National College of
Ireland

Research Project

Coffee Plant Nutritional Deficiencies Classification Using Transfer Learning

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Content

Introduction

1. Agriculture contributes 4% to the global GDP, it is crucial for reducing poverty and promoting shared prosperity, especially as the global population is expected to reach 10 billion by 2050.

2. This study aims to support smallholder farmers, who often lack advanced resources, by developing a deep learning framework that utilizes image recognition to detect nutrient deficiencies in coffee plants.

3. This research evaluates VGG-16, ResNet-50, DenseNet-121, MobileNetV2 and InceptionV3 to determine the most suitable deep-learning model.

Previous Researches

2020

KUMAR:

- CNN model with Transfer Learning using Inception v3 architecture for identifying coffee leaf diseases.
- Achieving 97.61% accuracy using the Softmax activation function and Mini-Batch Gradient Descent (MBGD) optimizer.

2020

LEWIS:

- Focused on identifying nutrient deficiencies in coffee plants using a CNN model.
- Achieved an average accuracy of 94.49%.

2021

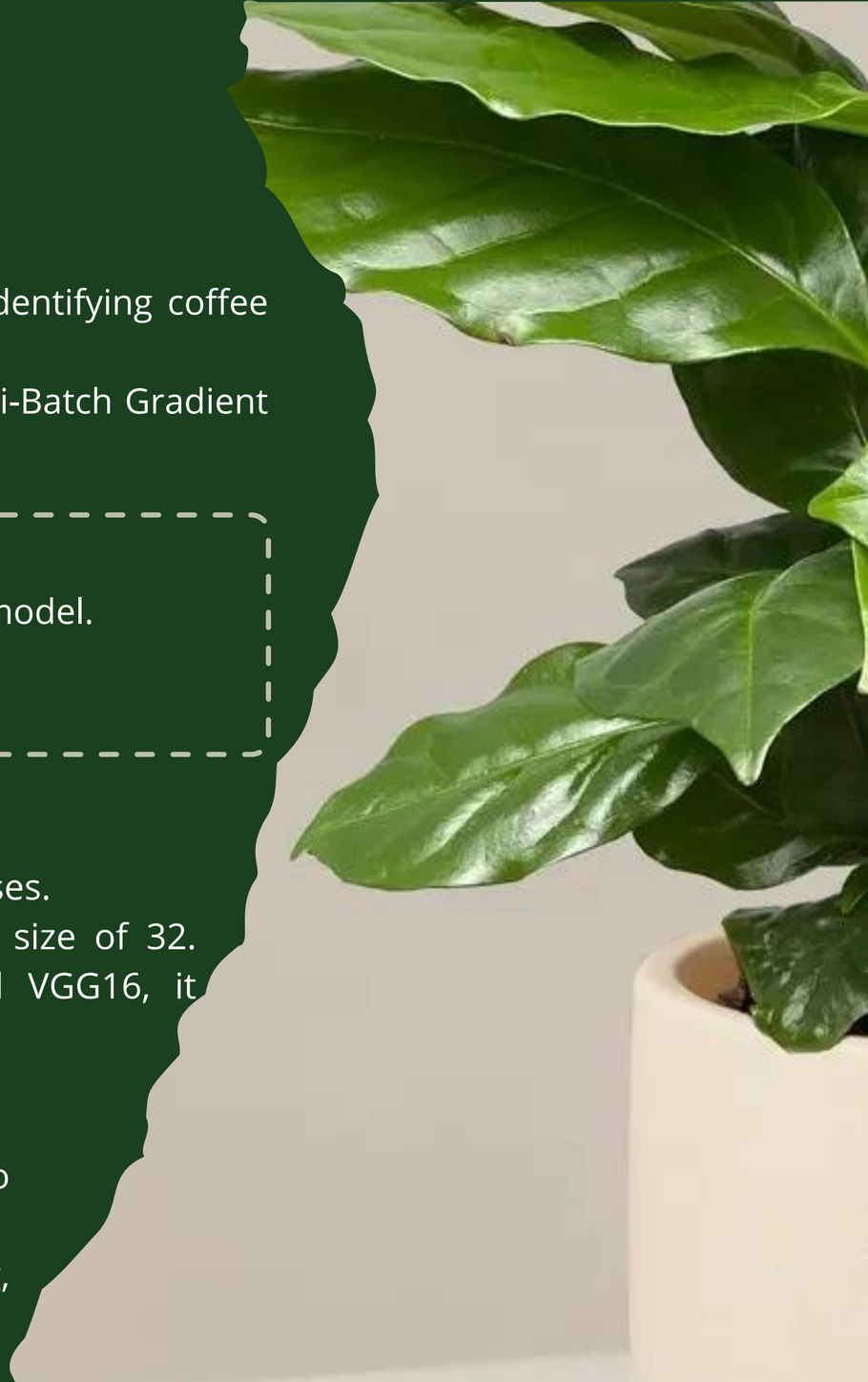
LISBOA:

- Proposed a pre-trained ResNet-50 model for classifying coffee leaf diseases.
- Achieved 97.18% accuracy after training with 20 epochs and a batch size of 32. Compared with other methods like Local Binary Pattern (LBP) and VGG16, it demonstrated superior performance.

2021

TAGLIONE:

- A dataset from Wolaita Sodo Agricultural Research Center, Ethiopia to classify coffee leaf diseases.
- Applied ResNet-50 and MobileNet architectures for transfer learning, achieving 99.86% and 97.01% accuracy, respectively.



NOVTAHANING:

- A dataset from Wolaita Sodo Agricultural Research Center, Ethiopia to classify coffee leaf diseases.
- Applied ResNet-50 and MobileNet architectures for transfer learning, achieving 99.86% and 97.01% accuracy.

2022

HITIMINA:

- Developed a dataset of Rwandan coffee plants, focusing on common diseases like rust, miner, and red spider mites.
- DenseNet achieved the highest accuracy of 99.57% among other models like Inception V3, ResNet-50, Xception, and VGG16.

2023

CONG PHAM:

- Explored ensemble methods combining various CNN models like MobileNet, DenseNet, EfficientNet, GoogleNet, ResNet, VGG, and Vision Transformer.
- The best results were achieved with early fusion (MobileNet and EfficientNet) and late fusion (MobileNet and Vision Transformer), both obtaining 97.80% accuracy for coffee leaf disease classification.

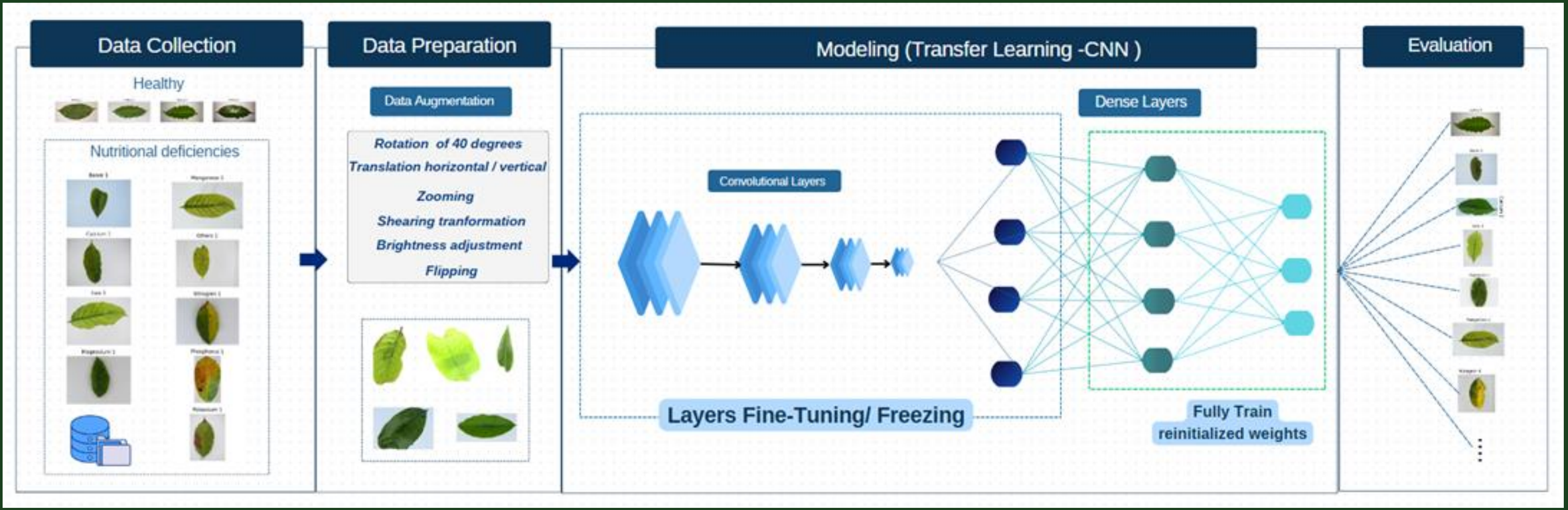
2023

BERA:

- Developed a Graph Convolutional Network (GNN) combined with CNN, named Plant Nutrition Deficiency and Disease Network (PND-Net), to classify plant diseases and nutrient deficiencies.
- The coffee dataset showed the best performance with the Xception model, achieving 90.54% accuracy. The potato disease classification dataset reached 96.18% accuracy.

2024

Research Methodology

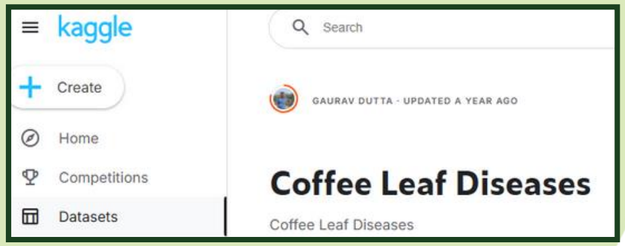


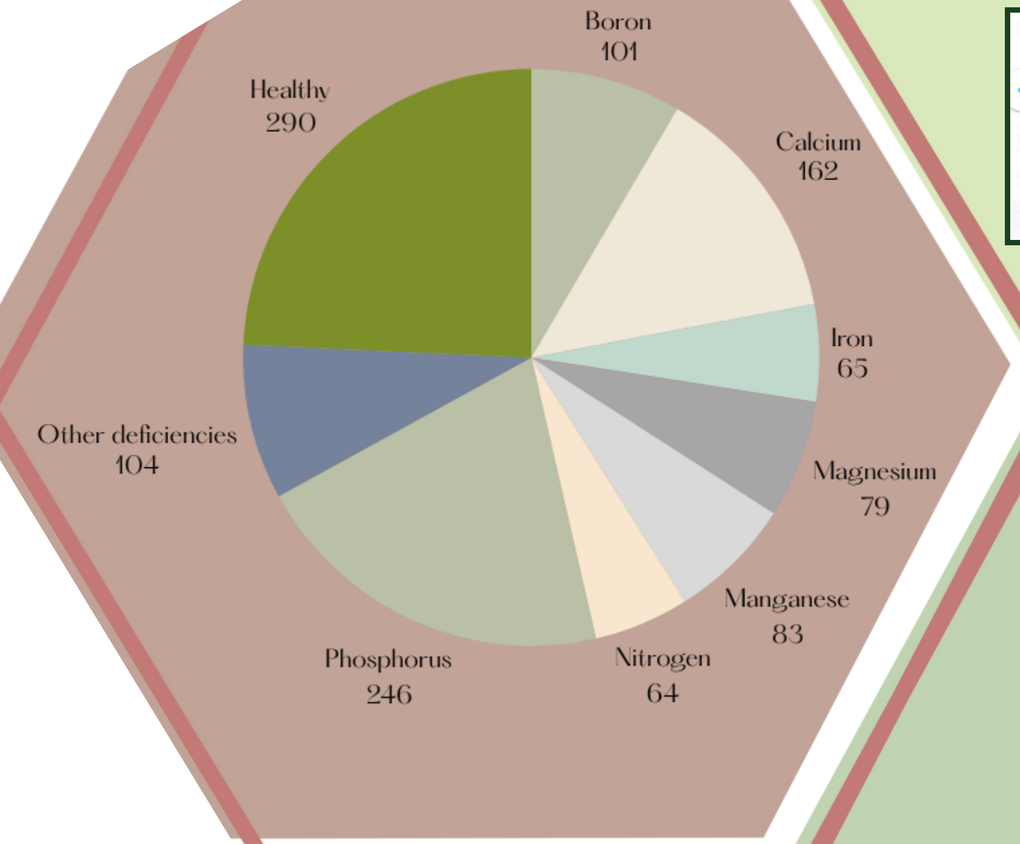
Research Methodology flow diagram highlighting key steps

Data Collection

Mendeley Data

CoLeaf DATASET





- Boron
- Calcium
- Iron
- Magnesium
- Manganese
- Nitrogen
- Phosphorus
- Potassium
- Other deficiencies
- Healthy

Boro

Calcium

Phosphorus

Others

Iron

Magnesium

Potassium

Healthy

Manganese

Nitrogen

Data Preparation

Input

Data Augmentation

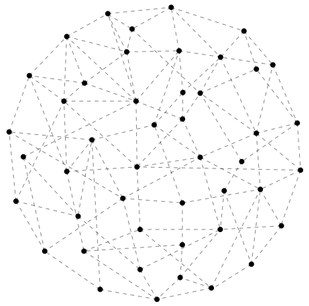
Rotation

Shearing

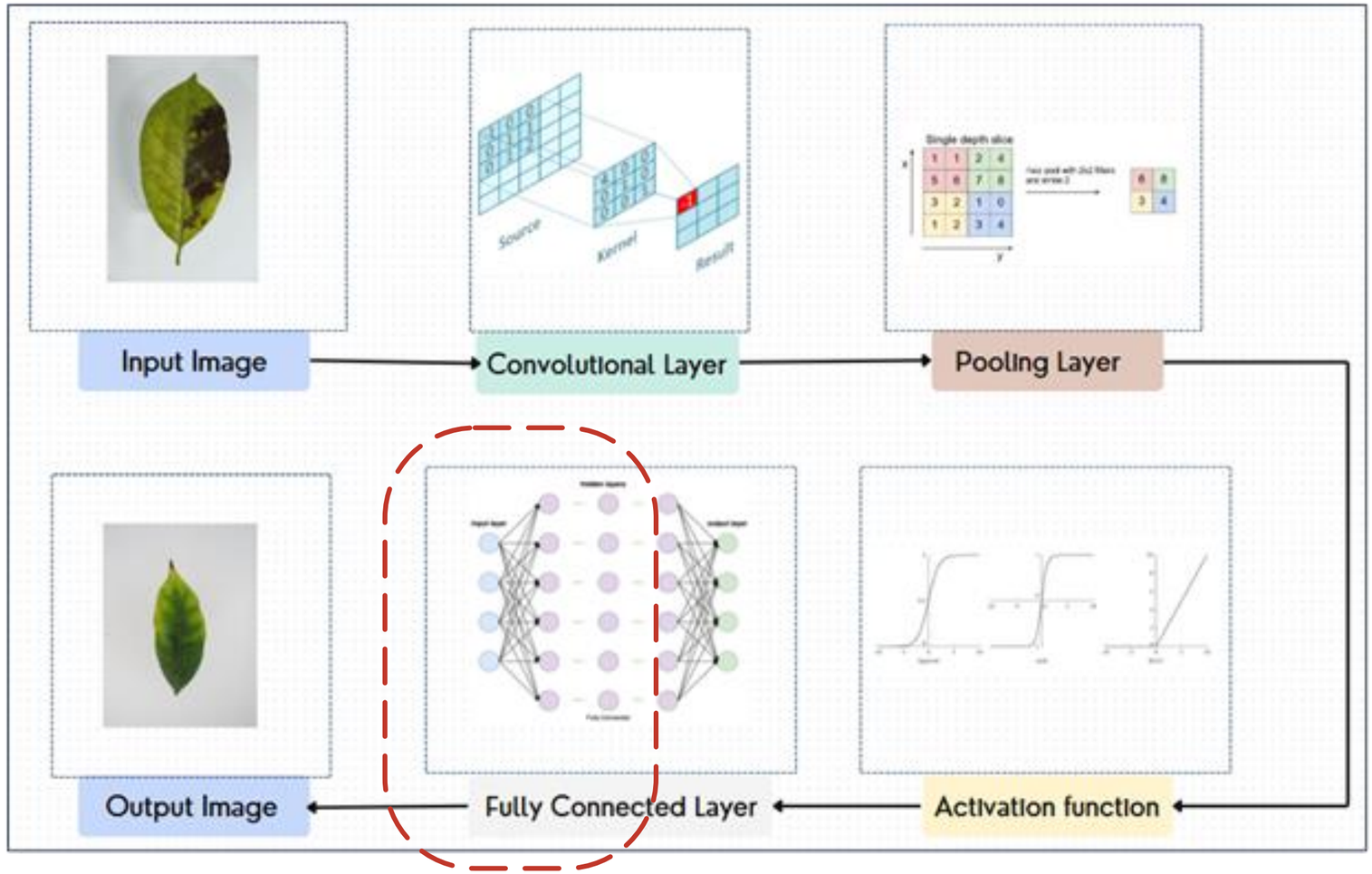
Zooming

Flipping

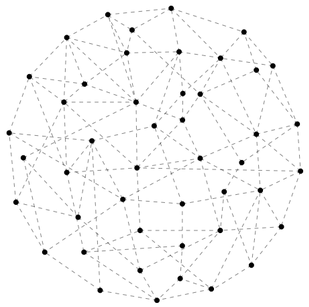
Modelling



Transfer Learning–CNN



Modelling



Parameters

1.Customized top Layers:

- Global Average Pooling (GAP)
- Batch Normalization
- Dense Layer: 1024 units, ReLU activation.
- Dropout Layer: 50% dropout rate.
- Output Layer: 10 units, softmax activation.

2. Optimizer

- Adam
- Learning Rate Schedule

3. Loss Function

- Categorial Cross-Entropy

4. Performance Metric

- Accuracy

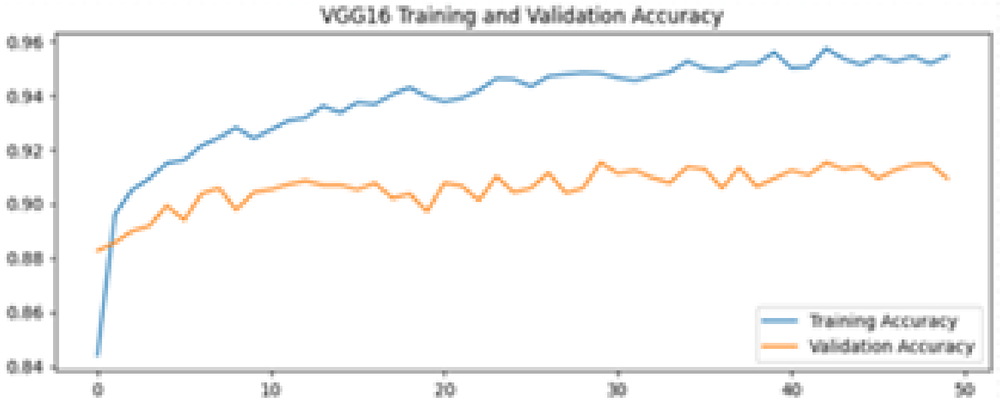
5. Training epochs

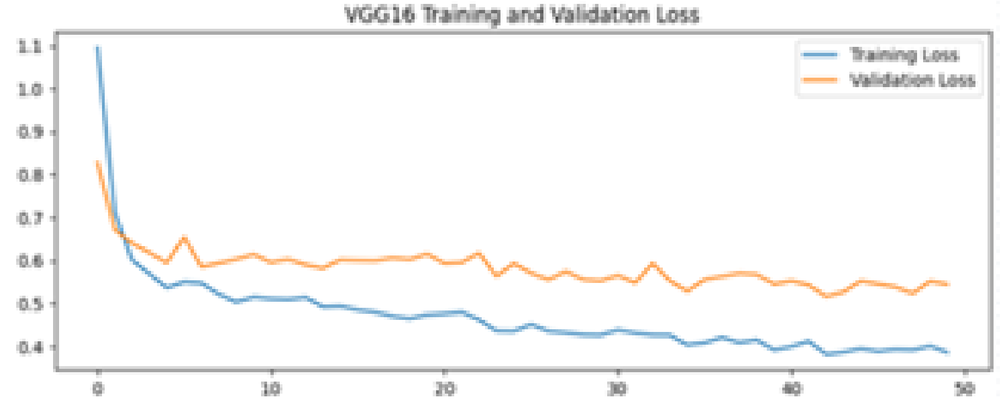
- Initial Training: 50 epochs
- Fine-Tuning: 10 epochs

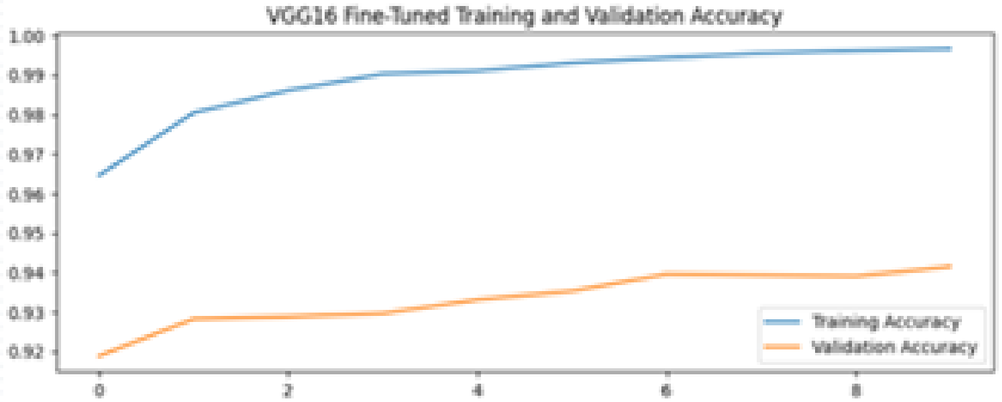
6. Fine-tuning

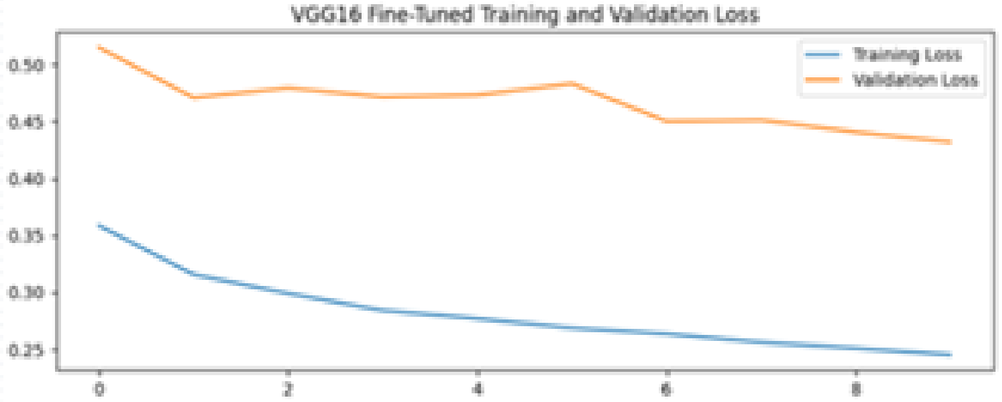
- Layers unfrozen: from layer onward of the base model

Modelling



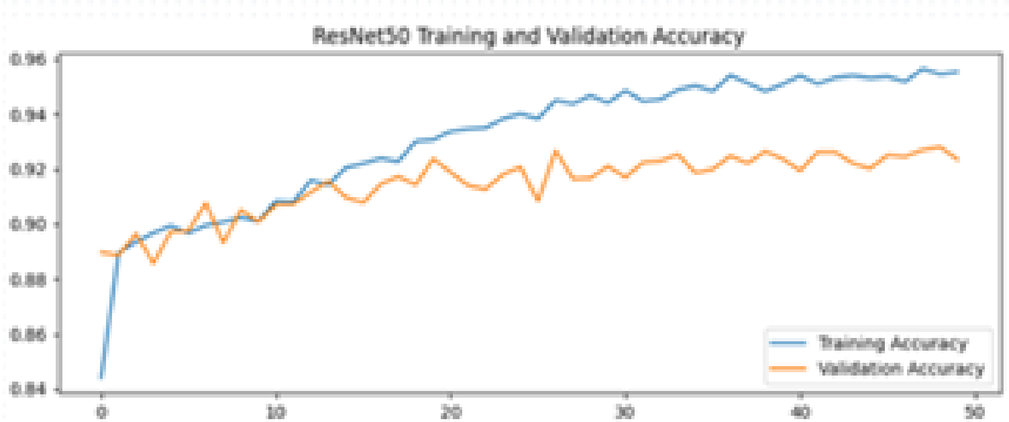


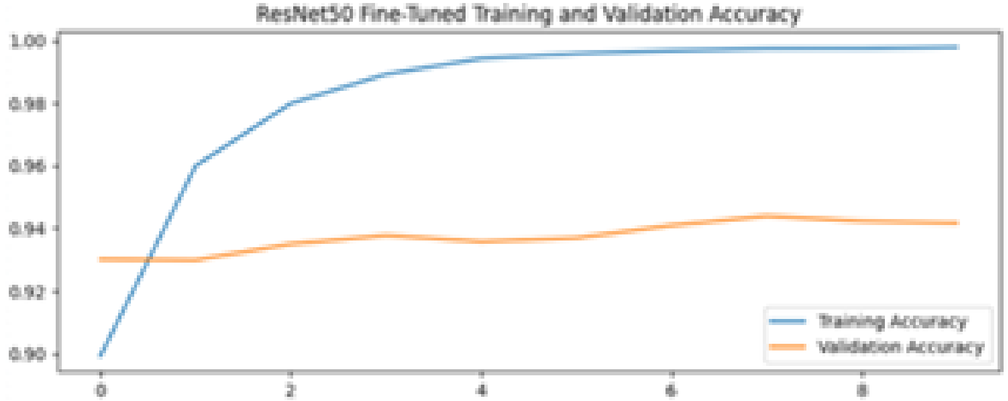


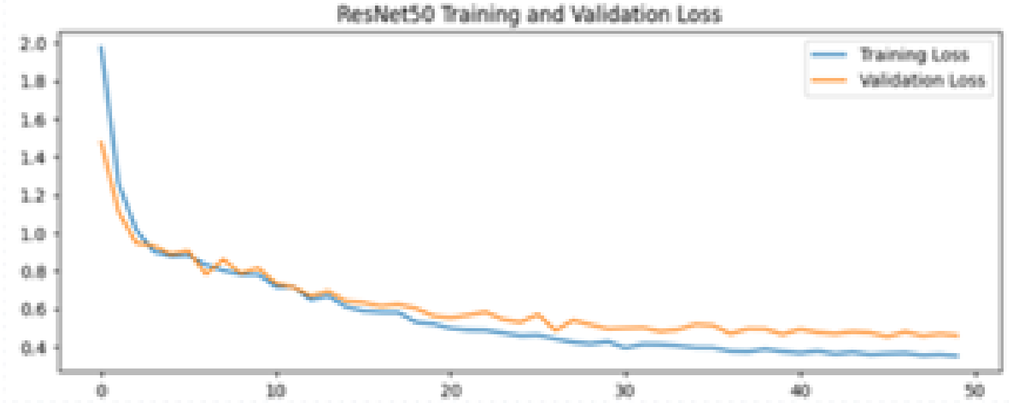


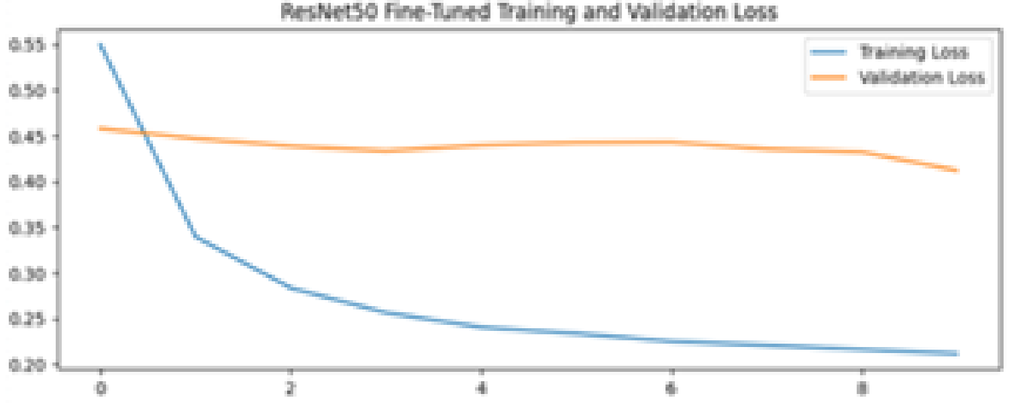
VGG-16

Modelling



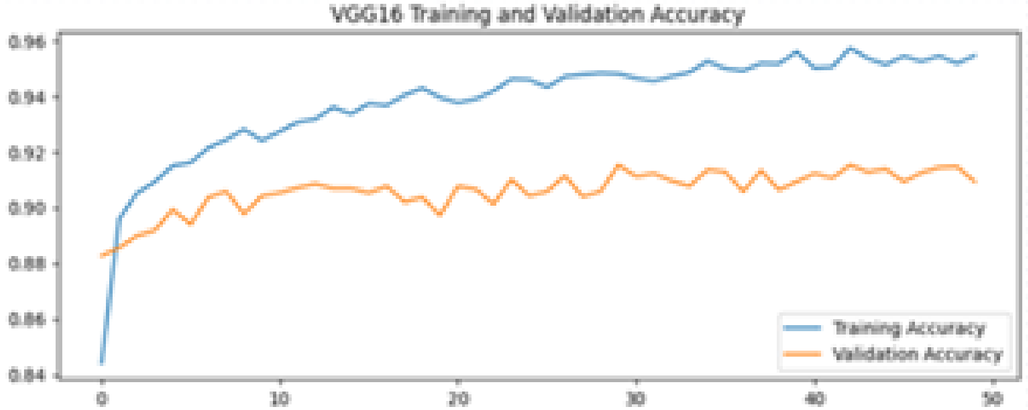


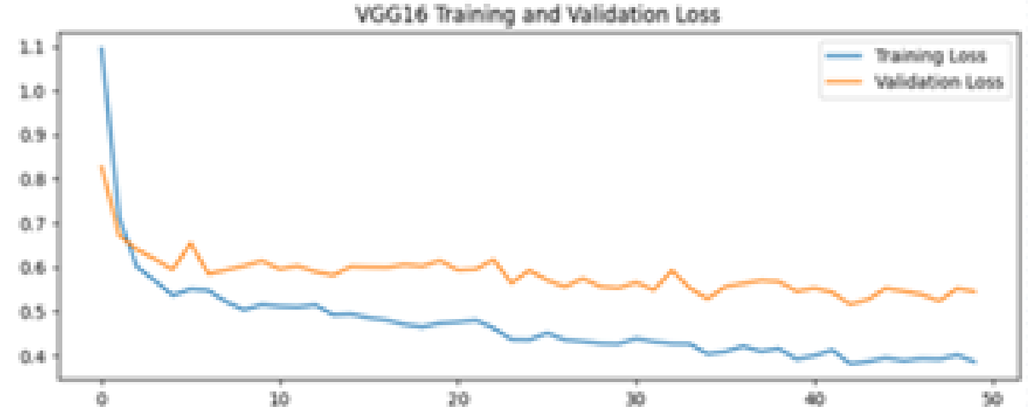


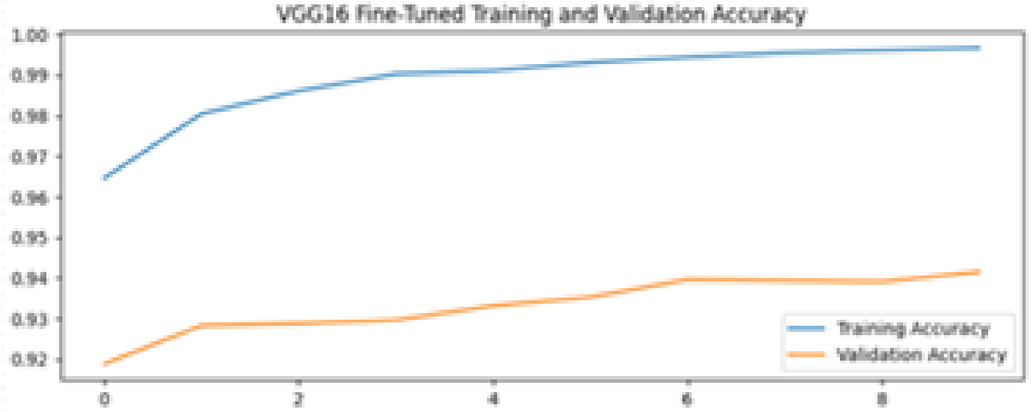


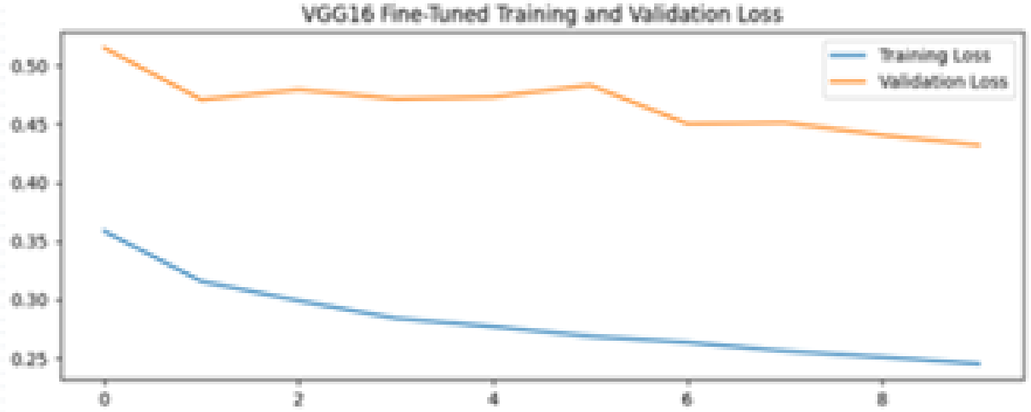
ResNet-50

Modelling



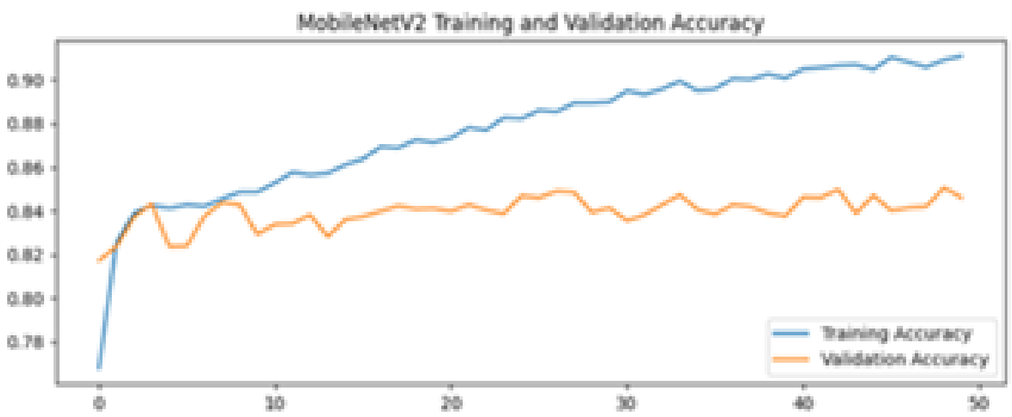


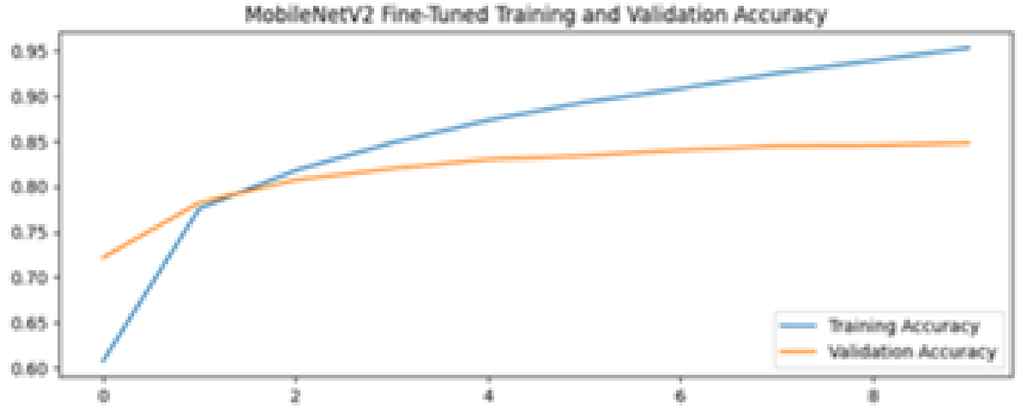


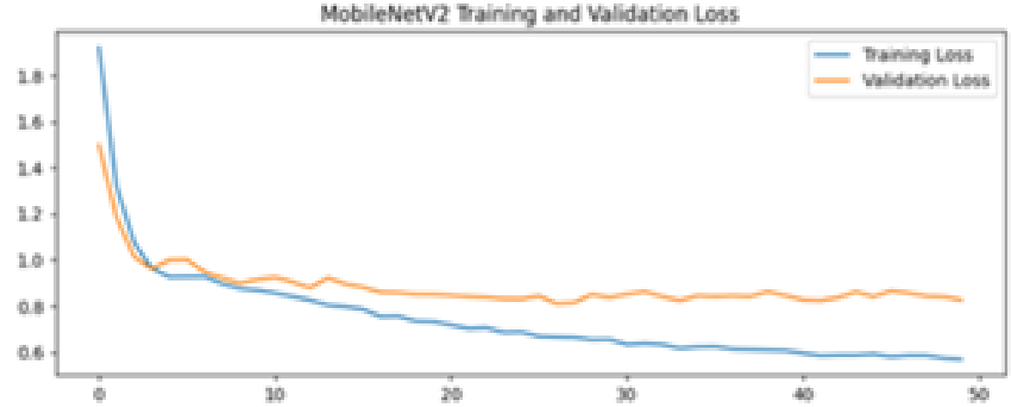


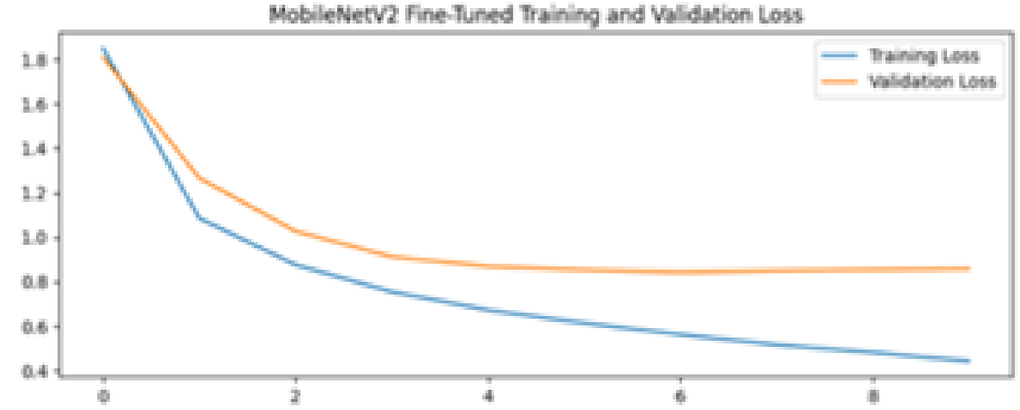
DenseNet-121

Modelling



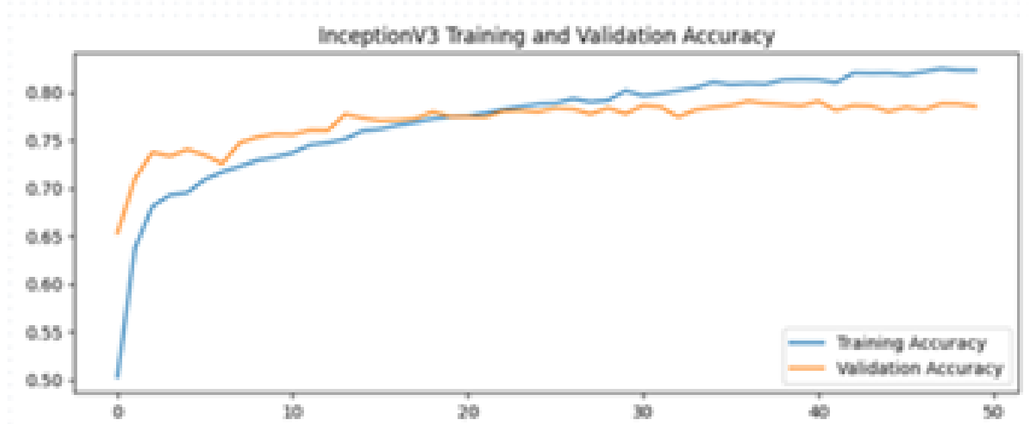


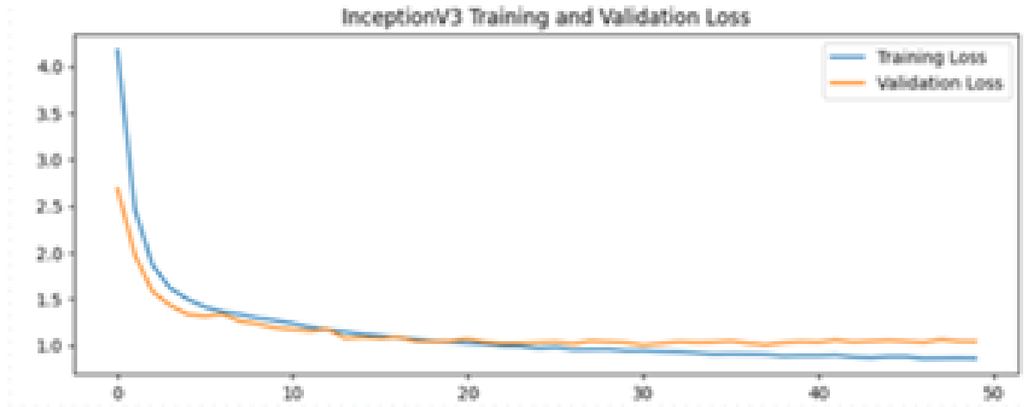


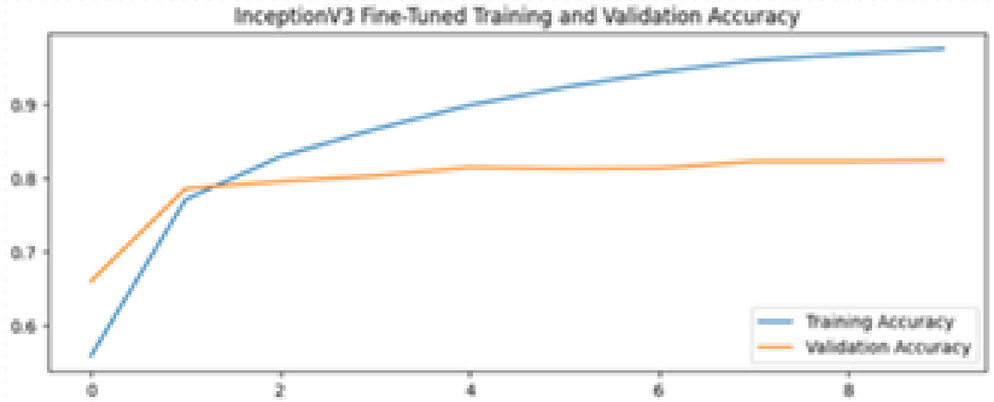


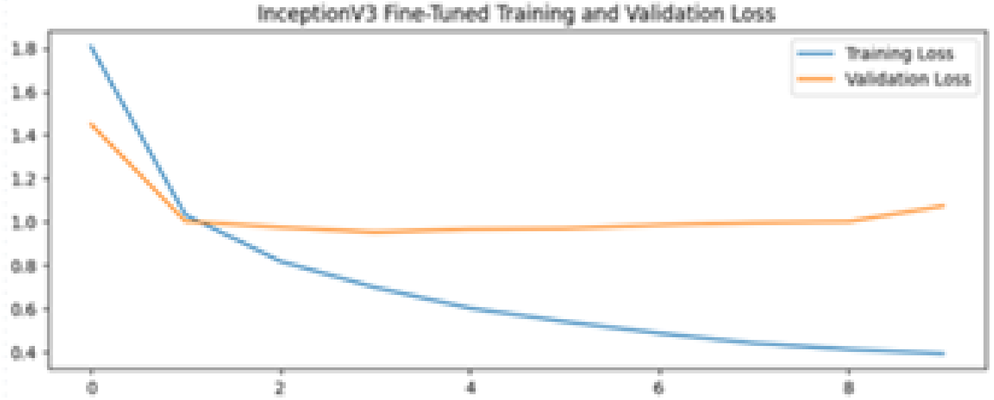
MobileNet-V2

Modelling









Inception-V3

Evaluation

	Training		Validation	
Models	Accuracy	Accuracy Fine-Tuned	Accuracy	Accuracy Fine-Tuned
VGG-16	**96.16%**	99.69%	90.94%	94.15%
ResNet-50	95.85%	**99.83%**	**92.34%**	**94.17%**
DenseNet-121	92.48%	96.24%	89.13%	90.88%
MobileNet-V2	91.68%	95.65%	84.60%	84.82%
Inception-V3	82.29%	97.89%	87.56%	82.42%

Table 2. Accuracy with and without Fine-Tuned on Training and Validation data.

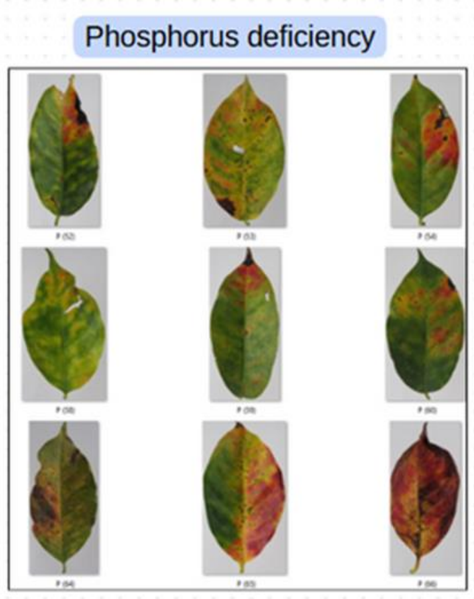
Models	Accuracy	Loss
VGG-16	94.05%	0.4404
ResNet-50	**94.23%**	**0.4246**
DenseNet-121	91.06%	0.4430
MobileNet-V2	85.29%	.8387
Inception-V3	83.24%	1.04

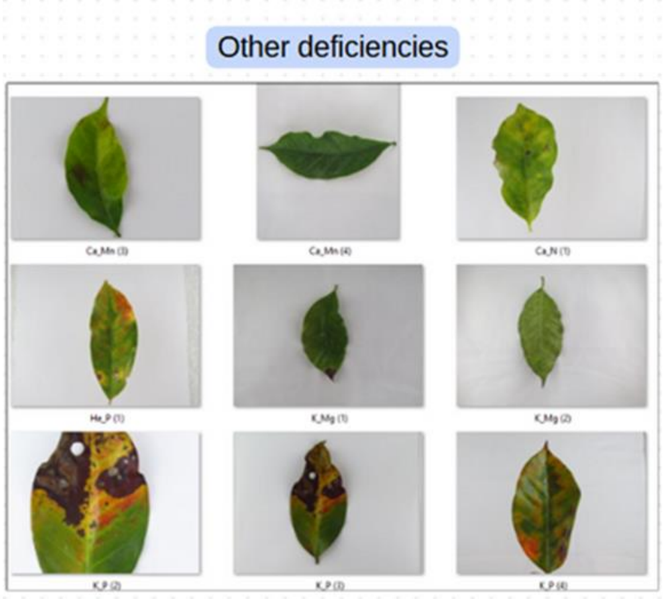
Table 3. Accuracy and Loss on Test datasets.

Results

Classes	Precision	Recall	F1-Score
Boron (B)	96%	97%	97%
Calcium (Ca)	93%	95%	94%
Iron (Fe)	92%	97%	94%
Magnesium (Mg)	91%	90%	90%
Manganese (Mn)	94%	90%	92%
Nitrogen (N)	95%	94%	95%
Phosphorus (P)	97%	96%	97%
Potassium (K)	98%	94%	96%
Other deficiencies	87%	90%	88%
Healthy	**99%**	**98%**	**99%**

Table 4. Metrics of ResNet-50 Model





Conclusion

1. Classification of coffee plant leaf based on symptoms that were affected by a disease, pests or nutritional deficiencies.

2. Availability of datasets for applying deep learning algorithms such as VGG-16, ResNet-50, DenseNet-121, MobileNet-V2 and Inception-V3

3. ResNet-50 Fine-Tuned in training dataset, accuracy of 99.83%

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Thanks

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