Plant Seedlings Classfication

Project : Plant Seedlings Classificaiton
Course : Computer Vision

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Contents

- Executive Summary
- Business Problem Overview and Solution Approach
- Data Overview & Analysis
- EDA Results
- Data Preprocessing
- Model Building & Performance Summary
- Conclusion
- Key Actionable Business Insights
- Our Recommendation
- Appendix

Executive Summary

Executive Summary – Business Context

- **Business Context:** Despite several advances in the agricultural technology, the ability to sort and recognize different plants and weeds is still a very labour-intensive task. Using technological innovations such as AI and Deep Learning, this task can be carried out far more efficiently and effectively, which could not only lead to better crop yields but also free up human involvement for higher-order agricultural decision making. Moreover, such methods will result in long term sustainable environmental practices in agriculture.
- **The Problem Statement :** To build a convolutional neural network to classify plant seedlings into their respective categories
- **Solution Approach:** In order to resolve the above problem, we will undertake the following key tasks:
  - Perform a deep-dive on the dataset using libraries such as numpy and pandas for data manipulation, and seaborn and matplotlib for data visualisation
  - Perform exploratory data analysis on the dataset (plant labels and images) to deliver key findings and insights
  - Build a classification model using a convolutional neural network that will be able to determine a plant's species from an image
  - Identify areas of improvement to boost the model's performance such that it can be tuned to obtain better classification results
  - Recommend opportunities for improvement that will help in better decision making

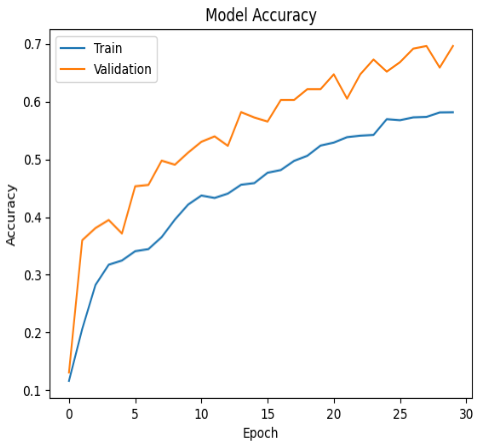
Executive Summary – Model Evaluation Criteria & Approach

- **Model Evaluation Criteria :** The primary objective for building the model is to classify plant seedlings into their respective categories i.e. to determine a plant's species from an image. It's important that the model classifies the species correctly, since any misclassification would result in poor decision making and would eventually lead to a loss.
  - Key Criteria – Accuracy: We have therefore used Accuracy as the key model evaluation criteria – higher the Accuracy, greater are the chances of minimising misclassifications
- **Model Building Approach:** We have split the data into Training, Validation and Testing datasets. We have built an initial CNN model using Adam as an optimizer and evaluated its performance (Accuracy) on the training, validation and testing dataset. To improve performance, we have built an additional model with Adam as an optimizer and used Data Augmentation and Learning Rate Reduction techniques to decrease the loss. We have then evaluated this model's performance (Accuracy) on the training, validation and testing datasets. Based on both the **Accuracy** scores, we have **finalised** the **best performing** model **(Model 2 : CNN Model with Data Augmentation)** and visualized the predictions
  - Model 1 : Convolutional Neural Network Model using Adam without Data Augmentation (Initial Model)
  - Model 2 : Convolutional Neural Network Model using Adam with Data Augmentation (Revised Model)

Executive Summary – Model 1 : CNN without Data Augmentation

- **Model 1 – CNN without Data Augmentation (Initial Model):** Based on the following parameters, the initial model has delivered an Accuracy score of 58.15% and 69.63% on the Training & Validation dataset respectively, and 72.42% on the Testing dataset
  - Optimizer Type: Adam
  - Loss Function: Categorical Cross Entropy
  - Input Shape: 64 x 64 (HxW), 3 Channels (RGB)
  - Total Layers: 9 : Input & Conv2D Layers – 3, MaxPooling – 3, Flatten & Fully Connected - 2 and Output Layer-1
  - No. of Neurons: Input & Conv2D Layers – 128, 64 & 32, Fully Connected -16 and Output Layer-12
  - Activation Functions: Input & Conv2D Layers – Relu, Fully Connected Layer – Relu and Output Layer – Softmax
  - Metric: Accuracy
  - Drop Out Rate – 0.3
  - Total Parameters: 128828
  - Total Trainable Parameters: 128828
  - Total Non-Trainable Parameters: 0

Model 1 : CNN without Data Augmentation (Initial Model)

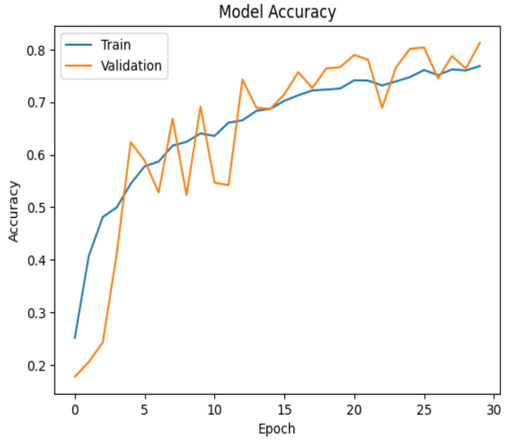


Key Performance Metrics		
Training Accuracy	**Validation Accuracy**	**Testing Accuracy**
0.5815	0.6963	0.7242

Executive Summary – Model 2 : CNN with Data Augmentation

- **Model 2 – CNN with Data Augmentation (Revised Model):** Based on the following parameters, the model delivered an Accuracy score of 76.87% and 81.31% on the Training & Validation dataset respectively, and a score of 80.42% on the Testing dataset
  - Optimizer Type: Adam
  - Loss Function: Categorical Cross Entropy
  - Input Shape: 64 x 64 (HxW), 3 Channels (RGB)
  - Total Layers: 7 : Input & Conv2D Layers – 2, MaxPooling – 2, Flatten & Fully Connected -2 and Output Layer-1
  - No. of Neurons: Input & Conv2D Layers – 64 & 32, Fully Connected -16 and Output Layer-12
  - Activation Functions: Input & Conv2D Layers – Relu, Fully Connected – Relu and Output – Softmax
  - Batch Normalization & Learning Rate Reduction – Yes
  - Data Augmentation – Yes (Rotation Range to 20)
  - Metric: Accuracy
  - Drop Out Rate: 0.3
  - Total Parameters: 151676
  - Total Trainable Parameters: 151612 | Total Non-Trainable Parameters: 64

Model 1 : CNN with Data Augmentation (Revised Model)



Key Performance Metrics		
Training Accuracy	**Validation Accuracy**	**Testing Accuracy**
0.7687	0.8131	0.8042

Executive Summary – Model Feature Comparison Summary

- Following is the feature comparison summary of the 2 models that were used on the training, validation and the testing dataset

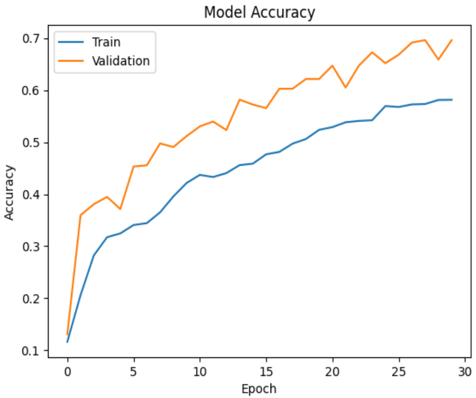
Model	Model Attributes											Model Parameters		
	Layer Type	No of Layers	No of Neurons	Kernel Size	Activation	Padding	Optimizer	Loss	Metric	Drop Out	Batch Normalize	Total	Trainable	Non Trainable
Model 1 : CNN without Data Augmentation (Initial Model)	Input & Conv2D	3	128,.64 & 32	3x3	Relu	Same	Adam	Categorical Cross Entropy	Accuracy	0.3	No	128828	128828	0
	MaxPooling	3	-	2x2	-	Same								
	Flatten & Fully Connected	2	16	-	Relu	-								
	Output	1	12	-	Softmax	-								
Model 2 : CNN with Data Augmentation (Revised Model)	Input & Conv2D	2	64 & 32	3x3	Relu	Same	Adam	Categorical Cross Entropy	Accuracy	0.3	Yes	151676	151612	64
	MaxPooling	2	-	2x2		Same								
	Flatten & Fully Connected	2	16	-	Relu	-								
	Output	1	12	-	Softmax	-								

Executive Summary – Model Performance Comparison Summary

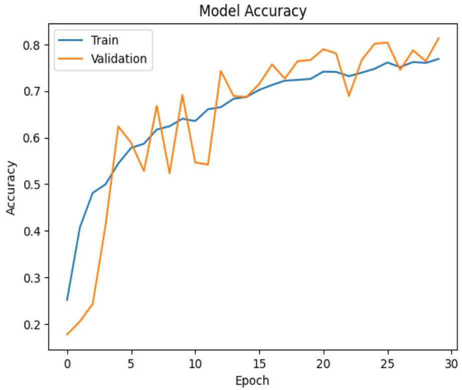
- Following is the performance metric summary of the 2 models on the Training, Validation and testing datasets. Model 1: CNN without Data Augmentation (Initial Model) has delivered an Accuracy score of 58.15% and 72.42% on the Training & Testing dataset respectively, whereas Model 2 : CNN with Data Augmentation (Revised Model) has delivered an Accuracy score of 76.87% & 80.42% on the Training & Testing dataset, respectively.
- Based on our key criteria - Accuracy, **Model 2 : CNN with Data Augmentation (Revised Model) has the best performance and has been used for visualising the plant species prediction.** It can be observed from the graphs that Model 2 faces a potential exploding gradient which can be further improvised by tuning model hyperparameters such as 1) Number Of Filters, 2) Filter Size, 3) Activation Function and 4) Drop Out Ratio

#	Model Type	Key Performance Metrics		
		Training Accuracy	Validation Accuracy	Testing Accuracy
1	Model 1 : CNN without Data Augmentation (Initial Model)	0.5815	0.6963	0.7242
2	Model 2 : CNN with Data Augmentation (Revised Model) 1	0.7687	0.8131	0.8042

Model 1 : CNN without Data Augmentation (Initial Model)



1 **Model 2 : CNN with Data Augmentation (Revised Model)**



Executive Summary – Model Performance Comparison Summary

- As per the classification report, the Model 1 CNN without Data Augmentation (Initial Model) has delivered the following performance scores:
  - Precision : 63% (Macro Avg) & 67% (Weighted Avg)
  - Recall : 62% (Macro Avg) & 72% (Weighted Avg)
  - F1 : 61% (Macro Avg) & 68% (Weighted Avg)
- As per the classification report, the Model 2 CNN with Data Augmentation (Revised Model) has delivered the following performance scores:
  - Precision : 79% (Macro Avg) & 80% (Weighted Avg)
  - Recall : 77% (Macro Avg) & 80% (Weighted Avg)
  - F1 : 80% (Macro Avg) & 80% (Weighted Avg)
- Based on scores, Model 2 CNN with Data Augmentation (Revised Model) has the highest Precision, Recall & F1 score and is the best performing model

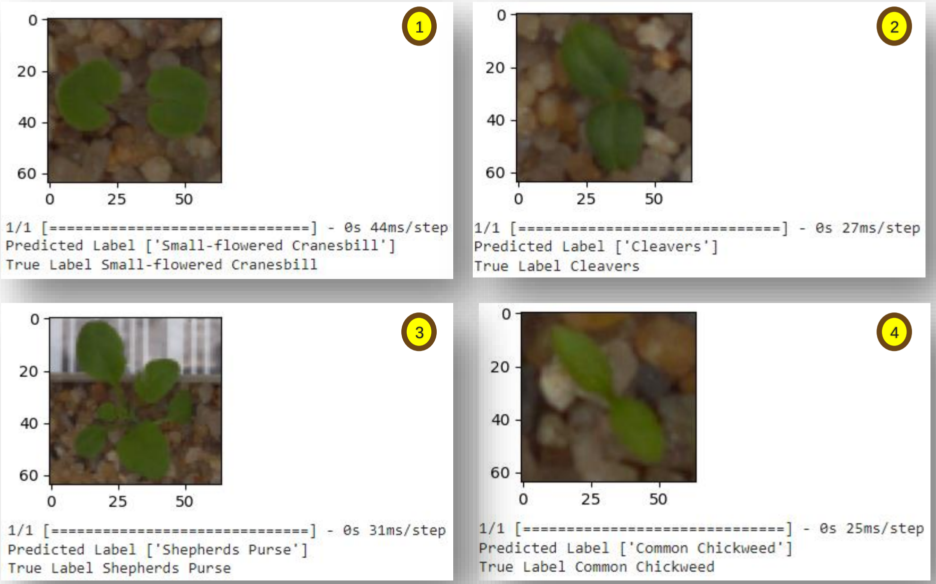
#	Model Type	Other Performance Metrics				
		Precision	Recall	F1	Support	Type
1	Model 1 : CNN without Data Augmentation (Initial Model)	0.63	0.62	0.61	475	Macro Avg
		0.67	0.72	0.68	475	Weighted Avg
2	Model 2 : CNN with Data Augmentation (Revised Model)	0.79	0.77	0.77	475	Macro Avg
		0.80	0.80	0.80	475	Weighted Avg

1

Executive Summary – Final Model : CNN with Data Augmentation

- **Best & Final Model:** Based on the performance comparison of the 2 models and their classfication reports, **Model 2 : CNN with Data Augmentation** has delivered an **Accuracy score of 80.42% on the Testing dataset**. We have therefore considered this as our **best and final model** and used it for visualising our prediction of plant species

- **Visualising Predictions:** As observed below, the model has correctly classified 1) Small-Flowered Cranesbill as Small-Flowered Cranesbill, 2) Cleavers as Cleavers, 3) Shepherds Purse as Shepherds Purse, and 4) Common Chickweed as Common Chickweed



Executive Summary – Conclusion

- We have built an initial CNN model using Adam as an optimizer and evaluated its performance (Accuracy) on the training, validation and testing dataset. To improve the model performance, we have built an additional CNN model using Data Augmentation and Learning Rate Reduction Techniques. We then evaluated this model's performance (Accuracy) on the training, validation and testing dataset.
  - Model 1 : CNN without Data Augmentation (Initial Model)
  - Model 2 : CNN with Data Augmentation (Revised Model)

- Based on the performance comparison (Accuracy) of all the 2 models, we have **finalised** the **best performing** model - **Model 2: CNN with Data Augmentation (Revised Model)**. This model has delivered **an Accuracy score of 76.87% & 81.31% on the Training & Validation dataset**, respectively. The model's **Accuracy score on the Testing dataset (80.42%)** is inline to the one observed on the Training & Validation datasets. This model has generalised its performance and can be considered as the final model. We have used this model to visualize predictions on the dataset.

- **Model 2: CNN with Data Augmentation (Revised Model)** can now be used to classify plant seedlings into their respective categories

- Model 2: CNN with Data Augmentation (Revised Model) performance (Accuracy) can further be improved by using different architectures and optimizers such as:
  - Use of Transfer Learning using VGG16 / VGG 19 Models for better image classification
  - Changing Model Hyperparameters such as 1) Number Of Filters, 2) Filter Size, 3) Activation Function and 4) Drop Out Ratio

Executive Summary – Key Actionable Business Insights

- **Summarised Key Observations & Insights :**
  - There is a significant imbalance in the dataset since there are high number of images in certain classes than compared to other. Moreover, the data is limited and less varied i.e. No Slanting, Rotated etc images This implies that for the model to deliver a better performance (translationally spatially and rotationally invariant), the dataset needs to be augmented and enriched using Data Augmentation techniques. We have used ImageDataGenerator() to augment our dataset
  - The best performing model – **Model 2: CNN with Data Augmentation has delivered an Accuracy of 80.42% on the Testing dataset**. However, this performance can further be improved by a) Adding additional layers with a combination of MaxPooling and Batch Normalisation; b) by tuning the hyperparameters such a drop out ratio, number of filters and filter size, and using different activation functions; and c) by increasing the number of epochs
  - Reducing the learning rate allowed the optimizer to take smaller steps to reach the global minimum, which increased the rate of convergence. We have used ReduceLROnPlateau() to reduce the learning rate when the validation accuracy stopped improving. This has benefitted our Model 2 performance
  - Confusion Matrix delivered better results in Model 2: CNN with Data Augmentation (Revised Model) than compared to Model 1: CNN without Data Augmentation (Initial Model)
  - Accuracy was much higher in Model 2: CNN with Data Augmentation (80.42%) than compared to Model 1: CNN without Data Augmentation (72.42%). Also, other metrics such as Precision, Recall & F1 score were much higher in Model 2 than compared to Model 1
  - Model 2: CNN with Data Augmentation performance can be further enhanced by using transfer learning techniques and adopting proven models such as VGG16 / VGG 19. These models have already been pre-trained using massive datasets and on high computing GPU. Adopting layers / parameters of such models can greatly enhance Model 2 performance

Executive Summary – Our Recommendation

Based on the key observations and insights, we recommend the following areas of improvement / opportunities that will lead to a better plant species classification

- **Implement Transfer Learning Techniques:** Adopt VGG16 / VGG19 pre-trained models and fine tune Model 2 performance by adding more layers and/or adjusting hyperparameters
- **Implement Data Augmentation Techniques:** Use data augmentation techniques to add and enrichen the dataset in order to improve model performance. CNN models trained on such datasets are proven to be spatially, translationally and rotationally invariant and deliver better predictions

Business Problem Overview & Solution Approach

Business Context

- **Business Context:** Despite several advances in the agricultural technology, the ability to sort and recognize different plants and weeds is still a very labour-intensive task. Using technological innovations such as AI and Deep Learning, this task can be carried out far more efficiently and effectively, which could not only lead to better crop yields but also free up human involvement for higher-order agricultural decision making. Moreover, such methods will result in long term sustainable environmental practices in agriculture.
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Data Overview & Analysis

Data Overview & Analysis

- **Dataset:** Images.npy includes a collection of plant species images & Labels.csv includes the labels of the plant species
- **Shape of the Dataset:**
  - Images : 4,750 images of shape 128 x 128 x 3, each image having 3 channels
  - Labels: Total No. Of Rows – 4,750 | Columns - 1

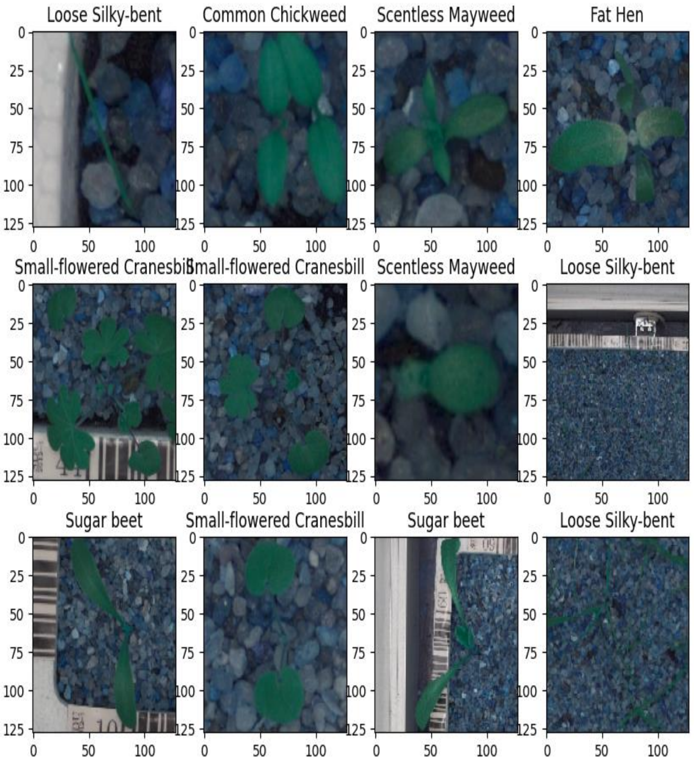
```
(4750, 128, 128, 3)
(4750, 1)
```

- **Plant Species:** There are 12 classes within the dataset
  - Black-grass
  - Charlock
  - Cleavers
  - Common Chickweed
  - Common wheat
  - Fat Hen
  - Loose Silky Bent
  - Maize
  - Scentless Mayweed
  - Shepherds Purse
  - Small-flowered Cranesbill
  - Sugar beet

EDA Results

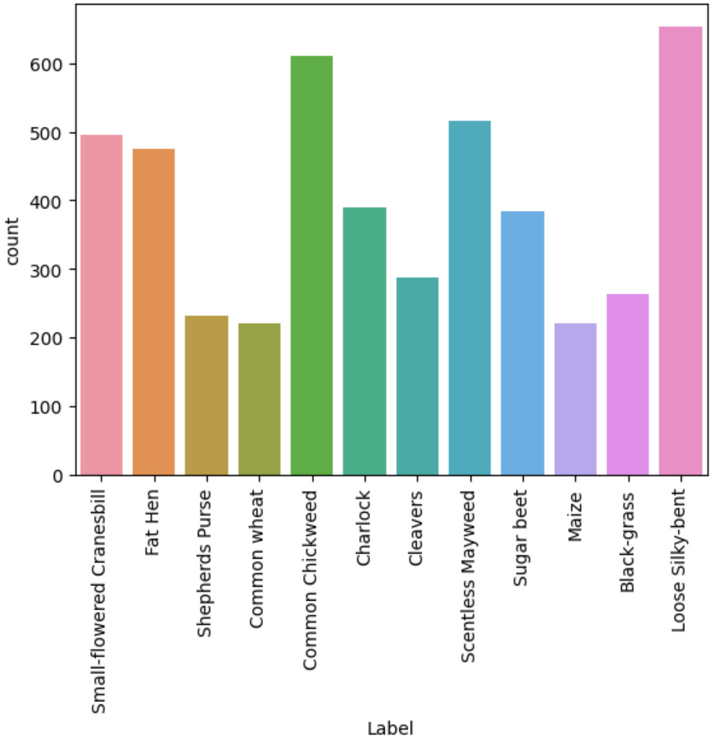
EDA Results

- Plotting 12 random images of the below classes with their respective labels:
  - 3 x Loose Silky Bent
  - 1 x Common Chickweed
  - 2 x Scentless Mayweed
  - 1 x Fat Hen
  - 3 x Small-flowered Cranesbill
  - 2 x Sugar beet



EDA Results (Cont'd)

- Target Variable Distribution: The dataset seems to be quite imbalanced. The total number of images in each of the 5 classes (highlighted below) are much higher than compared to the total number of images in remaining 7 classes
  - **Small-flowered Cranesbill - 496 Images**
  - **Flat Hen - 475 Images**
  - Shepherds Purse - 231 Images
  - Common Wheat - 221 Images
  - **Common Chickweed - 611 Images**
  - Charlock - 390 Images
  - Cleavers - 287
  - **Scentless Mayweed - 516 Images**
  - Sugar Beet - 385 Images
  - Maize - 221 Images
  - Black-grass - 263 Images
  - **Loose Silky-bent - 654 Images**



EDA – Key Observations & Insights

- **Key Observations & Insights:**
  - The dataset seems to be quite imbalanced. The total number of images in 5 classes are much higher than compared to the total number of images in remaining 7 classes.
  - The dataset doesn't seem to include a variety of images such as rotated, flipped, slanted etc.
  - To achieve better model performance, the dataset would need to be augmented and enriched with data augmentation techniques
  - All images are in 128 x 128 and in BGR format. In order to be computationally efficient, these images would need to be resized and converted to RGB format
  - All image pixel values range from 0-255 and would need to be normalised

Data Preprocessing

Data Preprocessing – Key Observations & Insights

- **Image Conversion:** All 4,750 images are in the BGR format so they have been converted into RGB format using OpenCV
- **Image Resizing:** Since all image sizes are 128 x 128, which are computationally expensive to train, the images are reduced to 64 x 64 (as below)
- **Dataset Segregation:** For our Initial Model (Model 1), we have split the data into Training (10%), Validation (10%) and Testing (80%) datasets.
  Training Dataset :
  - The Training dataset has 3,847 images of size 64x64(HxW) with 3 channels (RGB)
  - Validation Dataset : The Validation Dataset has 428 images of size 64x64(HxW) with 3 channels (RGB)
  - Testing Dataset (X_test, y_test) : The Testing Dataset has 475 images of size 64x64(HxW) with 3 channels (RGB)
- **Encoding Target Classes:**
  - All target variables within Training, Validation & Testing dataset are encoded using the LabelBinarizer() function

Image before resizing

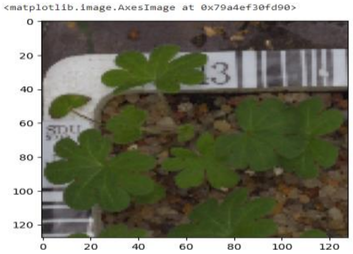


Image after resizing

Data Shape		
Training Dataset	(X_train, y_train)	(3847, 64, 64, 3) (3847, 1)
Validation Dataset	(X_val, y_val)	(428, 64, 64, 3) (428, 1)
Testing Dataset	(X_test, y_test)	(475, 64, 64, 3) (475, 1)

Data Shape Post Encoding Target Classes		
Training Dataset	Validation Dataset	Testing Dataset
y_train	y_val	y_test
(3847, 12)	(428, 1)	(475, 1)

Data Preprocessing – Key Observations & Insights

- **Dataset Normalisation:**
  - Since the image pixel values range from 0-255, we have normalised our data using scaling to standardize the images to have values between 0-1 for our Training, Validation and Testing datasets

- **Data Augmentation:**
  - Given, the limited size and variation in the dataset, we have augmented the dataset using Data Augmentation Techniques and implemented it in our Revised Model (Model 2)

Model Building & Performance

Model Evaluation Criteria & Approach

- **Model Evaluation Criteria :** The primary objective for building the model is to classify plant seedlings into their respective categories i.e. to determine a plant's species from an image. It's important that the model classifies the species correctly, since any misclassification would result in poor decision making and would eventually lead to a loss.
  - Key Criteria – Accuracy: We should therefore use Accuracy as the key model evaluation criteria – higher the Accuracy, greater are the chances of minimising misclassifications

- **Model Building Approach:** We have split the data into Training, Validation and Testing datasets. We have built an initial CNN model using Adam as an optimizer and evaluated its performance (Accuracy) on the training, validation and testing dataset. To improve performance, we have built an additional model with Adam as an optimizer and used Data Augmentation and Learning Rate Reduction techniques to decrease the loss. We have then evaluated this model's performance (Accuracy) on the training, validation and testing datasets. Based on <u>both</u> the **Accuracy** scores, we have **finalised** the **best performing** model **(Model 2 : CNN Model with Data Augmentation)** and visualized the predictions
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Model 1 : CNN without Data Augmentation

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  - Activation Functions: Input & Conv2D Layers – Relu, Fully Connected Layer – Relu and Output Layer – Softmax
  - Metric: Accuracy
  - Drop Out Rate – 0.3
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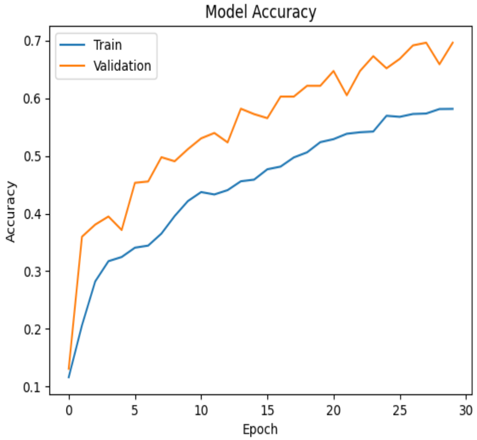
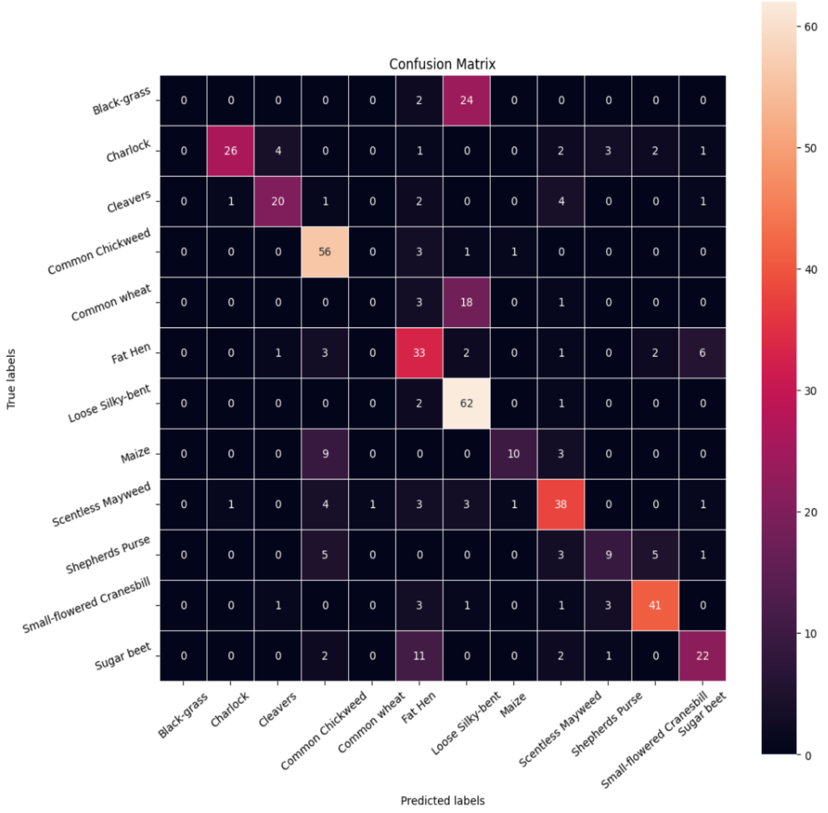
Model 1 : CNN without Data Augmentation (Initial Model)



Key Performance Metrics		
Training Accuracy	**Validation Accuracy**	**Testing Accuracy**
0.5815	0.6963	0.7242

Model 1 : Confusion Matrix - CNN without Data Augmentation

- Based on the Model 1 - Confusion Matrix, following are the key observations:
  - Black-grass & Common Wheat has not been identified at all
  - 26 times Black-grass was misclassified as Loose Silky-bent
  - 29 times Charlock was correctly classified as Charlock
  - 16 times Cleavers was correctly classified as Cleavers
  - 54 times Common Chickweed was correctly classified as Common Chickweed
  - 19 times Common Wheat was misclassified as Loose Silky-bent
  - 43 times Fat Hen was correctly classified as Fat Hen, whereas 5 times it was misclassified as others
  - 63 times Loose Silky-bent was correctly classified as Loose Silky-bent
  - 12 times Maize was correctly classified as Maize, whereas 5 times it was misclassified as Common Chickweed and 4 times as Scentless Mayweed
  - 46 times Scentless Mayweed has been classified correctly, whereas 6 times it has been misclassified as others



Model 1 : Confusion Matrix - CNN without Data Augmentation

- **Model 1 – Confusion Matrix (Cont'd):**
  - 9 times Shepherds Purse has been correctly classified, whereas 4 times it has been misclassified as Common Chickweed & Scentless Mayweed, and 3 times as Small-Flowered Cranesbill
  - 42 times Small-Flowered Cranesbill has been correctly classified as Small-Flowered Cranesbill, whereas 3 times it has been misclassified as Sugar beet and 5 times as others
  - 30 times Sugar beet has been correctly classified, whereas 3 times it has been misclassified as Fat Hen & Scentless Mayweed, and once as Small-Flowered Cranesbill

Model 1 Classification Report : CNN without Data Augmentation

- As per the classification report, the Model 1 CNN without Data Augmentation (Initial Model) has delivered the following performance scores:

Macro Average Scores:

- Precision : 63%
- Recall : 62%
- F1 : 61%

Weighted Average Scores:

- Precision : 67%
- Recall : 72%
- F1 : 68%

Classification Report - CNN without Data Augmentation (Initial Model)				
	Precision	**Recall**	**F1**	**Support**
0	0.00	0.00	0.00	26
1	0.91	0.74	0.82	39
2	0.70	0.55	0.62	29
3	0.81	0.89	0.84	61
4	0.00	0.00	0.00	22
5	0.84	0.90	0.87	48
6	0.55	0.97	0.70	65
7	0.80	0.55	0.65	22
8	0.62	0.88	0.73	52
9	0.64	0.39	0.49	23
10	0.89	0.84	0.87	50
11	0.79	0.79	0.79	38
Accuracy			0.72	475
Macro Avg	0.63	0.62	0.61	475
Weighted Avg	0.67	0.72	0.68	475

Model 2 : CNN with Data Augmentation

- **Model 2 – CNN with Data Augmentation (Revised Model):** Based on the following parameters, the model delivered an Accuracy score of 76.87% and 81.31% on the Training & Validation dataset respectively, and a score of 80.42% on the Testing dataset
  - Optimizer Type: Adam
  - Loss Function: Categorical Cross Entropy
  - Input Shape: 64 x 64 (HxW), 3 Channels (RGB)
  - Total Layers: 7 : Input & Conv2D Layers – 2, MaxPooling – 2, Flatten & Fully Connected -2 and Output Layer-1
  - No. of Neurons: Input & Conv2D Layers – 64 & 32, Fully Connected -16 and Output Layer-12
  - Activation Functions: Input & Conv2D Layers – Relu, Fully Connected – Relu and Output – Softmax
  - Batch Normalization & Learning Rate Reduction – Yes
  - Data Augmentation – Yes (rotation_range to 20)
  - Metric: Accuracy
  - Drop Out Rate: 0.3
  - Total Parameters: 151676
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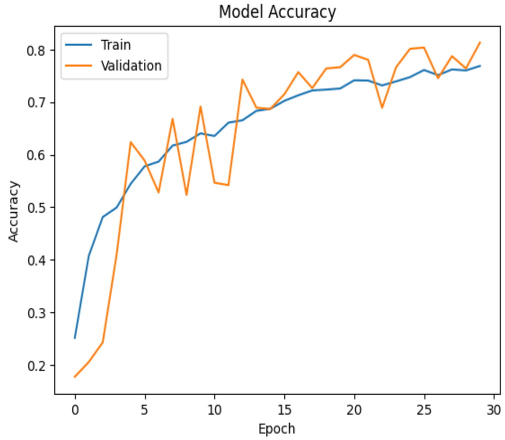
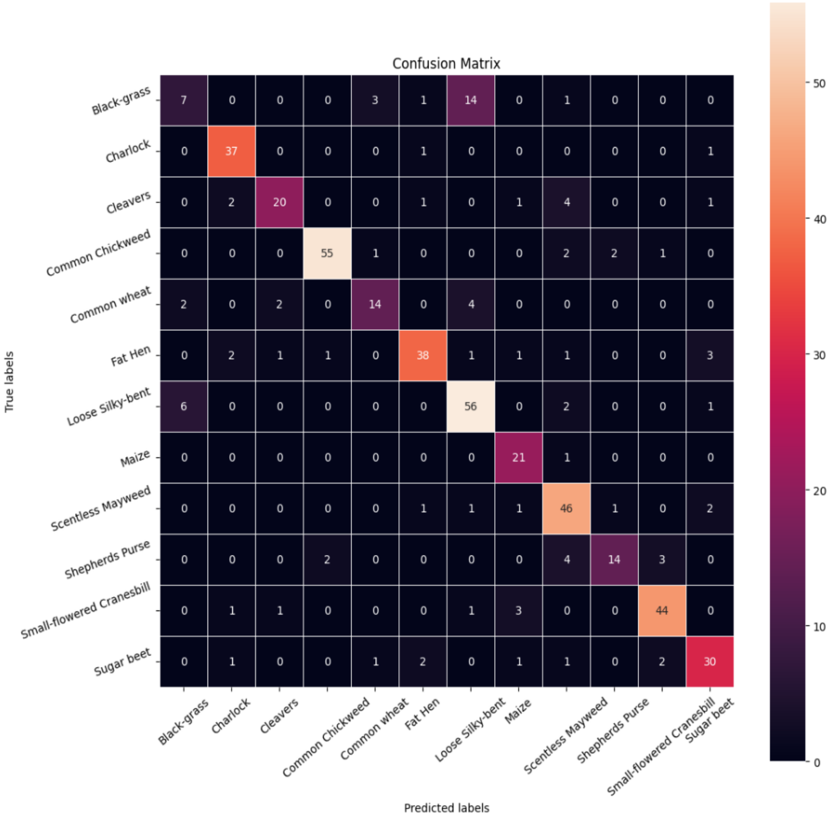
Model 1 : CNN with Data Augmentation (Revised Model)



Key Performance Metrics		
Training Accuracy	**Validation Accuracy**	**Testing Accuracy**
0.7687	0.8131	0.8042

Model 2 : Confusion Matrix – CNN with Data Augmentation

- Based on the Model 2 – Confusion Matrix, following are the key observations:
  - Only 7 times Black-grass was correctly classified as Black-grass, whereas 14 times Black-grass was misclassified as Loose Silky-bent
  - 37 times Charlock was correctly classified as Charlock, whereas once Charlock was misclassified as Cleavers and Sugar beet
  - 20 times Cleavers was correctly classified as Cleavers, whereas 4 times it was misclassified as Scentless Mayweed
  - 55 times Common Chickweed was correctly classified as Common Chickweed, whereas twice it was misclassified as Scentless Mayweed & Shepherds Purse
  - 14 times Common Wheat was correctly classified as Common Wheat, whereas 4 times it was misclassified as Loose Silky-bent
  - 38 times Fat Hen was correctly classified as Fat Hen, whereas 3 times it was misclassified as Sugar beet and 6 times as others
  - 56 times Loose Silky-bent was correctly classified as Loose Silky-bent, whereas 6 times it was misclassified as Black-grass and 2 times as Scentless Mayweed
  - 21 times Maize was classified as Maize but once misclassified as Scentless Mayweed



Model 2 : Confusion Matrix – CNN with Data Augmentation

- **Model 2 – Confusion Matrix (Cont'd):**
  - 46 times Scentless Mayweed has been correctly classified as Scentless Mayweed, whereas 2 times it was misclassified as Sugar beet
  - 14 times Shepherds Purse has been correctly classified as Shepherds Purse, whereas 4 times it has been misclassified as Scentless Mayweed
  - 44 times Small-Flowered Cranesbill has been correctly classified as Small-Flowered Cranesbill, whereas 3 times it has been misclassified as Maize, and 3 times as others
  - 30 times Sugar beet has been correctly classified as Sugar beet, whereas 2 times as Small-Flowered Cranesbill & Fat Hen and 4 times as others

Model 2 Classification Report : CNN with Data Augmentation

- As per the classification report, the Model 2 CNN with Data Augmentation (Revised Model) has delivered the following performance scores:

Macro Average Scores:

- Precision : 79%
- Recall : 77%
- F1 : 77%

Weighted Average Scores:

- Precision : 80%
- Recall : 80%
- F1 : 80%

Classification Report - CNN with Data Augmentation (Revised Model)				
	Precision	**Recall**	**F1**	**Support**
0	0.47	0.27	0.34	26
1	0.86	0.95	0.90	39
2	0.83	0.69	0.75	29
3	0.95	0.90	0.92	61
4	0.74	0.64	0.68	22
5	0.86	0.79	0.83	48
6	0.73	0.86	0.79	65
7	0.75	0.95	0.84	22
8	0.74	0.88	0.81	52
9	0.82	0.61	0.70	23
10	0.88	0.88	0.88	50
11	0.79	0.79	0.79	38
Accuracy			0.80	475
Macro Avg	0.79	0.77	0.77	475
Weighted Avg	0.80	0.80	0.80	475

Model Feature Comparison Summary

- Following is the feature comparison summary of the 2 models that were used on the training, validation and the testing dataset

Model	Model Attributes											Model Parameters		
	Layer Type	No of Layers	No of Neurons	Kernel Size	Activation	Padding	Optimizer	Loss	Metric	Drop Out	Batch Normalize	Total	Trainable	Non Trainable
Model 1 : CNN without Data Augmentation (Initial Model)	Input & Conv2D	3	128,.64 & 32	3x3	Relu	Same	Adam	Categorical Cross Entropy	Accuracy	0.3	No	128828	128828	0
	MaxPooling	3	-	2x2	-	Same								
	Flatten & Fully Connected	2	16	-	Relu	-								
	Output	1	12	-	Softmax	-								
Model 2 : CNN with Data Augmentation (Revised Model)	Input & Conv2D	2	64 & 32	3x3	Relu	Same	Adam	Categorical Cross Entropy	Accuracy	0.3	Yes	151676	151612	64
	MaxPooling	2	-	2x2		Same								
	Flatten & Fully Connected	2	16	-	Relu	-								
	Output	1	12	-	Softmax	-								

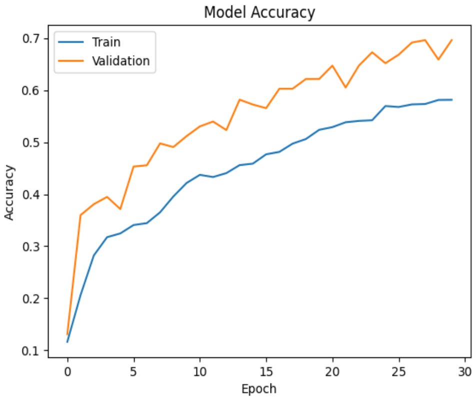
Model Performance Comparison Summary – Accuracy Metric

- Following is the performance metric summary of the 2 models on the Training, Validation and testing datasets. Model 1: CNN without Data Augmentation (Initial Model) has delivered an Accuracy score of 58.15% and 72.42% on the Training & Testing dataset respectively, whereas Model 2 : CNN with Data Augmentation (Revised Model) has delivered an Accuracy score of 76.87% & 80.42% on the Training & Testing dataset, respectively.

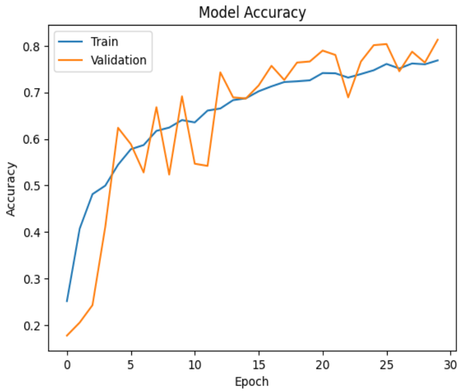
- Based on our key criteria - Accuracy, **Model 2 : CNN with Data Augmentation (Revised Model) has the best performance and has been used for visualising the plant species prediction.** It can be observed from the graphs that Model 2 faces a potential exploding gradient which can be further improvised by tuning model hyperparameters such as 1) Number Of Filters, 2) Filter Size, 3) Activation Function and 4) Drop Out Ratio

#	Model Type	Key Performance Metrics		
		Training Accuracy	Validation Accuracy	Testing Accuracy
1	Model 1 : CNN without Data Augmentation (Initial Model)	0.5815	0.6963	0.7242
2	Model 2 : CNN with Data Augmentation (Revised Model) 1	0.7687	0.8131	0.8042

Model 1 : CNN without Data Augmentation (Initial Model)



1 Model 2 : CNN with Data Augmentation (Revised Model)



Model Performance Comparison – Precision, Recall & F1 Metrics

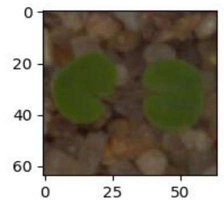
- As per the classification report, the Model 1 CNN without Data Augmentation (Initial Model) has delivered the following performance scores:
  - Precision : 63% (Macro Avg) & 67% (Weighted Avg)
  - Recall : 62% (Macro Avg) & 72% (Weighted Avg)
  - F1 : 61% (Macro Avg) & 68% (Weighted Avg)
- As per the classification report, the Model 2 CNN with Data Augmentation (Revised Model) has delivered the following performance scores:
  - Precision : 79% (Macro Avg) & 80% (Weighted Avg)
  - Recall : 77% (Macro Avg) & 80% (Weighted Avg)
  - F1 : 80% (Macro Avg) & 80% (Weighted Avg)
- Based on scores, Model 2 CNN with Data Augmentation (Revised Model) has the highest Precision, Recall & F1 score and is the best performing model

#	Model Type	Other Performance Metrics				
		Precision	Recall	F1	Support	Type
1	Model 1 : CNN without Data Augmentation (Initial Model)	0.63	0.62	0.61	475	Macro Avg
		0.67	0.72	0.68	475	Weighted Avg
2	Model 2 : CNN with Data Augmentation (Revised Model)	0.79	0.77	0.77	475	Macro Avg
		0.80	0.80	0.80	475	Weighted Avg

1

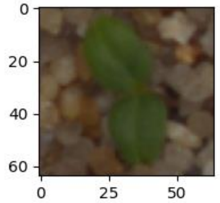
Final Model : CNN with Data Augmentation

- **Best & Final Model:** Based on the performance comparison of the 2 models and their classfication reports, **Model 2 : CNN with Data Augmentation** has delivered an **Accuracy score of 80.42% on the Testing dataset**. We have therefore considered this as our **best and final model** and used it for visualising our prediction of plant species
- **Visualising Predictions:** As observed below, the model has correctly classified 1) Small-Flowered Cranesbill as Small-Flowered Cranesbill, 2) Cleavers as Cleavers, 3) Shepherds Purse as Shepherds Purse, and 4) Common Chickweed as Common Chickweed



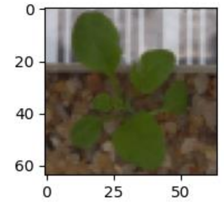
1

```
1/1 [==============================] - 0s 44ms/step
Predicted Label ['Small-flowered Cranesbill']
True Label Small-flowered Cranesbill
```



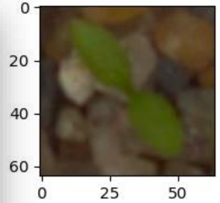
2

```
1/1 [==============================] - 0s 27ms/step
Predicted Label ['Cleavers']
True Label Cleavers
```



3

```
1/1 [==============================] - 0s 31ms/step
Predicted Label ['Shepherds Purse']
True Label Shepherds Purse
```



4

```
1/1 [==============================] - 0s 25ms/step
Predicted Label ['Common Chickweed']
True Label Common Chickweed
```

Conclusion

Conclusion

- We have built an initial CNN model using Adam as an optimizer and evaluated its performance (Accuracy) on the training, validation and testing dataset. To improve the model performance, we have built an additional CNN model using Data Augmentation and Learning Rate Reduction Techniques. We then evaluated this model's performance (Accuracy) on the training, validation and testing dataset.
  - Model 1 : CNN without Data Augmentation (Initial Model)
  - Model 2 : CNN with Data Augmentation (Revised Model)

- Based on the performance comparison (Accuracy) of all the 2 models, we have **finalised** the **best performing** model - **Model 2: CNN with Data Augmentation (Revised Model)**. This model has delivered **an Accuracy score of 76.87% & 81.31% on the Training & Validation dataset**, respectively. The model's **Accuracy score on the Testing dataset (80.42%)** is inline to the one observed on the Training & Validation datasets. This model has generalised its performance and can be considered as the final model. We have used this model to visualize predictions on the dataset.

- **Model 2: CNN with Data Augmentation (Revised Model)** can now be used to classify plant seedlings into their respective categories

- Model 2: CNN with Data Augmentation (Revised Model) performance (Accuracy) can further be improved by using different architectures and optimizers such as:
  - Use of Transfer Learning using VGG16 / VGG 19 Models for better image classification
  - Changing Model Hyperparameters such as 1) Number Of Filters, 2) Filter Size, 3) Activation Function and 4) Drop Out Ratio

Key Actionable Insights & Recommendations

Key Actionable Business Insights

- **Summarised Key Observations & Insights :**
  - There is a significant imbalance in the dataset since there are high number of images in certain classes than compared to other. Moreover, the data is limited and less varied i.e. No Slanting, Rotated etc images This implies that for the model to deliver a better performance (translationally spatially and rotationally invariant), the dataset needs to be augmented and enriched using Data Augmentation techniques. We have used ImageDataGenerator() to augment our dataset
  - The best performing model – **Model 2: CNN with Data Augmentation has delivered an Accuracy of 80.42% on the Testing dataset**. However, this performance can further be improved by a) Adding additional layers with a combination of MaxPooling and Batch Normalisation; b) by tuning the hyperparameters such a drop out ratio, number of filters and filter size, and using different activation functions; and c) by increasing the number of epochs
  - Reducing the learning rate allowed the optimizer to take smaller steps to reach the global minimum, which increased the rate of convergence. We have used ReduceLRonPlateau() to reduce the learning rate when the validation accuracy stopped improving. This has benefitted our Model 2 performance
  - Confusion Matrix delivered better results in Model 2: CNN with Data Augmentation (Revised Model) than compared to Model 1: CNN without Data Augmentation (Initial Model)
  - Accuracy was much higher in Model 2: CNN with Data Augmentation (80.42%) than compared to Model 1: CNN without Data Augmentation (72.42%). Also, other metrics such as Precision, Recall & F1 score were much higher in Model 2 than compared to Model 1
  - Model 2: CNN with Data Augmentation performance can be further enhanced by using transfer learning techniques and adopting proven models such as VGG16 / VGG 19. These models have already been pre-trained using massive datasets and on high computing GPU. Adopting layers / parameters of such models can greatly enhance Model 2 performance

Our Recommendation

Based on the key observations and insights, we recommend the following areas of improvement / opportunities that will lead to a better plant species classification

- **Implement Transfer Learning Techniques:** Adopt VGG16 / VGG19 pre-trained models and fine tune Model 2 performance by adding more layers and/or adjusting hyperparameters
- **Implement Data Augmentation Techniques:** Use data augmentation techniques to add and enrichen the dataset in order to improve model performance. CNN models trained on such datasets are proven to be spatially, translationally and rotationally invariant and deliver better predictions

APPENDIX

Appendix - Notes

Great Learning

Happy Learning !