

Plant Leaf Diseases Diagnosis with Deep Learning

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Why This Project?

Automated Agricultural Systems



<https://images.pexels.com/photos/96715/pexels-photo-96715.jpeg?cs=srgb&dl=pexels-alejandro-barr%C3%B3n-96715.jpg&fm=jpg>

Mobile App for Houseplant Hobbyists



https://hips.hearstapps.com/hmg-prod/images/man-watering-houseplants-royalty-free-image-1678736179.jpg?crop=0.668xw:1.00xh;0.136xw,0&resize=640:*

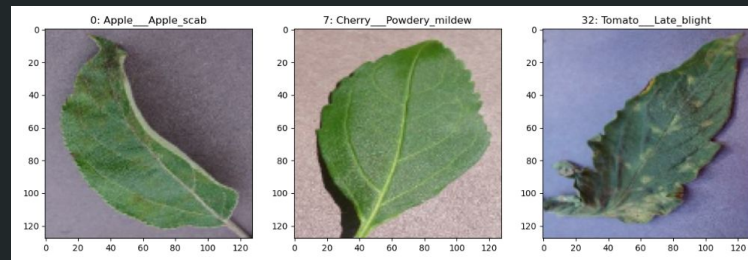


Data

Images of Plant Leaves

- Source: [Mendeley Data](#), originally from a journal paper.¹
- Total Class: 39, including 1 background (not plants)
- Total Images: 61,486
- Total Species: 15

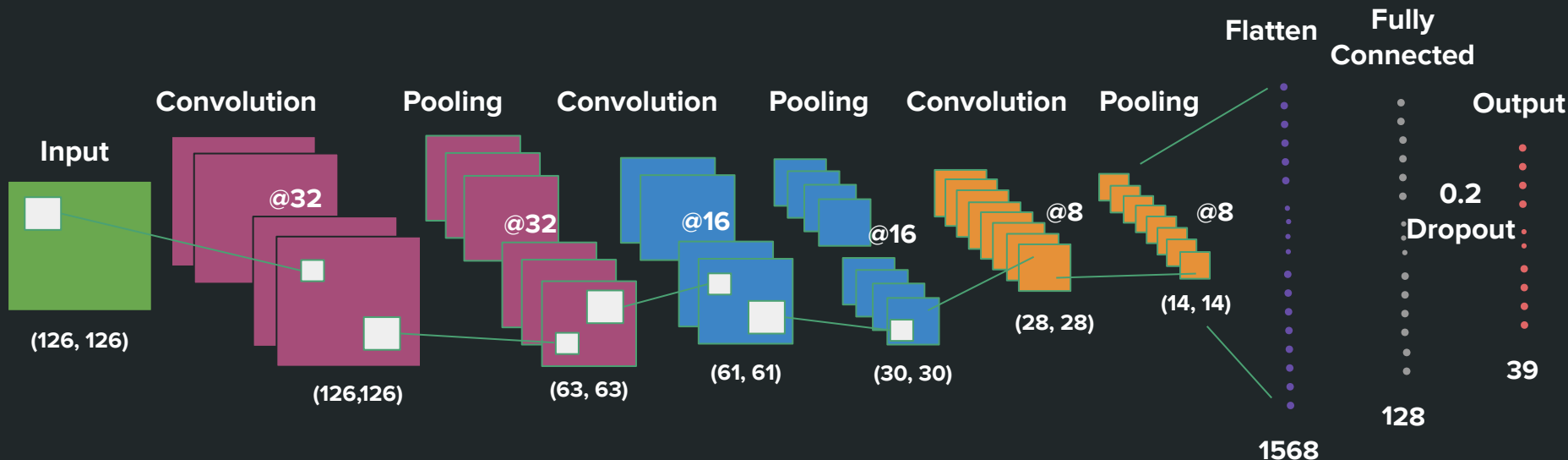
| | | | | | | | | | | |
|------------|--------|-----------|--------|--------|--------|-------|-----------|------------|--|--|
| Crops | Corn | Soybean | | | | | | | | |
| Vegetables | Pepper | Potato | Squash | Tomato | | | | | | |
| Fruits | Apple | Blueberry | Cherry | Grape | Orange | Peach | Raspberry | Strawberry | | |



¹Geetharamani G., Arun Pandian J., "Identification of plant leaf diseases using a nine-layer deep convolutional neural network", Computers & Electrical Engineering, V76, p323-338, June 2019

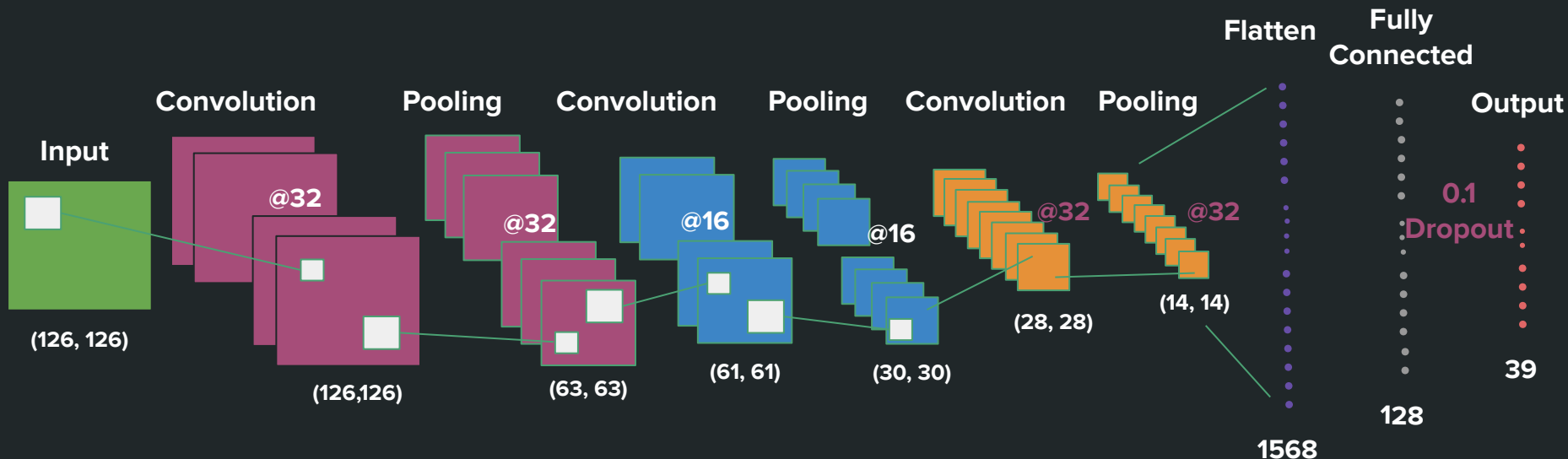
Method

Convolutional Neural Network (original)



A 9-layer structure same as in the journal paper

Convolutional Neural Network (tuned)



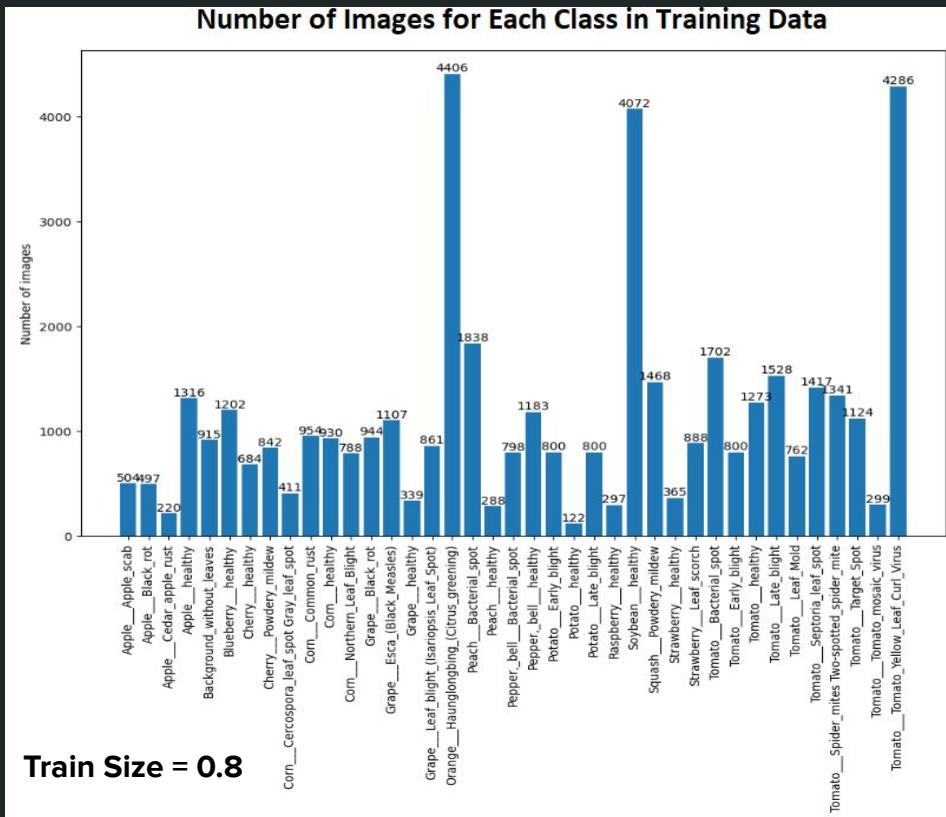
After hyper-parameter tuning

Data Challenges

Imbalance Class

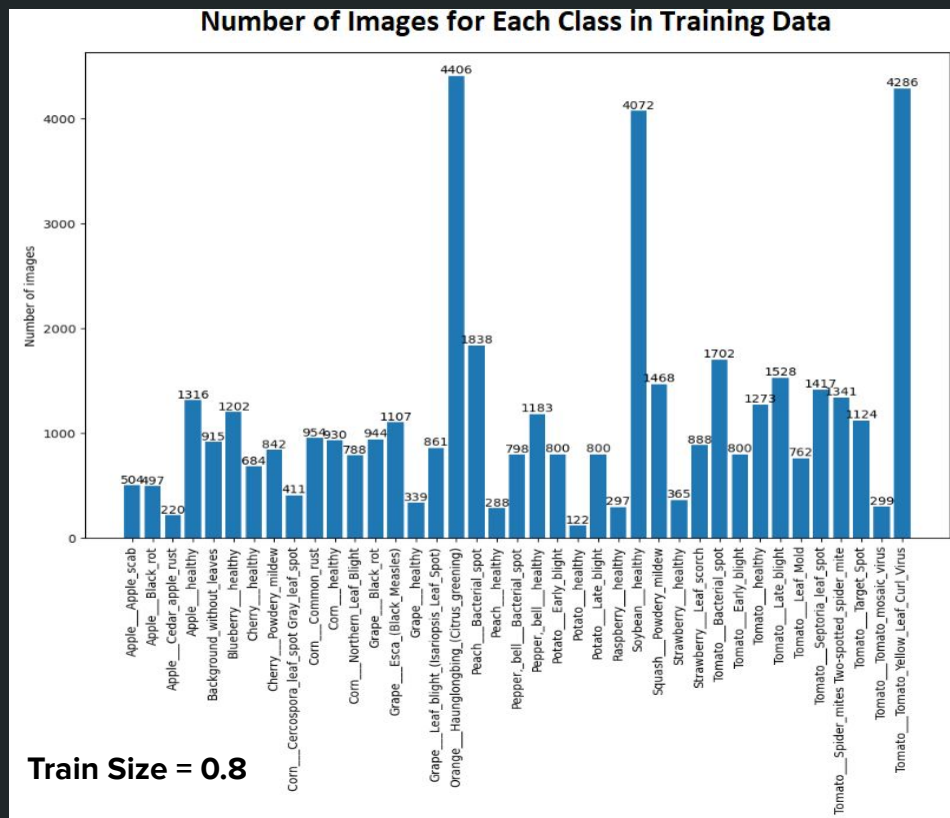
Wavy distribution

Varies from 122 to 4406



Insufficient Data

Potato_heathy only has 122 images in the training data.



Solutions

Hybrid approaches listed below:

| Approaches | Upsampling (Data Augmentation*) | Data Ensembling (Bootstrapping) | Model Ensembling (Bagging) | Data Imbalanced | Class Sample Size |
|------------|------------------------------------|------------------------------------|-------------------------------|--------------------|----------------------|
| 1 | No | No | No | Yes | 122-4406 |
| 2 | Yes | No | No | Yes | 915-4406 |
| 3 | No | Yes (5 times) | Yes (5 times) | No | 200 |
| 4 | Yes | Yes (5 times) | Yes (5 times) | No | 900 |

* *Data augmentation: rotating, flipping, scaling, adding noises, etc. of existing data.*

Models & Evaluation

Original CNN

Model Metrics (original CNN)

TensorFlow.Keras.Models

```
# create a model
model = Sequential()
# Add layers to the model
model.add(Conv2D(32, (3,3), 1, activation = 'relu', input_shape = (128,128,3)))
model.add(MaxPooling2D())
model.add(Conv2D(16, (3,3), 1, activation = 'relu'))
model.add(MaxPooling2D())
model.add(Conv2D(8, (3,3), 1, activation = 'relu'))
model.add(MaxPooling2D())
model.add(Flatten())
model.add(Dense(128, activation = 'relu'))
model.add(Dropout(0.2))
model.add(Dense(39, activation = 'softmax'))
# compile the model
model.compile('adam', loss = 'sparse_categorical_crossentropy', metrics = ['accuracy'])
# train the model
model.fit(train, epochs = 15, validation_data = val)
```



Model Evaluation

| Models | Accuracy | Cross Entropy | Upsampling (Data Augmentation) | Data Ensembling (Bootstrapping) | Model Ensembling (Bagging) | Data Imbalanced | Class Sample Size |
|--------|----------|---------------|--------------------------------|---------------------------------|----------------------------|-----------------|-------------------|
| 1 | 0.871 | 0.426 | No | No | No | Yes | 122-4406 |
| 2 | 0.858 | 0.452 | Yes | No | No | Yes | 915-4406 |
| 3 | 0.795* | 0.853* | No | Yes (5 times) | Yes (5 times) | No | 200 |
| 4 | 0.883* | 0.460* | Yes | Yes (5 times) | Yes (5 times) | No | 900 |

** Majority vote was used for Model 3 and Model 4*

Winner: Model 1 & Model 4

Classification Reports

Testing Data also imbalanced

Classification Reports are helpful

Upsampling + Ensembling
(Model 4)

Performs better for most classes
with less images

Except for Potato_healthy(23),
which has too less images

Model 1

Model 4

| | precision | recall | f1-score | support | | precision | recall | f1-score | support |
|--------------|-----------|--------|----------|---------|--------------|-----------|--------|----------|---------|
| 0 | 0.80 | 0.65 | 0.72 | 126 | 0 | 0.69 | 0.80 | 0.74 | 126 |
| 1 | 0.77 | 0.85 | 0.81 | 124 | 1 | 0.80 | 0.85 | 0.83 | 124 |
| 2 | 0.74 | 0.36 | 0.49 | 55 | 2 | 0.71 | 0.64 | 0.67 | 55 |
| 3 | 0.74 | 0.88 | 0.80 | 329 | 3 | 0.80 | 0.79 | 0.79 | 329 |
| 4 | 0.91 | 0.89 | 0.90 | 228 | 4 | 0.92 | 0.89 | 0.90 | 228 |
| 5 | 0.92 | 0.89 | 0.90 | 300 | 5 | 0.90 | 0.94 | 0.92 | 300 |
| 6 | 0.91 | 0.79 | 0.84 | 210 | 6 | 0.91 | 0.95 | 0.93 | 210 |
| 7 | 0.87 | 0.88 | 0.87 | 170 | 7 | 0.84 | 0.92 | 0.88 | 170 |
| 8 | 0.58 | 0.66 | 0.61 | 102 | 8 | 0.67 | 0.54 | 0.60 | 102 |
| 9 | 0.97 | 1.00 | 0.98 | 238 | 9 | 0.95 | 1.00 | 0.97 | 238 |
| 10 | 0.87 | 0.65 | 0.75 | 197 | 10 | 0.80 | 0.86 | 0.83 | 197 |
| 11 | 0.97 | 0.98 | 0.98 | 232 | 11 | 0.97 | 0.99 | 0.98 | 232 |
| 12 | 0.88 | 0.84 | 0.86 | 236 | 12 | 0.83 | 0.92 | 0.87 | 236 |
| 13 | 0.93 | 0.92 | 0.93 | 276 | 13 | 0.95 | 0.91 | 0.93 | 276 |
| 14 | 0.93 | 0.94 | 0.94 | 215 | 14 | 0.95 | 0.96 | 0.96 | 215 |
| 15 | 0.94 | 0.80 | 0.86 | 84 | 15 | 0.92 | 0.92 | 0.92 | 84 |
| 16 | 0.97 | 0.98 | 0.98 | 1101 | 16 | 0.97 | 0.96 | 0.97 | 1101 |
| 17 | 0.89 | 0.85 | 0.87 | 459 | 17 | 0.90 | 0.85 | 0.88 | 459 |
| 18 | 0.84 | 0.88 | 0.86 | 72 | 18 | 0.78 | 0.88 | 0.82 | 72 |
| 19 | 0.75 | 0.69 | 0.72 | 199 | 19 | 0.66 | 0.84 | 0.74 | 199 |
| 20 | 0.94 | 0.81 | 0.87 | 295 | 20 | 0.80 | 0.91 | 0.85 | 295 |
| 21 | 0.86 | 0.94 | 0.90 | 200 | 21 | 0.88 | 0.95 | 0.92 | 200 |
| 22 | 0.72 | 0.70 | 0.71 | 200 | 22 | 0.80 | 0.72 | 0.76 | 200 |
| 23 | 0.79 | 0.73 | 0.76 | 30 | 23 | 0.69 | 0.60 | 0.64 | 30 |
| 24 | 0.78 | 0.80 | 0.79 | 74 | 24 | 0.95 | 0.82 | 0.88 | 74 |
| 25 | 0.92 | 0.98 | 0.95 | 1018 | 25 | 0.99 | 0.93 | 0.96 | 1018 |
| 26 | 0.89 | 0.93 | 0.91 | 367 | 26 | 0.93 | 0.96 | 0.95 | 367 |
| 27 | 0.90 | 0.81 | 0.85 | 221 | 27 | 0.92 | 0.84 | 0.88 | 221 |
| 28 | 0.92 | 0.86 | 0.89 | 91 | 28 | 0.87 | 0.90 | 0.89 | 91 |
| 29 | 0.91 | 0.87 | 0.89 | 425 | 29 | 0.90 | 0.83 | 0.86 | 425 |
| 30 | 0.65 | 0.46 | 0.53 | 200 | 30 | 0.53 | 0.67 | 0.59 | 200 |
| 31 | 0.78 | 0.65 | 0.71 | 381 | 31 | 0.75 | 0.76 | 0.75 | 381 |
| 32 | 0.81 | 0.64 | 0.71 | 190 | 32 | 0.77 | 0.75 | 0.76 | 190 |
| 33 | 0.59 | 0.81 | 0.68 | 354 | 33 | 0.81 | 0.70 | 0.75 | 354 |
| 34 | 0.81 | 0.90 | 0.85 | 335 | 34 | 0.89 | 0.84 | 0.87 | 335 |
| 35 | 0.81 | 0.83 | 0.82 | 280 | 35 | 0.83 | 0.84 | 0.84 | 280 |
| 36 | 0.94 | 0.97 | 0.96 | 1071 | 36 | 0.96 | 0.94 | 0.95 | 1071 |
| 37 | 0.82 | 0.92 | 0.87 | 74 | 37 | 0.95 | 0.93 | 0.94 | 74 |
| 38 | 0.90 | 0.98 | 0.94 | 318 | 38 | 0.97 | 0.97 | 0.97 | 318 |
| accuracy | | | 0.87 | 11077 | accuracy | | | 0.88 | 11077 |
| macro avg | 0.84 | 0.82 | 0.83 | 11077 | macro avg | 0.85 | 0.85 | 0.85 | 11077 |
| weighted avg | 0.87 | 0.87 | 0.87 | 11077 | weighted avg | 0.89 | 0.88 | 0.88 | 11077 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-----|-----|----|-----|-----|-----|-----|---|---|---|---|---|-----|-----|-----|----|----|-----|-----|-----|-----|---|----|-----|---|----|---|-----|----|-----|----|-----|-----|-----|-----|----|-----|-----|----|----|----|---|---|---|---|---|
| Apple__Apple_scab | -82 | 4 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | 4 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 3 | 5 | 0 | 0 | 0 | 0 | 1 | | | | | |
| Apple__Black_rot | -1 | 106 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | | | | |
| Apple__Cedar_apple_rust | -0 | 0 | 20 | 0 | 0 | 0 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 0 | 11 | 0 | 0 | 0 | | | | | |
| Apple__healthy | -4 | 3 | 0 | 209 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 1 | 2 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 2 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | | | | |
| Background_without_leaves | -0 | 0 | 0 | 3 | 203 | 0 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 1 | 0 | 0 | | | | |
| Blueberry__healthy | -3 | 2 | 0 | 10 | 0 | 266 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 3 | 7 | 2 | 1 | 0 | 0 | 0 | 0 | | | | |
| Cherry__healthy | -1 | 1 | 3 | 10 | 0 | 0 | 185 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 2 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | | | | |
| Cherry__Powdery_mildew | -0 | 1 | 0 | 0 | 0 | 1 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | | |
| Corn__Cercospora_leaf_spot Gray_leaf_spot | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 2 | 13 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | | |
| Corn__Common_rust | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 237 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Corn__healthy | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 129 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | | |
| Corn__Northern_Leaf_Blight | -0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 227 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Grape__Black_rot | -0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 199 | 17 | 9 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | | |
| Grape__Esca_(Black_Measles) | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 254 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | |
| Grape__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 202 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | |
| Grape__Leaf_blight_(Isariopsis_Leaf_Spot) | -0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Orange__Haunglongbing_(Citrus_greening) | -0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 5 | 0 | 0 | | |
| Peach__Bacterial_spot | -2 | 3 | 1 | 11 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 360 | 1 | 2 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 7 | 5 | 5 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | |
| Peach__healthy | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | |
| Pepper__bell__Bacterial_spot | -1 | 5 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 | 0 | 138 | 7 | 2 | 2 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 20 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | |
| Pepper__bell__healthy | -0 | 0 | 0 | 0 | 0 | 3 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 239 | 0 | 0 | 1 | 7 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Potato__Early_blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 189 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Potato__Late_blight | -2 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 5 | 0 | 2 | 141 | 1 | 0 | 3 | 1 | 2 | 1 | 1 | 2 | 6 | 0 | 16 | 1 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | | |
| Potato__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 22 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Raspberry__healthy | -0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 59 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| Soybean__healthy | -0 | 0 | 0 | 5 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 0 |
| Squash__Powdery_mildew | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 342 | 2 | 0 | 3 | 0 | 3 | 0 | 4 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 0 | | |
| Strawberry__healthy | -0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 180 | 2 | 0 | 0 | 4 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Strawberry__Leaf_scorch | -1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 78 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Tomato__Bacterial_spot | -1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 6 | 1 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 15 | 1 | 2 | 15 | 0 | 1 | 0 | 0 | 0 | | |
| Tomato__Early_blight | -0 | 1 | 0 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 2 | 8 | 0 | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 91 | 11 | 0 | 19 | 12 | 15 | 11 | 1 | 0 | 0 | | |
| Tomato__healthy | -0 | 2 | 1 | 7 | 2 | 0 | 3 | 0 | 0 | 5 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | 4 | 3 | 6 | 2 | 6 | 13 | 0 | 3 | 1 | 3 | 4 | 0 | 0 | 16 | 206 | 3 | 28 | 3 | 1 | 4 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | | |
| Tomato__Late_blight | -1 | 1 | 0 | 11 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 121 | 20 | 11 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | | | |
| Tomato__Leaf_Mold | -0 | 5 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 5 | 3 | 1 | 1 | 2 | 2 | 1 | 7 | 6 | 2 | 8 | 285 | 6 | 2 | 0 | 4 | 3 | 0 | 0 | 0 | 0 | | | |
| Tomato__Septoria_leaf_spot | -0 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 300 | 16 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | | | |
| Tomato__Spider_mites Two-spotted_spider_mite | -1 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 14 | 233 | 0 | 2 | 13 | 0 | 0 | 0 | | | |
| Tomato__Target_Spot | -0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 1 | 9 | 0 | 104 | 1 | 0 | 0 | 0 | 0 | | | |
| Tomato__Tomato_mosaic_virus | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | |
| Tomato__Tomato_Yellow_Leaf_Curl_Virus | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 |

Confusion Matrix

Model 1

Misclassification within
the same species

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|------|-----|----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|---|----|---|----|----|-----|----|-----|---|---|---|---|-----|---|---|----|-----|----|----|-----|-----|---|---|---|---|---|---|---|
| Apple__Apple_scab | -101 | 3 | 2 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | | |
| Apple__Black_rot | -1 | 106 | 0 | 7 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | | |
| Apple__Cedar_apple_rust | -0 | 0 | 35 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 3 | 0 | | |
| Apple__healthy | -15 | 6 | 0 | 259 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 4 | 5 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 5 | 2 | 1 | 3 | 0 | 0 | | |
| Background_without_leaves | -2 | 0 | 0 | 2 | 203 | 0 | 0 | 0 | 1 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | | |
| Blueberry__healthy | -0 | 0 | 0 | 5 | 0 | 263 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | | |
| Cherry__healthy | -1 | 0 | 1 | 1 | 0 | 0 | 200 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | | |
| Cherry__Powdery_mildew | -0 | 2 | 0 | 0 | 0 | 0 | 0 | 157 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Corn__Cercospora_leaf_spot Gray_leaf_spot | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 55 | 6 | 33 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Corn__Common_rust | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 257 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Corn__healthy | -0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 16 | 0 | 169 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Corn__Northern_Leaf_Blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 230 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Grape__Black_rot | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 216 | 11 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Grape__Esca_(Black_Measles) | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 252 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Grape__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 297 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Grape__Leaf_blight_(Isariopsis_Leaf_Spot) | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| Orange__Haunglongbing_(Citrus_greening) | -2 | 0 | 1 | 2 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 3 | 1 | 0 | 6 | 0 | |
| Peach__Bacterial_spot | -9 | 0 | 3 | 4 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 36 | 2 | 8 | 7 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 4 | 12 | 3 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | | |
| Peach__healthy | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 63 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Pepper__bell__Bacterial_spot | -1 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 167 | 10 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | |
| Pepper__bell__healthy | -0 | 2 | 0 | 0 | 0 | 1 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 269 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Potato__Early_blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 191 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Potato__Late_blight | -6 | 0 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 6 | 1 | 4 | 144 | 5 | 0 | 0 | 0 | 1 | 2 | 0 | 5 | 11 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Potato__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 4 | 18 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Raspberry__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | |
| Soybean__healthy | -2 | 3 | 0 | 9 | 1 | 1 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 2 | 26 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 0 |
| Squash__Powdery_mildew | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Strawberry__healthy | -0 | 0 | 0 | 7 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 196 | 3 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Strawberry__Leaf_scorch | -2 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Tomato__Bacterial_spot | -2 | 0 | 1 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 0 | 5 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tomato__Early_blight | -0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Tomato__healthy | -0 | 0 | 4 | 2 | 1 | 0 | 1 | 0 | 2 | 7 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 3 | 0 | 5 | 6 | 8 | 0 | 0 | 0 | 1 | 5 | 0 | 1 | 29 | 200 | 5 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | | | |
| Tomato__Late_blight | -0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 143 | 17 | 6 | 0 | 1 | 0 | 0 | | |
| Tomato__Leaf_Mold | -2 | 5 | 0 | 1 | 0 | 3 | 0 | 5 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 7 | 4 | 3 | 1 | 7 | 7 | 1 | 1 | 0 | 0 | 7 | 0 | 3 | 15 | 7 | 14 | 248 | 0 | 4 | 1 | 2 | 1 | 0 | | |
| Tomato__Septoria_leaf_spot | -0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 12 | 2 | 3 | 2 | 282 | 20 | 6 | 1 | 0 | 0 | | | |
| Tomato__Spider_mites Two-spotted_spider_mite | -0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 7 | 3 | 0 | 2 | 13 | 236 | 0 | 0 | 0 | 0 | | | |
| Tomato__Target_Spot | -0 | 0 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 15 | 11 | 2 | 2 | 0 | 30 | 0 | 0 | 0 | 0 | | | |
| Tomato__Tomato_mosaic_virus | -0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Tomato_Yellow_Leaf_Curl_Virus | -0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |

Confusion Matrix

Model 4

Misclassification within
the same species

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-----|-----|----|-----|-----|-----|-----|----|-----|-----|---|-----|-----|-----|----|---|---|-----|-----|-----|---|----|-----|-----|----|----|-----|-----|---|----|-----|-----|-----|-----|-----|-----|----|-----|---|---|---|---|
| Apple__Apple_scab | -82 | 4 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | 4 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 3 | 5 | 0 | 0 | 0 | 0 | 1 | |
| Apple__Black_rot | -1 | 106 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | | |
| Apple__Cedar_apple_rust | -0 | 0 | 20 | 0 | 0 | 0 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 0 | 11 | 0 | 0 | | | |
| Apple__healthy | -4 | 3 | 0 | 209 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 1 | 2 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 2 | 1 | 2 | 0 | 0 | 1 | | | |
| Background_without_leaves | -0 | 0 | 0 | 3 | 203 | 0 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | |
| Blueberry__healthy | -3 | 2 | 0 | 10 | 0 | 266 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 3 | 7 | 2 | 1 | 0 | 0 | | |
| Cherry__healthy | -1 | 1 | 3 | 10 | 0 | 0 | 165 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 2 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | | | | |
| Cherry__Powdery_mildew | -0 | 1 | 0 | 0 | 0 | 1 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | | | |
| Corn__Cercospora_leaf_spot Gray_leaf_spot | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 2 | 13 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Corn__Common_rust | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 237 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | |
| Corn__healthy | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 45 | 0 | 129 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Corn__Northern_Leaf_Blight | -0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 227 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Grape__Black_rot | -0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 199 | 17 | 9 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | | |
| Grape__Esca_(Black_Measles) | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 254 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | |
| Grape__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 202 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | | |
| Grape__Leaf_blight_(Isariopsis_Leaf_Spot) | -0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Orange__Haunglongbing_(Citrus_greening) | -0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 5 | 0 |
| Peach__Bacterial_spot | -2 | 3 | 1 | 11 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 369 | 1 | 2 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 7 | 5 | 5 | 6 | 0 | 0 | 1 | 0 | 0 | | |
| Peach__healthy | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | | | |
| Pepper__bell__Bacterial_spot | -1 | 5 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 | 0 | 138 | 7 | 2 | 2 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 20 | 2 | 2 | 1 | 1 | 0 | 0 | | | |
| Pepper__bell__healthy | -0 | 0 | 0 | 0 | 0 | 3 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 239 | 0 | 0 | 1 | 7 | 21 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | | | |
| Potato__Early_blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 189 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | | |
| Potato__Late_blight | -2 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 5 | 0 | 2 | 141 | 1 | 0 | 3 | 1 | 2 | 1 | 1 | 2 | 6 | 0 | 16 | 1 | 5 | 0 | 0 | 1 | | | |
| Potato__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 22 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Raspberry__healthy | -0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 1 | 59 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | | |
| Soybean__healthy | -0 | 0 | 0 | 5 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | | |
| Squash__Powdery_mildew | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 342 | 2 | 0 | 3 | 0 | 3 | 0 | 4 | 0 | 0 | 1 | 0 | 5 | | |
| Strawberry__healthy | -0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 11 | 180 | 2 | 0 | 0 | 4 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Strawberry__Leaf_scorch | -1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 76 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | | | |
| Tomato__Bacterial_spot | -1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 6 | 1 | 2 | 0 | 356 | 0 | 3 | 0 | 15 | 1 | 2 | 15 | 0 | 1 | | |
| Tomato__Early_blight | -0 | 1 | 0 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 2 | 8 | 0 | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 95 | 11 | 0 | 19 | 12 | 15 | 11 | 1 | 0 | | |
| Tomato__healthy | -0 | 2 | 1 | 7 | 2 | 0 | 3 | 0 | 0 | 5 | 2 | 1 | 2 | 1 | 1 | 0 | 4 | 3 | 6 | 2 | 6 | 13 | 0 | 3 | 1 | 3 | 4 | 0 | 0 | 18 | 506 | 3 | 28 | 3 | 1 | 4 | 0 | 8 | 0 | | | |
| Tomato__Late_blight | -1 | 1 | 0 | 11 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 121 | 26 | 11 | 1 | 0 | 1 | 1 | | | | |
| Tomato__Leaf_Mold | -0 | 5 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 5 | 3 | 1 | 1 | 2 | 2 | 1 | 7 | 6 | 2 | 8 | 285 | 6 | 2 | 0 | 4 | 3 | | | | |
| Tomato__Septoria_leaf_spot | -0 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 300 | 16 | 2 | 3 | 2 | | | | |
| Tomato__Spider_mites Two-spotted_spider_mite | -1 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 14 | 233 | 0 | 2 | 13 | | | | |
| Tomato__Target_Spot | -0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 9 | 0 | 104 | 1 | 0 | | | | |
| Tomato__Tomato_mosaic_virus | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 68 | 0 | | | | |
| Tomato__Tomato_Yellow_Leaf_Curl_Virus | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 312 | | | | |

Confusion Matrix

Model 1

Misclassification within
the same species

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------------------|-----|----|-----|-----|-----|-----|----|----|-----|-----|----|-----|----|---|---|---|---|-----|-----|-----|-----|----|----|---|---|---|---|---|---|-----|----|----|-----|---|---|---|----|---|---|---|---|---|---|---|---|---|---|
| Apple__Apple_scab | -101 | 3 | 2 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| Apple__Black_rot | -1 | 106 | 0 | 7 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | | | | | | | |
| Apple__Cedar_apple_rust | -0 | 0 | 35 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | | | | | | |
| Apple__healthy | -15 | 6 | 0 | 259 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 4 | 5 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 5 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | | | | | | |
| Background_without_leaves | -2 | 0 | 0 | 2 | 203 | 0 | 0 | 0 | 1 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| Blueberry__healthy | -0 | 0 | 0 | 5 | 0 | 263 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| Cherry__healthy | -1 | 0 | 1 | 1 | 0 | 0 | 200 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| Cherry__Powdery_mildew | -0 | 2 | 0 | 0 | 0 | 0 | 157 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | |
| Corn__Cercospora_leaf_spot | Gray_leaf_spot | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 55 | 6 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Corn__Common_rust | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 237 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Corn__healthy | -0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 16 | 0 | 169 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Corn__Northern_Leaf_Blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 236 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Grape__Black_rot | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 216 | 11 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| Grape__Esca_(Black_Measles) | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 252 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Grape__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 297 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Grape__Leaf_blight_(Isariopsis_Leaf_Spot) | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | | | |
| Orange__Haunglongbing_(Citrus_greening) | -2 | 0 | 1 | 2 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 165 | 3 | 0 | 9 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 3 | 1 | 0 | 6 | 0 | 0 | | | | |
| Peach__Bacterial_spot | -9 | 0 | 3 | 4 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 36 | 2 | 8 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 4 | 12 | 3 | 3 | 0 | 0 | 1 | 0 | 0 | | | |
| Peach__healthy | -0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 63 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Pepper__bell__Bacterial_spot | -1 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 167 | 10 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Pepper__bell__healthy | -0 | 2 | 0 | 0 | 0 | 1 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 269 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Potato__Early_blight | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 191 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Potato__Late_blight | -6 | 0 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 6 | 1 | 4 | 144 | 5 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 5 | 11 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Potato__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 4 | 18 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Raspberry__healthy | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 61 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | |
| Soybean__healthy | -2 | 3 | 0 | 9 | 1 | 1 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 26 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 0 | 0 |
| Squash__Powdery_mildew | -0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | | | |
| Strawberry__healthy | -0 | 0 | 0 | 0 | 7 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 9 | 196 | 3 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Strawberry__Leaf_scorch | -2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Bacterial_spot | -2 | 0 | 1 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 0 | 5 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Tomato__Early_blight | -0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__healthy | -0 | 0 | 4 | 2 | 1 | 0 | 1 | 0 | 2 | 7 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 3 | 0 | 5 | 6 | 8 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 1 | 29 | 0 | 0 | 5 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Tomato__Late_blight | -0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Leaf_Mold | -2 | 5 | 0 | 1 | 0 | 3 | 0 | 5 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 7 | 4 | 3 | 1 | 7 | 7 | 1 | 1 | 0 | 0 | 7 | 0 | 3 | 15 | 7 | 14 | 248 | 0 | 4 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | | | | | |
| Tomato__Septoria_leaf_spot | -0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Spider_mites | Two-spotted_spider_mite | -0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Target_Spot | -0 | 0 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 9 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Tomato_mosaic_virus | -0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Tomato__Tomato_Yellow_Leaf_Curl_Virus | -0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |

Confusion Matrix

Model 4

Misclassification within
the same species

Models & Evaluation

Tuned CNN on Training Data 4

Model Metrics (tuned CNN)

TensorFlow.Keras.Models

```
# create a model
model = Sequential()
# Add layers to the model
model.add(Conv2D(32, (3,3), 1, activation = 'relu', input_shape = (128,128,3)))
model.add(MaxPooling2D())
model.add(Conv2D(16, (3,3), 1, activation = 'relu'))      [16, 24, 32]
model.add(MaxPooling2D())
model.add(Conv2D(32, (3,3), 1, activation = 'relu'))      [16, 24, 32]
model.add(MaxPooling2D())
model.add(Flatten())
model.add(Dense(128, activation = 'relu'))
model.add(Dropout(0.1))      [0.1, 0.2, 0.3, 0.4]
model.add(Dense(39, activation = 'softmax'))
# compile the model
model.compile('adam', loss = 'sparse_categorical_crossentropy', metrics = ['accuracy'])  ['adam', 'sgd']
# train the model
model.fit(train, epochs = 15, validation_data = val)
```



keras-tuner
keras_tuner.Hyperband

Model Evaluation

| Models | Accuracy | Cross Entropy | AUC (one over rest) |
|----------|----------|---------------|------------------------|
| original | 0.896 | 0.450 | 0.996 |
| tuned | 0.909 | 0.441 | 0.997 |

** Training data 4 (bootstrapping + augmentation; 900 images for each class) was used for both models.*

Winner: tuned model

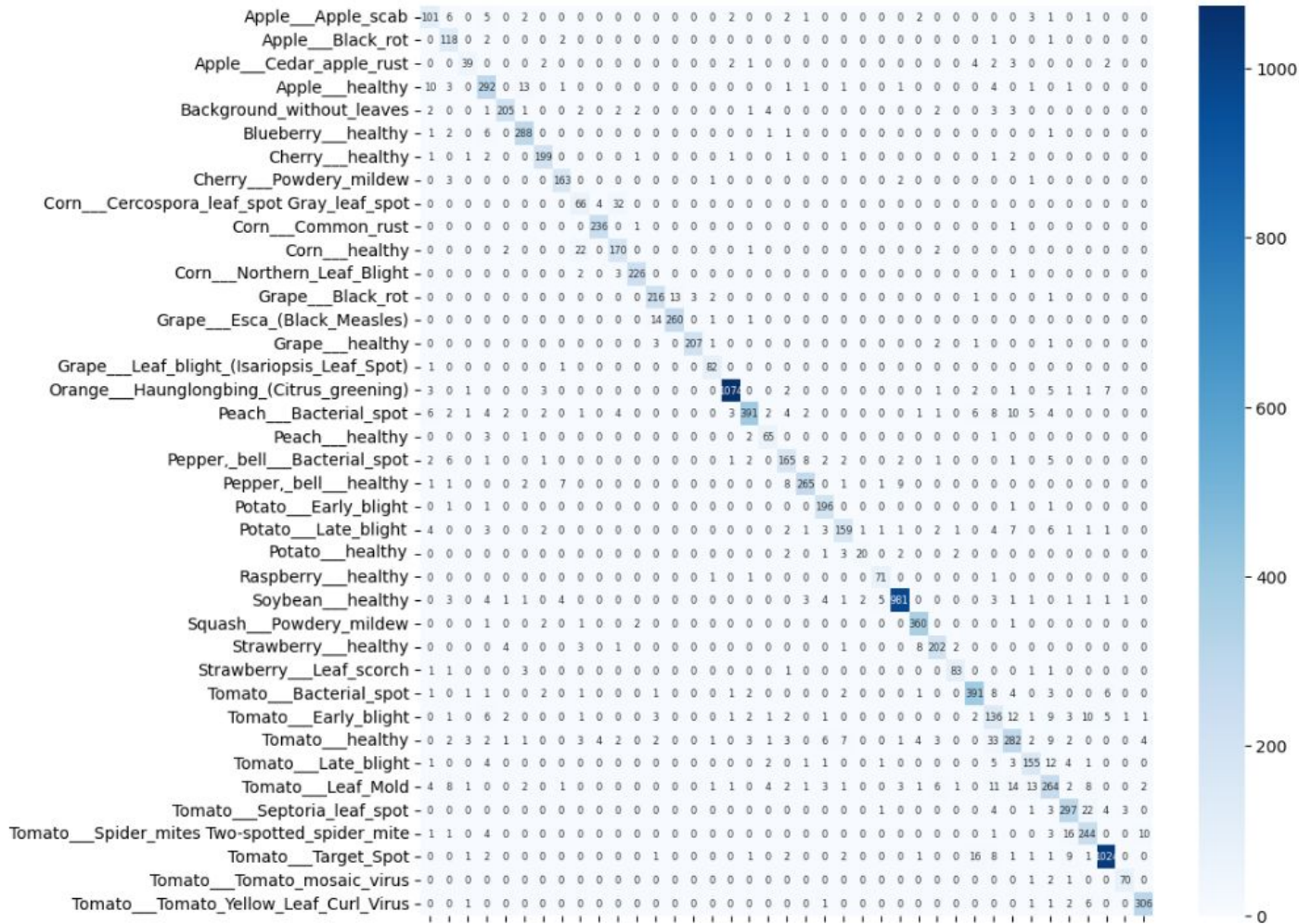
Classification Reports

Testing Data also imbalanced

Classification Reports are helpful

Tuned model performs better than the original one.

| tuned | | | | | original | | | | |
|--------------|-----------|--------|----------|---------|--------------|-----------|--------|----------|---------|
| | precision | recall | f1-score | support | | precision | recall | f1-score | support |
| 0 | 0.72 | 0.80 | 0.76 | 126 | 0 | 0.69 | 0.80 | 0.74 | 126 |
| 1 | 0.75 | 0.95 | 0.84 | 124 | 1 | 0.80 | 0.85 | 0.83 | 124 |
| 2 | 0.80 | 0.71 | 0.75 | 55 | 2 | 0.71 | 0.64 | 0.67 | 55 |
| 3 | 0.85 | 0.89 | 0.87 | 329 | 3 | 0.80 | 0.79 | 0.79 | 329 |
| 4 | 0.94 | 0.90 | 0.92 | 228 | 4 | 0.92 | 0.89 | 0.90 | 228 |
| 5 | 0.92 | 0.96 | 0.94 | 300 | 5 | 0.90 | 0.94 | 0.92 | 300 |
| 6 | 0.93 | 0.95 | 0.94 | 210 | 6 | 0.91 | 0.95 | 0.93 | 210 |
| 7 | 0.91 | 0.96 | 0.93 | 170 | 7 | 0.84 | 0.92 | 0.88 | 170 |
| 8 | 0.65 | 0.65 | 0.65 | 102 | 8 | 0.67 | 0.54 | 0.60 | 102 |
| 9 | 0.97 | 0.99 | 0.98 | 238 | 9 | 0.95 | 1.00 | 0.97 | 238 |
| 10 | 0.79 | 0.86 | 0.83 | 197 | 10 | 0.80 | 0.86 | 0.83 | 197 |
| 11 | 0.97 | 0.97 | 0.97 | 232 | 11 | 0.97 | 0.99 | 0.98 | 232 |
| 12 | 0.90 | 0.92 | 0.91 | 236 | 12 | 0.83 | 0.92 | 0.87 | 236 |
| 13 | 0.95 | 0.94 | 0.95 | 276 | 13 | 0.95 | 0.91 | 0.93 | 276 |
| 14 | 0.99 | 0.96 | 0.97 | 215 | 14 | 0.95 | 0.96 | 0.96 | 215 |
| 15 | 0.91 | 0.98 | 0.94 | 84 | 15 | 0.92 | 0.92 | 0.92 | 84 |
| 16 | 0.99 | 0.98 | 0.98 | 1101 | 16 | 0.97 | 0.96 | 0.97 | 1101 |
| 17 | 0.96 | 0.85 | 0.90 | 459 | 17 | 0.90 | 0.85 | 0.88 | 459 |
| 18 | 0.81 | 0.90 | 0.86 | 72 | 18 | 0.78 | 0.88 | 0.82 | 72 |
| 19 | 0.83 | 0.83 | 0.83 | 199 | 19 | 0.66 | 0.84 | 0.74 | 199 |
| 20 | 0.94 | 0.90 | 0.92 | 295 | 20 | 0.80 | 0.91 | 0.85 | 295 |
| 21 | 0.90 | 0.98 | 0.94 | 200 | 21 | 0.88 | 0.95 | 0.92 | 200 |
| 22 | 0.88 | 0.80 | 0.83 | 200 | 22 | 0.80 | 0.72 | 0.76 | 200 |
| 23 | 0.87 | 0.67 | 0.75 | 30 | 23 | 0.69 | 0.60 | 0.64 | 30 |
| 24 | 0.89 | 0.96 | 0.92 | 74 | 24 | 0.95 | 0.82 | 0.88 | 74 |
| 25 | 0.98 | 0.96 | 0.97 | 1018 | 25 | 0.99 | 0.93 | 0.96 | 1018 |
| 26 | 0.95 | 0.98 | 0.97 | 367 | 26 | 0.93 | 0.96 | 0.95 | 367 |
| 27 | 0.91 | 0.91 | 0.91 | 221 | 27 | 0.92 | 0.84 | 0.88 | 221 |
| 28 | 0.93 | 0.91 | 0.92 | 91 | 28 | 0.87 | 0.90 | 0.89 | 91 |
| 29 | 0.92 | 0.92 | 0.92 | 425 | 29 | 0.90 | 0.83 | 0.86 | 425 |
| 30 | 0.58 | 0.68 | 0.63 | 200 | 30 | 0.53 | 0.67 | 0.59 | 200 |
| 31 | 0.81 | 0.74 | 0.77 | 381 | 31 | 0.75 | 0.76 | 0.75 | 381 |
| 32 | 0.83 | 0.82 | 0.82 | 190 | 32 | 0.77 | 0.75 | 0.76 | 190 |
| 33 | 0.79 | 0.75 | 0.77 | 354 | 33 | 0.81 | 0.70 | 0.75 | 354 |
| 34 | 0.87 | 0.89 | 0.88 | 335 | 34 | 0.89 | 0.84 | 0.87 | 335 |
| 35 | 0.82 | 0.87 | 0.85 | 280 | 35 | 0.83 | 0.84 | 0.84 | 280 |
| 36 | 0.98 | 0.96 | 0.97 | 1071 | 36 | 0.96 | 0.94 | 0.95 | 1071 |
| 37 | 0.93 | 0.95 | 0.94 | 74 | 37 | 0.95 | 0.93 | 0.94 | 74 |
| 38 | 0.95 | 0.96 | 0.95 | 318 | 38 | 0.97 | 0.97 | 0.97 | 318 |
| accuracy | | | 0.91 | 11077 | accuracy | | | 0.88 | 11077 |
| macro avg | 0.88 | 0.89 | 0.88 | 11077 | macro avg | 0.85 | 0.85 | 0.85 | 11077 |
| weighted avg | 0.91 | 0.91 | 0.91 | 11077 | weighted avg | 0.89 | 0.88 | 0.88 | 11077 |



Confusion Matrix
tuned

Less misclassification

Takeaways

- Simple CNN model works well
- Hyper-parameter tuning improves model performance
- Image quality and quantity are key
- Bootstrapping and bagging help improve model performance



Next Steps

- Collect more data
- Reduce cost: gray scale?
- Find sweet spot for Bootstrapping sample size
- Is 5-time ensemble a good number
- More hyper-parameter tuning



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