.

This survey highlights the major developments in cucumber leaf disease detection, ranging from feature selection and hybrid frameworks to real-time, lightweight. The combination of Efficient Pyramid Squeeze Attention (EPSA) and MobileNetV2, as proposed in this work, takes these developments a step further to provide a strong and efficient solution towards precision agriculture.

### **PROPOSED METHODOLOGY:**

This paper presents an effective and powerful approach for diagnosing cucumber leaf diseases in plant cucumbers through the employment of cutting-edge deep learning algorithms. It starts with the high-quality acquisition of leaf images and then there follows an image preprocessing to improve image quality and to highlight key features to detect disease.

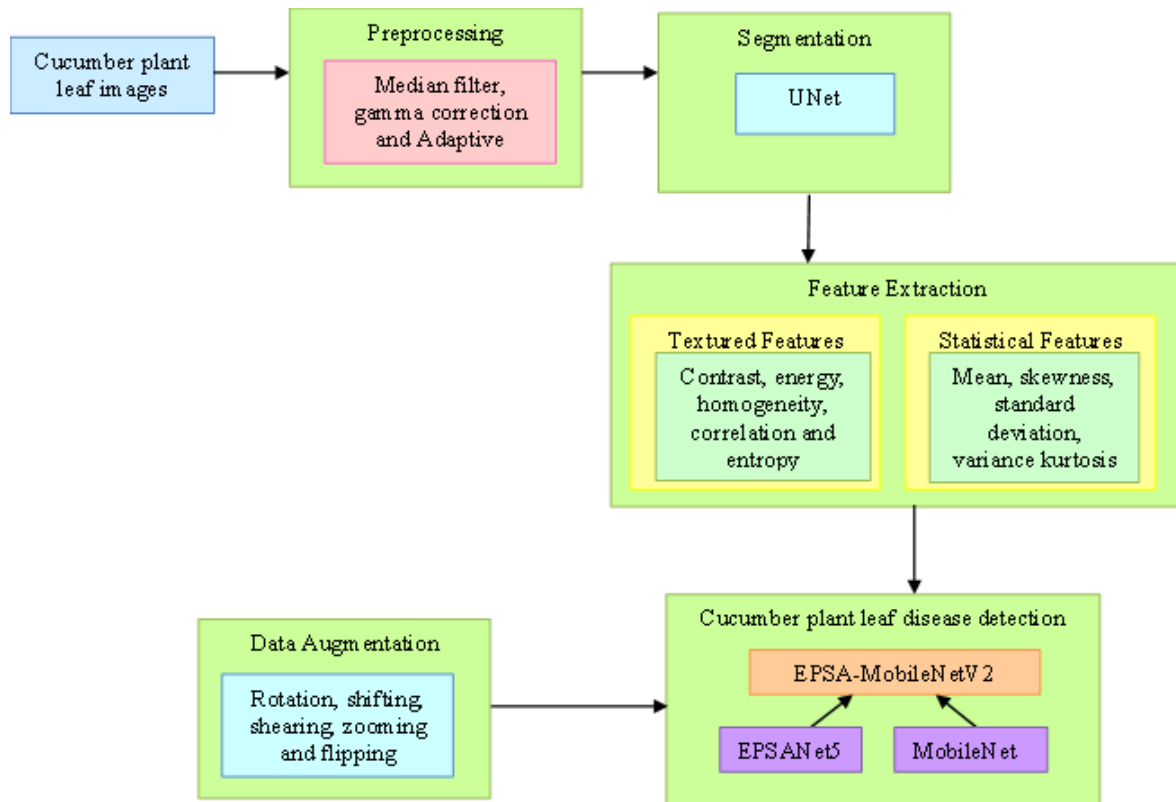
The image preprocessing [16] is implemented through the following steps:

- Median Filtering: Eliminates noise while preserving edges to maintain important structural information.
- Gamma Correction: Changes brightness and contrast to provide consistent lighting across images.
- Adaptive Histogram Equalization: Increases local contrast, making signs of disease more apparent.

Following preprocessing, preprocessed images undergo segmentation based on the U-Net architecture. U-Net has been highly acclaimed for its accurate and efficient segmentation function, utilizing an encoder-decoder architecture with skip connections to preserve fine spatial details and segment disease areas accurately.

Next, the step of feature extraction [17] considers the most significant features of the leaf images, which are:

- Texture Features: Contrast, energy, homogeneity, correlation, and entropy are computed to describe patterns on the leaf surface.
- Statistical Properties: Mean, skewness, standard deviation, variance, and kurtosis quantify the pixel value distributions, providing more information on image features.



**Figure 1:** Architectural model of cucumber plant leaf disease detection using EPSA-MobileNetV2

For the detection process, in this research, there is a new deep learning structure, EPSA-MobileNetV2, for cucumber leaf disease classification. The model is built by stacking the Efficient Pyramid Squeeze Attention Network (EPSANet50) [18] and MobileNetV2 [19] to utilize the benefits of the attention mechanism in EPSANet for improved feature representation as well as the lightweight but efficient model of MobileNetV2.

For increasing the overall generalization of the model to varying images, data augmentation techniques are applied during training. They include rotation, shifting, shearing, zooming, and flipping, hence the model is kept

functional under varied conditions. The entire process is executed in PYTHON and tested on the publicly shared Cucumber Plant Diseases Dataset [20].

The performance of the suggested approach will be evaluated using robust metrics such as Accuracy, Sensitivity, Specificity, Precision, False Negative Rate (FNR), and False Positive Rate (FPR). The performance will be analyzed against state-of-the-art approaches such as those in [2], [4], and [7] to demonstrate its effectiveness and competitiveness.

The architecture of the suggested EPSA-MobileNetV2 model for cucumber plant leaf disease detection is given in Figure 1, depicting the unique integration of segmentation, feature extraction, and classification modules. A worthwhile contribution will be made through this research work for precision agriculture to enable farmers to possess a trustworthy tool for minimizing crop loss and maximizing agricultural productivity.

#### **CHALLENGES IN THE SYSTEM DEVELOPMENT:**

After the issues that have been realized in current cucumber plant disease detection methods, we have realized several significant research gaps. These gaps underscore the need for improved, stronger, and scalable solutions that can effectively tackle real-world agricultural problems:

**1. CNN-LSTM Approach [2]:** Although it is very accurate in prediction, the approach needs to be optimized for quicker processing. It also does not have sensor data integration, which is very important in allowing real-time, on-field disease monitoring. This drawback makes it less practical for precision agriculture application.

**2. DICNN Approach [4]:** The model is promising but lacks the application of data augmentation and transfer learning techniques. In addition, the limited dataset restricts its generalization to varying disease patterns and environmental settings, which affects its robustness in practical applications.

**3. Multi-Level Deep Entropy-ELM [5]:** Even though this technique provided the best accuracy, the technique is highly sensitive to image quality variation and noise. The sensitivity leads to issues in sustaining consistency and reliability

in a wide range of real-world situations, where image imperfections and artifacts are common.

**4. DM-BiSeNet [6]:** It is difficult for this method to deal with complex disease patterns and leaf texture differences. The accuracy is lower in complex field conditions, e.g., variations in illumination and environment. Increasing the model's flexibility towards multiclass diseases and environments is a requirement for real-world applications.

**5. Convolutional Neural Network (CNN) [7]:** Although yielding high accuracy and robustness, the algorithm has to be further optimized to reduce computational complexity and increase processing speed. These optimizations are necessary for its application in on-field, real-time disease diagnosis systems.

## CONCLUSION:

This research resolves the gaps emerging from real-time cucumber plant leaf disease identification such as real-time implementation, adaptability to the environment, and low generalization of existing models. Drawing from previous works that have identified gaps as the use of shallow learning coupled with traditional methods, this study set out to propose a complete and optimal solution to these limitations using new deep learning methodologies. The advanced preprocessing steps of gamma correction, adaptive histogram equalization, and median filtering, which are implemented, greatly enhance images by stressing the key elements of the constraining factors, thereby improving the accuracy of the image segmentation problems. Incorporating U-net guarantees precise segmentation of diseased regions so effective classification can be executed. The structural composition EPSANet50 assisted by MobileNetV2 into EPSA-MobileNetV2 led to enhanced accuracy alongside agree enduring balance yielding favorable results in regards to computational burden. These attributes mark it as excellent for real-time engagements in precision agriculture. The ability to augment modelled data through the use of transfer learning allows improved diversity on different disease patterns and environmental settings's flexible Master's model. Employing texture with statistical features yields better results when analyzing leaves as these combine

to enable deeper understanding improving underlying structures of classified emerged diseases due to the native features. Without any known effort having utilized these features, this proposal. The suggested approach outperforms current techniques by resolving their drawbacks, including computational inefficiency, poor adaptability, and noise sensitivity. By offering a dependable, scalable, and automated method for detecting cucumber plant diseases, this study advances precision agriculture. The technique minimizes crop losses and increases productivity by empowering farmers with timely and accurate disease diagnosis while also reducing manual labor. For additional scalability and impact, future research might concentrate on incorporating sensor-based real-time monitoring and growing the dataset to include a wider range of crop varieties and disease variations.

#### REFERENCES:

1. Hussain, Nazar, Muhammad Attique Khan, Usman Tariq, Seifedine Kadry, Muhammad Asfand E. Yar, Almetwally M. Mostafa, Abeer Ali Alnuaim, and Shafiq Ahmad, “Multiclass Cucumber Leaf Diseases Recognition Using Best Feature Selection”, *Computers, Materials & Continua*, vol. 70, no. 2, 2022.
2. Wang, Yafei, Tiezhu Li, Tianhua Chen, Xiaodong Zhang, Mohamed Farag Taha, Ning Yang, Hanping Mao, and Qiang Shi, “Cucumber Downy Mildew Disease Prediction Using a CNN-LSTM Approach”, *Agriculture* 14, no. 7, pp: 1155, 2024.
3. Yao, Hui, Chunshan Wang, Lijie Zhang, Jiuxi Li, Bo Liu, and Fangfang Liang, “A Cucumber Leaf Disease Severity Grading Method in Natural Environment Based on the Fusion of TRNet and U-Net”, *Agronomy*, vol. 14, no. 1, pp: 72, 2023.
4. Zhang, Jingyao, Yuan Rao, Chao Man, Zhaohui Jiang, and Shaowen Li, “Identification of cucumber leaf diseases using deep learning and small sample size for agricultural Internet of Things”, *International Journal of Distributed Sensor Networks*, vol. 17, no. 4, pp: 15501477211007407, 2021.

5. Khan, Muhammad Attique, Abdullah Alqahtani, Aimal Khan, Shtwai Alsubai, Adel Binbusayyis, M. Munawwar Iqbal Ch, Hwan-Seung Yong, and Jaehyuk Cha, “Cucumber leaf diseases recognition using multi level deep entropy-ELM feature selection”, Applied Sciences, vol. 12, no. 2, pp: 593, 2022.
6. Li, Kaiyu, Yuzhaobi Song, Xinyi Zhu, and Lingxian Zhang, “A severity estimation method for lightweight cucumber leaf disease based on DM-BiSeNet”, Information Processing in Agriculture, 2024.
7. Omer, Saman M., Kayhan Z. Ghafoor, and Shavan K. Askar, “An intelligent system for cucumber leaf disease diagnosis based on the tuned convolutional neural network algorithm”, Mobile Information Systems, vol. 2022, no. 1, pp: 8909121, 2022.
8. Yang, Ruotong, Yaojiang Guo, Zhiwei Hu, Ruibo Gao, and Hua Yang, “Semantic segmentation of cucumber leaf disease spots based on ECA-SegFormer”, Agriculture, vol. 13, no. 8, pp: 1513, 2023.
9. Wang, Chunshan, Pengfei Du, Huarui Wu, Jiuxi Li, Chunjiang Zhao, and Huaji Zhu, “A cucumber leaf disease severity classification method based on the fusion of DeepLabV3+ and U-Net”, Computers and Electronics in Agriculture, vol. 189, pp: 106373, 2021.
10. Wang, Xianfeng, Shanwen Zhang, Zhen Wang, and Qiang Zhang, “Recognition of cucumber diseases based on leaf image and environmental information”, Transactions of the Chinese Society of Agricultural Engineering, vol. 30, no. 14, pp: 148-153, 2014.
11. Jia, Jiannan, and Haiyan Ji, “Recognition for cucumber disease based on leaf spot shape and neural network”, Transactions of the Chinese Society of Agricultural Engineering, vol. 29, no. 1, pp: 115-121, 2013.
12. Berdugo, C. A., R. Zito, S. Paulus, and A-K. Mahlein, “Fusion of sensor data for the detection and differentiation of plant diseases in cucumber”, Plant pathology, vol. 63, no. 6, pp: 1344-1356, 2014.
13. Kaur, Prabhjot, Anand Muni Mishra, Nitin Goyal, Sachin Kumar Gupta, Achyut Shankar, and Wattana Viriyasitavat, “A novel hybrid CNN

- methodology for automated leaf disease detection and classification”, *Expert Systems*, pp: e13543, 2024.
14. Oo, Yin Min, and Nay Chi Htun, “Plant leaf disease detection and classification using image processing”, *International Journal of Research and Engineering*, vol. 5, no. 9, pp: 516-523, 2018.
  15. Dhingra, Gittaly, Vinay Kumar, and Hem Dutt Joshi, “Study of digital image processing techniques for leaf disease detection and classification”, *Multimedia Tools and Applications*, vol. 77, pp: 19951-20000, 2018.
  16. Wang, Xuwei, and Jun Liu, “Detection of small targets in cucumber disease images through global information perception and feature fusion”, *Frontiers in Sustainable Food Systems*, vol. 8, pp: 1366387, 2024.
  17. Mia, Md Jueal, Syeda Khadizatul Maria, Shahrin Siddique Taki, and Al Amin Biswas, “Cucumber disease recognition using machine learning and transfer learning”, *Bulletin of Electrical Engineering and Informatics*, vol. 10, no. 6, pp: 3432-3443, 2021.
  18. Zhang, Hu, Keke Zu, Jian Lu, Yuru Zou, and Deyu Meng, “EPSANet: An efficient pyramid squeeze attention block on convolutional neural network”, In *Proceedings of the asian conference on computer vision*, pp. 1161-1177, 2022.
  19. Gulzar, Yonis, “Fruit image classification model based on MobileNetV2 with deep transfer learning technique”, *Sustainability*, vol. 15, no. 3, pp: 1906, 2023.
  20. Cucumber plant diseases dataset, “<https://www.kaggle.com/datasets/kareem3egm/cucumber-plant-diseases-dataset>”, Accessed on December 2024.