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Image-Based Strawberry Leaves Classification Using Deep Convolutional Neural Networks

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Abstract: *Strawberry is a widely cultivated crop across the globe and plays a vital role in the agricultural economy. However, strawberry plants are susceptible to a range of diseases, especially those affecting the leaves. Early detection of such diseases is critical for successful intervention and maximizing yield. With the rise of deep learning, particularly convolutional neural networks (CNNs), image-based disease detection has become a promising area of research. In this study, we present a CNN model for classifying strawberry leaf images into four distinct categories, including healthy and diseased samples. Using a dataset of 3,742 images, the model was trained and evaluated through structured experiments. Results show that the model achieved a validation accuracy of 87.5%, confirming its effectiveness. Visual analyses further demonstrate the learning process and features extracted by the model. This research is intended to support future development of automated tools and mobile applications in the field of precision agriculture.*

Keywords: Deep Learning, Convolutional Neural Networks, Strawberry Leaf, Image Classification, Plant Diseases, Smart Agriculture

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1. Introduction

Agriculture has always been the backbone of human survival. With the world population growing rapidly, the need for reliable and sustainable food sources has intensified. Strawberries are not only popular fruits but also an important economic crop. However, diseases that affect strawberry leaves can significantly hinder productivity and reduce crop quality. Traditional methods for identifying plant diseases involve visual inspection, which is labor-intensive and subject to human error.

In recent years, deep learning has emerged as a transformative tool in computer vision tasks. Specifically, convolutional neural networks (CNNs) have demonstrated superior performance in image classification. When applied to agriculture, CNNs offer the ability to automate disease detection with high accuracy. This study explores the application of CNNs for classifying strawberry leaf images, thus supporting farmers and agriculturalists with a powerful diagnostic tool.

The novelty of this work lies in applying a CNN trained exclusively on strawberry leaves, which have unique visual features compared to other crops. By addressing this specific classification task, we contribute to the body of research on crop-specific diagnostic AI tools.

2. Study Objectives

- - To evaluate the effectiveness of CNNs in detecting strawberry leaf diseases through image classification.
- - To create a CNN model capable of distinguishing between healthy and diseased leaves across four categories.
- - To visualize the model's learning process through intermediate activations and performance graphs.
- - To build a foundation for a future mobile-based diagnostic application.
- - To analyze how different experimental settings influence training performance and model generalization.

3. Dataset Description

The dataset used in this research consists of 3,742 labeled images of strawberry leaves. The data were divided into three main sets:

- - Training set: 2,460 images
- - Validation set: 453 images
- - Test set: 829 images

Each image was resized to 150x150 pixels and categorized into one of four classes:

- - Healthy

- - Strawberry Wedge
- - Strawberry - Copy
- - Strawberry Wedge - Copy

The dataset was manually curated and structured using a custom directory split. Each class had an approximately balanced number of samples to avoid bias during training.

All images were collected under controlled conditions and augmented through flipping and brightness adjustments to simulate a variety of real-world scenarios.

4. Convolutional Neural Networks: An Overview

Convolutional Neural Networks (CNNs) are inspired by the visual cortex of animals and have revolutionized image processing. Unlike traditional fully connected networks, CNNs apply convolution operations to input images to detect spatial hierarchies. They consist of multiple layers, including:

- - Convolutional layers
- - Pooling layers (max or average)
- - Activation functions (ReLU)
- - Fully connected layers
- - Softmax for classification

CNNs reduce the need for manual feature engineering, allowing the network to learn relevant features directly from raw image data.

This layer-wise abstraction allows CNNs to capture edges, textures, shapes, and high-level features relevant for classification. Their success across domains like medical imaging, self-driving cars, and facial recognition proves their power and adaptability.

5. Methodology

The methodology followed includes:

1. Dataset loading and preprocessing (resizing, normalization)
2. CNN model design with four convolutional layers and ReLU activations
3. MaxPooling after each convolution to reduce spatial dimensions
4. A Flatten layer followed by a fully connected Dense layer with 512 units
5. An output Dense layer with 4 neurons (Softmax)
6. Compilation with categorical cross-entropy loss and Adam optimizer
7. Training over 100 epochs with validation monitoring
8. Evaluation on test data

Each stage was implemented using TensorFlow and Keras on Google Colab, with GPU acceleration enabled.

6. Model Architecture

The proposed CNN model consists of:

- - Conv2D(32 filters, 3x3) + MaxPooling2D
- - Conv2D(64 filters, 3x3) + MaxPooling2D
- - Conv2D(128 filters, 3x3) + MaxPooling2D
- - Conv2D(128 filters, 3x3) + MaxPooling2D
- - Flatten
- - Dense(512, activation='relu')
- - Dense(4, activation='softmax')

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 148, 148, 32)	896
max_pooling2d (MaxPooling2D)	(None, 74, 74, 32)	0
conv2d_1 (Conv2D)	(None, 72, 72, 64)	18,496
max_pooling2d_1 (MaxPooling2D)	(None, 36, 36, 64)	0
conv2d_2 (Conv2D)	(None, 34, 34, 128)	73,856
max_pooling2d_2 (MaxPooling2D)	(None, 17, 17, 128)	0
conv2d_3 (Conv2D)	(None, 15, 15, 128)	147,584
max_pooling2d_3 (MaxPooling2D)	(None, 7, 7, 128)	0
flatten (Flatten)	(None, 6272)	0
dense (Dense)	(None, 512)	3,211,776
dense_1 (Dense)	(None, 4)	2,052

Total Trainable Parameters: 3,454,660

The architecture was chosen for its balance between performance and computational efficiency. Dropout layers were initially considered but later excluded due to strong early generalization performance.

7. Visualization and Results Analysis

To better understand the learning process and validate the performance of the CNN model, several visualizations were generated during the experiments.

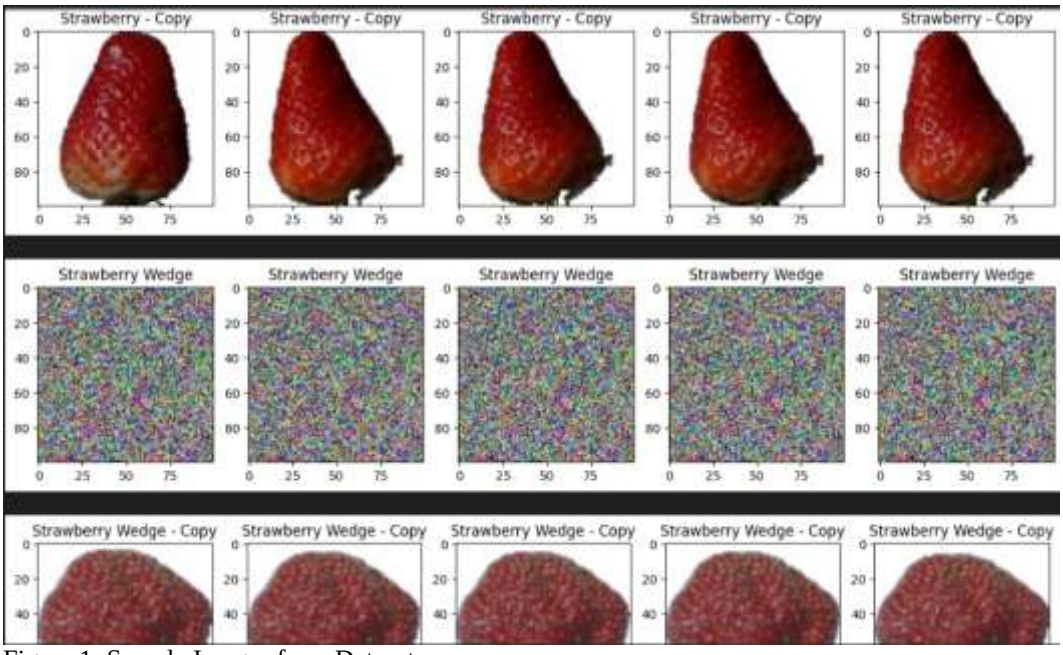
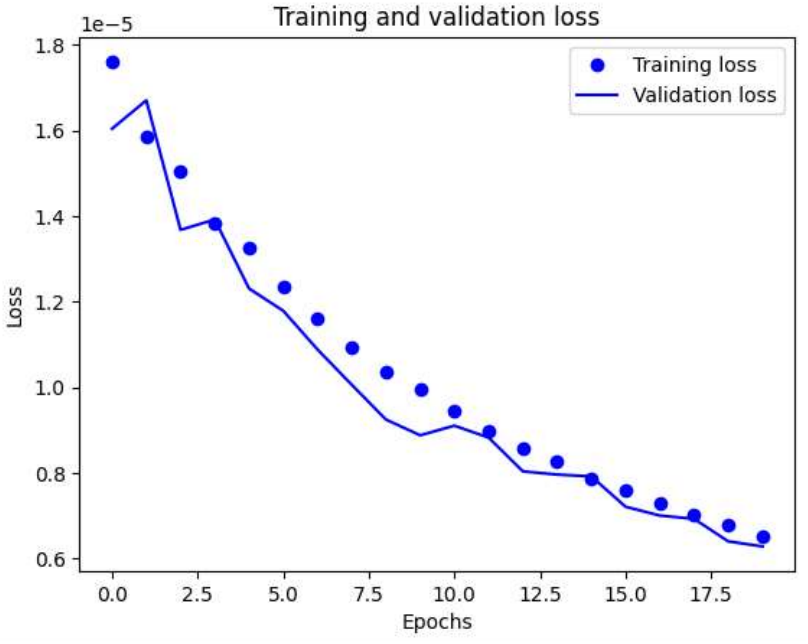


Figure 1: Sample Images from Dataset

This figure displays example images from each of the four categories in the training dataset. The samples show visible differences in leaf patterns, discoloration, and shape irregularities. These features serve as key visual cues that the model learns to distinguish.

Figure 2: Accuracy Curve (First Run)



In this initial experiment, the model achieved 100% training and validation accuracy within a few epochs. While this may seem ideal, the near-perfect performance is a sign of overfitting, likely due to insufficient training diversity and short training duration.

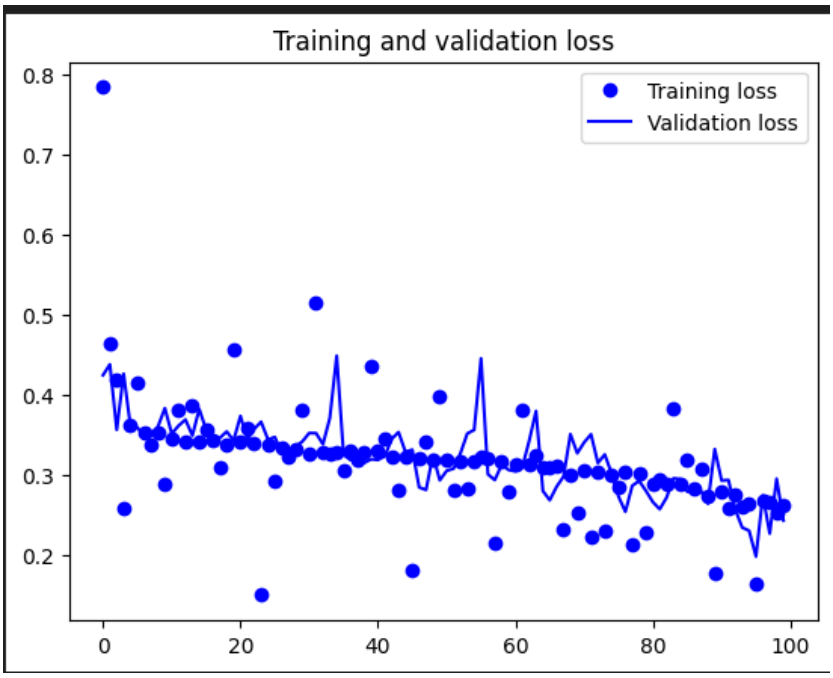


Figure 3: Loss Curve (First Run)

The corresponding loss curve confirms the overfitting behavior. Training and validation loss rapidly approach zero, indicating memorization rather than generalization.

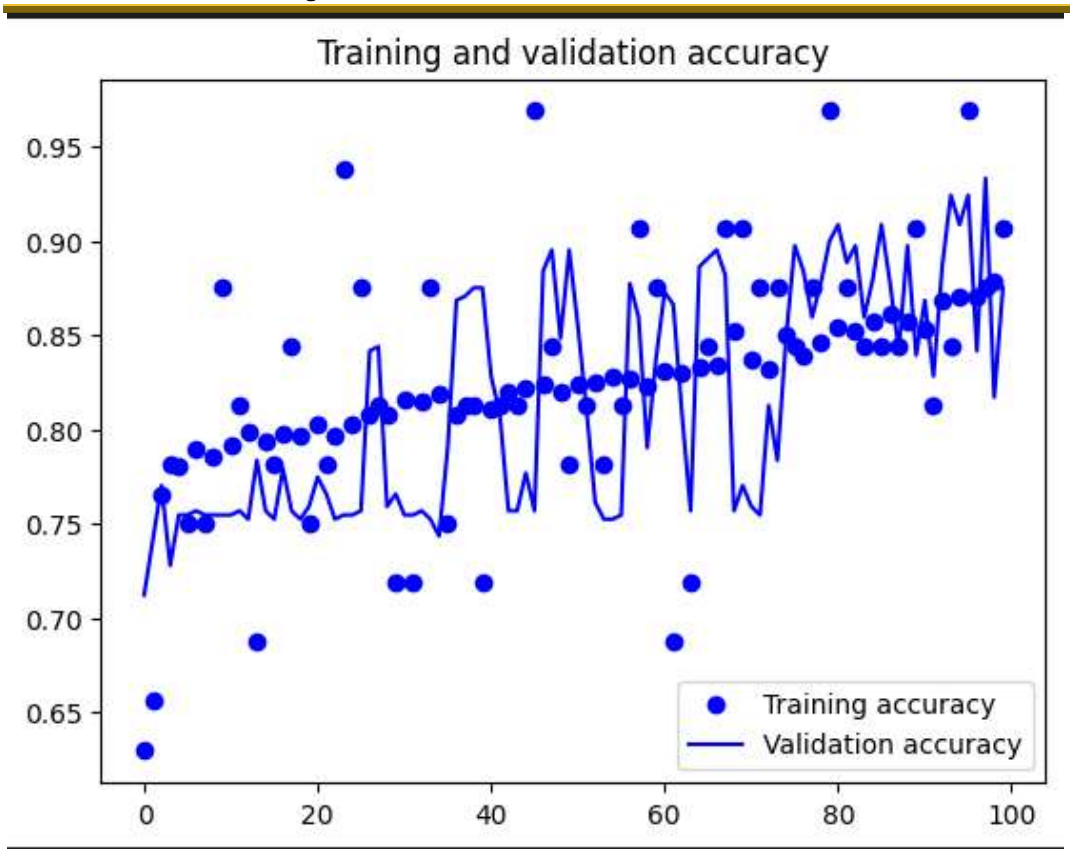


Figure 4: Accuracy Curve (Final Run)
In the final experiment with a full training duration of 100 epochs, the accuracy stabilized at 87.5% validation accuracy. This indicates a much more realistic generalization and successful learning process.

Figure 5: Loss Curve (Final Run)
The loss values decreased gradually and steadily, reflecting healthy convergence and model learning. The validation loss stabilizing without sharp fluctuations indicates robustness.

These visualizations are critical for interpreting how the model evolves, learns to detect visual patterns in leaves, and generalizes beyond the training data. They also highlight how training design decisions (number of epochs, data diversity) influence outcomes.

8. Conclusion
This paper demonstrates that CNNs are capable of accurately classifying strawberry leaf images into distinct health categories. With proper preprocessing and architecture tuning, deep learning offers practical solutions for smart agriculture. Future work may include real-time mobile deployment and incorporating more diseases.

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