Ninjacart CaseStudy: CV Classification

About Ninjacart

Ninjacart is India's largest fresh produce supply chain company. They are pioneers in solving one of the toughest supply chain problems of the world by leveraging innovative technology. They source fresh produce from farmers and deliver them to businesses within 12 hours.

Problem Statement

An integral component of the automation process is the development of robust classifiers which can distinguish between images of different types of vegetables, while also correctly labeling images that do not contain any one type of vegetable as noise.

Ninjacart has provided us with a dataset containing images scraped from the web.The dataset provided has images of the following food items:

- noise - Indian market
- images of vegetables - onion, potato and tomato.

This dataset contains train and test folders, each having 4 sub-folders with images of onions, potatoes, tomatoes and some market scenes.

The folder **train** has a total of 3135 images, split into four folders as follows:

> - Tomato : 789
> - Potato : 898
> - Onion : 849
> - Indian market : 599

The folder **test** has a total of 351 images, split into four folders

> - Tomato : 106
> - Potato : 83
> - Onion : 81
> - Indian market : 81

Objective

To develop a program that can recognize the vegetable item(s) in a photo and identify them for the user.

Concepts Tested:

> - Dataset Preparation & Visualization
> - CNN models
> - Implementing Callbacks
> - Deal with Overfitting
> - Transfer Learning

In [1]:
```
# importing libraries
import os
import glob
import random
import pandas as pd
import seaborn as sns
import tensorflow as tf
import matplotlib.pyplot as plt
import numpy as np
import cv2

import warnings
warnings.filterwarnings('ignore')
```

In [2]:
```
import gdown
url = 'https://drive.google.com/uc?id=1clZX-lV_MLxKHSyeyTheX5OCQtNCUcqT'
output = 'ninjacart_data.zip'
gdown.download(url, output, quiet=False)
!unzip -q ninjacart_data.zip
```

```
Downloading...
From: https://drive.google.com/uc?id=1clZX-lV_MLxKHSyeyTheX5OCQtNCUcqT
To: /content/ninjacart_data.zip
100%|████████| 275M/275M [00:04<00:00, 61.8MB/s]
```

In [3]:
```
root_dir = "/content/ninjacart_data/"
train_dir = f"{root_dir}train/"
test_dir = f"{root_dir}test/"
```

Dataset Overview & Exploratory Data Analysis

In [4]:
```
import pathlib
def count_files(rootdir):
    '''counts the number of files in each subfolder in a directory'''
    for path in pathlib.Path(rootdir).iterdir():
        if path.is_dir():
            print("     >  " + str(len([name for name in os.listdir(path) \
            if os.path.isfile(os.path.join(path, name))])) + " files in " + \
            str(path.name))
    print()


print("In Train data,there are :")
count_files(os.path.join(train_dir))
class_names = sorted(os.listdir(train_dir))
n_classes = len(class_names)
print(f"    Total number of classes: {n_classes}")
print(f"    Name of classes: {class_names}")

print("-"*50)
print("In Test data,there are :")
count_files(os.path.join(test_dir))
class_names = sorted(os.listdir(test_dir))
n_classes = len(class_names)
print(f"    Total number of classes: {n_classes}")
print(f"    Name of classes: {class_names}")
```

```
In Train data,there are :
     >  849 files in onion
     >  789 files in tomato
     >  898 files in potato
     >  599 files in indian market

    Total number of classes: 4
    Name of classes: ['indian market', 'onion', 'potato', 'tomato']
--------------------------------------------------
In Test data,there are :
     >  83 files in onion
     >  106 files in tomato
     >  81 files in potato
     >  81 files in indian market

    Total number of classes: 4
    Name of classes: ['indian market', 'onion', 'potato', 'tomato']
```

Visualization of Train data

- To visualize the data, use the dataset directory to create a list containing all the image paths in the training folder.
- Plot a grid sample of the images fetched from the list of image paths.

In [5]:
```
# Collect image paths
images = []
for folder in os.listdir(train_dir):
    for image in os.listdir(os.path.join(train_dir, folder)):
        images.append(os.path.join(train_dir, folder, image))

# Plot a random selection of images
fig, axes = plt.subplots(3,5, figsize=(14, 5))
fig.suptitle('Overview of Train data', fontsize=25)
plt.axis('off')

for ax in axes.flatten():
    # Randomly select an image
    random_img = random.choice(images)

    # Load and display the image
    img = tf.keras.utils.load_img(random_img)  # Adjust target_size as needed
    ax.imshow(img)
    ax.axis('off')

plt.show()
```

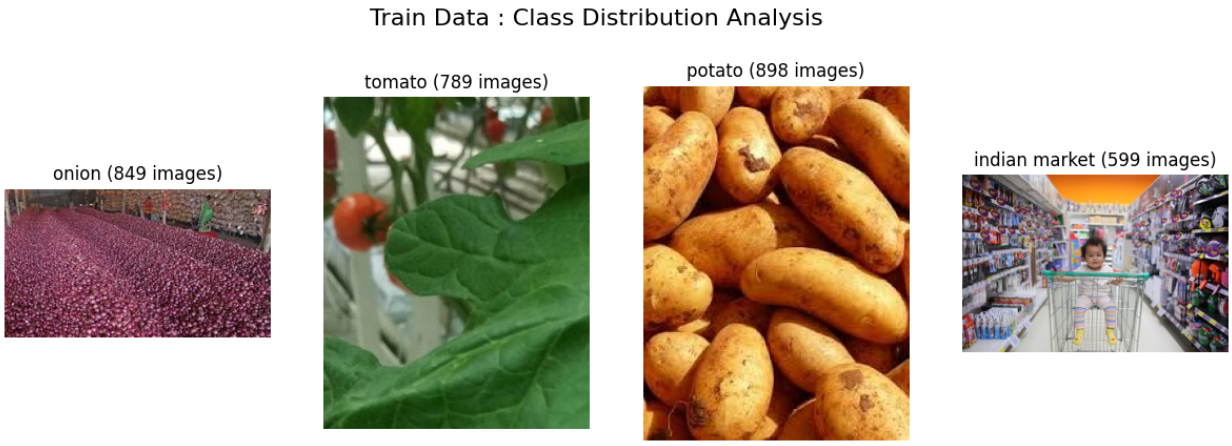
Overview of Train data

In [6]:
```
class_dirs = os.listdir(train_dir)
image_dict = {}
count_dict = {}

# iterate over all class_dirs
for cls in class_dirs:
    # get list of all paths inside the subdirectory
    file_paths = glob.glob(os.path.join(train_dir, cls, '*'))

    # count number of files in each class and add it to count_dict
    count_dict[cls] = len(file_paths)

    # select a random item from the list of image paths
    random_image_path = random.choice(file_paths)

    # load image using keras utility function and save it in image_dict
    img = tf.keras.utils.load_img(random_image_path)  # Adjust target_size as needed
    image_dict[cls] = img
```

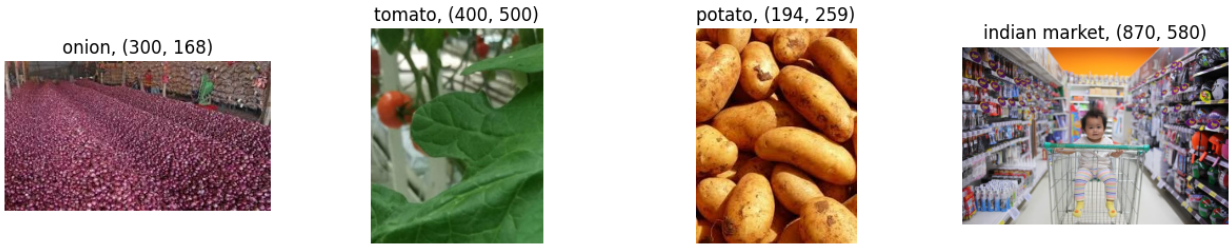
In [7]:
```
##  Data Distribution of Training Data across Classes
df_count_train = pd.DataFrame({
    "class": count_dict.keys(),     # keys of count_dict are class labels
    "count": count_dict.values(),   # value of count_dict contain counts of each class
})
print("Count of training samples per class:\n\n", df_count_train)
```

```
Count of training samples per class:

            class  count
0          onion    849
1         tomato    789
2         potato    898
3  indian market    599
```

In [8]:
```
# Plot the random images
fig, axes = plt.subplots(1, len(class_dirs), figsize=(15, 5))
fig.suptitle('Train Data : Class Distribution Analysis', fontsize=16)

for i, cls in enumerate(class_dirs):
    axes[i].imshow(image_dict[cls])
    axes[i].set_title(f'{cls} ({count_dict[cls]} images)')
    axes[i].axis('off')

plt.show()
```



In [9]:
```
# Plot the random images with dimension

fig, axes = plt.subplots(1, len(class_dirs), figsize=(15, 9))
fig.suptitle('Train Data : Random Sample Dimension Analysis', fontsize=16)

# iterate over dictionary items (class label, image array)
for i, (cls,img) in enumerate(image_dict.items()):
    # create a subplot axis
    ax = plt.subplot(3,4, i + 1)
    # plot each image
    plt.imshow(img)
    # set "class name" along with "image size" as title
    plt.title(f'{cls}, {img.size}')
    plt.axis("off")
```



Distribution of classes in Train data

In [10]:
```
import plotly.express as px
# Calculate class distribution
class_dis = [len(os.listdir(train_dir +'/'+ name)) for name in class_names]

# Visualize using interactive pie chart
pie_chart = px.pie(values=class_dis, names=class_names, color=class_names)
pie_chart.update_layout({'title':{'text':"Class Distribution Analysis in Train data"}},title_x=0.5)
pie_chart.update_traces(textposition='inside', textinfo='label + percent')

pie_chart.show()

# Visualize using interactive bar chart
bar_chart = px.bar(y=class_dis, x=class_names, color=class_names,text = class_dis ,labels={'x': 'Class', 'y':'Sample Count'}
bar_chart.update_layout({'title':{'text':"Class Distribution Analysis in Train data"}},title_x=0.5)
bar_chart.show()
```

Visualization of Test data

- To visualize the data, use the dataset directory to create a list containing all the image paths in the testing folder.
- Plot a grid sample of the images fetched from the list of image paths.

In [11]:
```
# Collect image paths
images = []
for folder in os.listdir(test_dir):
    for image in os.listdir(os.path.join(test_dir, folder)):
        images.append(os.path.join(test_dir, folder, image))

# Plot a random selection of images
fig, axes = plt.subplots(3,5, figsize=(14, 5))
fig.suptitle('Overview of Test data', fontsize=25)
plt.axis('off')

for ax in axes.flatten():
    # Randomly select an image
    random_img = random.choice(images)

    # Load and display the image
```

```
    img = tf.keras.utils.load_img(random_img)  # Adjust target_size as needed
    ax.imshow(img)
    ax.axis('off')

plt.show()
```

In [12]:
```
class_dirs = os.listdir(test_dir)
image_dict = {}
count_dict = {}

# iterate over all class_dirs
for cls in class_dirs:
    # get list of all paths inside the subdirectory
    file_paths = glob.glob(os.path.join(test_dir, cls, '*'))

    # count number of files in each class and add it to count_dict
    count_dict[cls] = len(file_paths)

    # select a random item from the list of image paths
    random_image_path = random.choice(file_paths)

    # load image using keras utility function and save it in image_dict
    img = tf.keras.utils.load_img(random_image_path)  # Adjust target_size as needed
    image_dict[cls] = img

##  Data Distribution of Testing Data across Classes
df_count_test = pd.DataFrame({
    "class": count_dict.keys(),     # keys of count_dict are class labels
    "count": count_dict.values(),   # value of count_dict contain counts of each class
})
print("Count of testing samples per class:\n\n", df_count_test)
```

```
Count of testing samples per class:

           class  count
0          onion     83
1         tomato    106
2         potato     81
3  indian market     81
```

In [13]:
```
# Plot the class distribution
fig, axes = plt.subplots(1, len(class_dirs), figsize=(15, 5))
fig.suptitle('Test data : Class Distribution Analysis', fontsize=16)

for i, cls in enumerate(class_dirs):
    axes[i].imshow(image_dict[cls])
    axes[i].set_title(f'{cls} ({count_dict[cls]} images)')
    axes[i].axis('off')

plt.show()
```

Test data : Class Distribution Analysis

onion (83 images)

tomato (106 images)

potato (81 images)

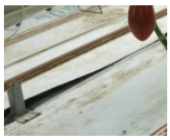
indian market (81 images)

In [14]:
```
## Random Sample from each class with their dimension

# Plot the random images
fig, axes = plt.subplots(1, len(class_dirs), figsize=(15, 7))
fig.suptitle('Test data : Random Sample Dimension Analysis', fontsize=16)

# iterate over dictionary items (class label, image array)
for i, (cls,img) in enumerate(image_dict.items()):
    # create a subplot axis
    ax = plt.subplot(4, 4, i + 1)
    # plot each image
    plt.imshow(img)
    # set "class name" along with "image size" as title
    plt.title(f'{cls} {img.size}')
    plt.axis("off")
```

Test data : Random Sample Dimension Analysis

onion (750, 500)

tomato (500, 400)



potato (222, 227)

indian market (612, 408)

Distribution of classes in Test data

In [15]:
```
import plotly.express as px
# Calculate class distribution
class_dis = [len(os.listdir(test_dir+ '/' + name)) for name in class_names]

# Visualize using interactive pie chart
pie_chart = px.pie(values=class_dis, names=class_names, color=class_names)
pie_chart.update_layout({'title':{'text':"Class Distribution Analysis in Test data"}},title_x=0.5)
pie_chart.update_traces(textposition='inside', textinfo='label + percent')

pie_chart.show()

# Visualize using interactive bar chart
bar_chart = px.bar(y=class_dis, x=class_names, color=class_names,text = class_dis,labels={'x': 'Class', 'y':'Sample Count'})

bar_chart.update_layout({'title':{'text':"Class Distribution Analysis in Test data"}},title_x=0.5)

bar_chart.show()
```

Data Preparation

Split the dataset to a train and validation set.

In [16]:
```
root_dir = "/content/ninjacart_data/"
train_dir = f"{root_dir}train/"
test_dir = f"{root_dir}test/"

image_size = (256, 256)
```

In [17]:
```
train_ds = tf.keras.utils.image_dataset_from_directory(directory = train_dir,
                                                       label_mode = 'categorical',
                                                       batch_size = 32,
                                                       image_size = image_size,
                                                       seed = 2022,
                                                       validation_split = 0.2,
                                                       subset = "training",
                                                       shuffle=True)
```

```
Found 3135 files belonging to 4 classes.
Using 2508 files for training.
```

In [18]:
```
valid_ds = tf.keras.utils.image_dataset_from_directory(directory = train_dir,
                                                       label_mode = 'categorical',
                                                       batch_size = 32,
                                                       image_size = image_size,
                                                       seed = 2022,
                                                       validation_split = 0.2,
                                                       subset = "validation")
```

```
Found 3135 files belonging to 4 classes.
Using 627 files for validation.
```

In [19]:
```
test_ds = tf.keras.utils.image_dataset_from_directory(directory = test_dir,
                                                      label_mode = 'categorical',
                                                      batch_size = 32,
                                                      image_size = image_size,
                                                      seed = 2022,
                                                     )
```

```
Found 351 files belonging to 4 classes.
```

Here `label_mode = 'categorical'` , hence one-hot encodes the classes alphabetically, i.e,

- *indian market* (noise) = class 0
- *onion* = class 1
- *potato* = class 2
- *tomato* = class 3

In [20]:
```
class_names = ['noise', 'onion', 'potato', 'tomato']
class_map = {0:'noise',1:'onion',2:'potato',3:'tomato'}
```

Creating model architecture and training of models

1) Base CNN Classifier Model

In [21]:
```
model = tf.keras.Sequential([


tf.keras.layers.Rescaling(1./255),
tf.keras.layers.InputLayer(input_shape = [image_size[0], image_size[1], 3]),

tf.keras.layers.Conv2D(filters = 32, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.Conv2D(filters = 32, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.MaxPool2D(pool_size = (2,2)),

tf.keras.layers.Conv2D(filters = 64, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.Conv2D(filters = 64, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.MaxPool2D(pool_size = (2,2)),

tf.keras.layers.Conv2D(filters = 128, kernel_size = (3,3), padding = 'Same', activation = 'relu'),

tf.keras.layers.GlobalAveragePooling2D(),
tf.keras.layers.Dense(4, activation = 'softmax')
])
```

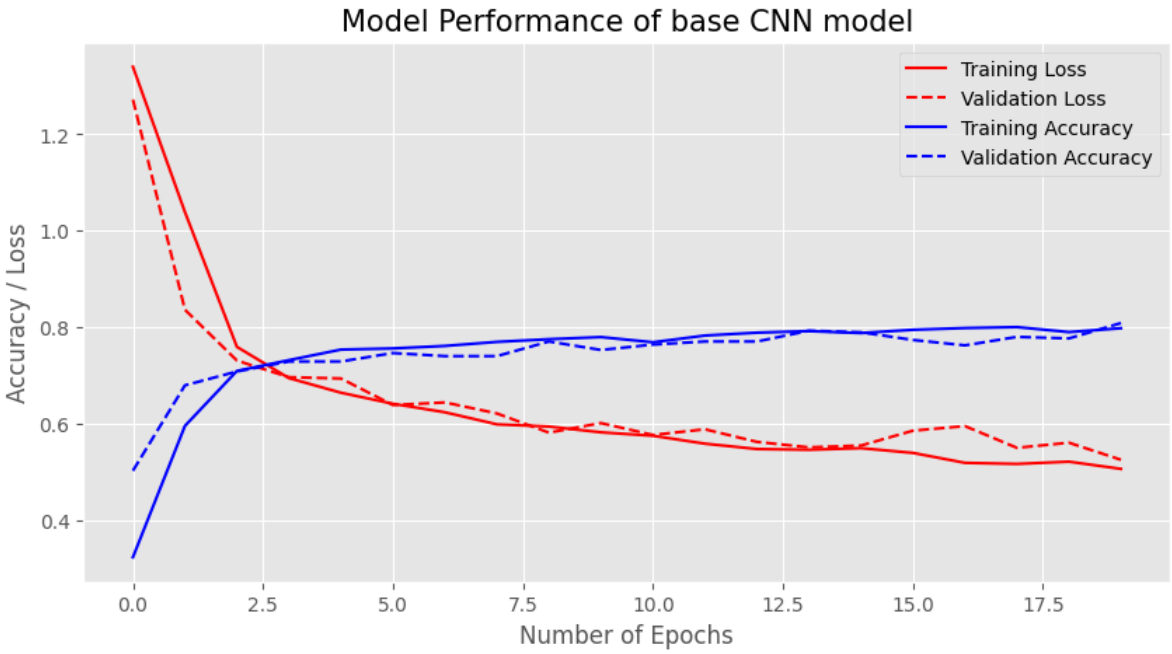
In [22]:
```
model.compile(optimizer = tf.keras.optimizers.Adam(learning_rate = 1e-4),
              loss = tf.keras.losses.CategoricalCrossentropy(),
              metrics = ['accuracy', 'Precision', 'Recall'])
```

In [23]:
```
log_dir_base = "logs/base_model"
tensorboard_cb = tf.keras.callbacks.TensorBoard(log_dir=log_dir_base, histogram_freq=1)
%load_ext tensorboard
log_folder = log_dir_base
history = model.fit(train_ds, epochs=20, validation_data=valid_ds, callbacks=[tensorboard_cb])
```

```
Epoch 1/20
79/79 [==============================] - 30s 190ms/step - loss: 1.3401 - accuracy: 0.3230 - precision: 0.0000e+00 - recall:
0.0000e+00 - val_loss: 1.2720 - val_accuracy: 0.5024 - val_precision: 0.0000e+00 - val_recall: 0.0000e+00
Epoch 2/20
79/79 [==============================] - 14s 165ms/step - loss: 1.0388 - accuracy: 0.5953 - precision: 0.8583 - recall: 0.205
3 - val_loss: 0.8363 - val_accuracy: 0.6794 - val_precision: 0.8653 - val_recall: 0.4099
Epoch 3/20
79/79 [==============================] - 14s 166ms/step - loss: 0.7592 - accuracy: 0.7093 - precision: 0.8139 - recall: 0.554
6 - val_loss: 0.7308 - val_accuracy: 0.7081 - val_precision: 0.7831 - val_recall: 0.6045
Epoch 4/20
79/79 [==============================] - 14s 164ms/step - loss: 0.6944 - accuracy: 0.7317 - precision: 0.8041 - recall: 0.635
2 - val_loss: 0.6963 - val_accuracy: 0.7289 - val_precision: 0.7805 - val_recall: 0.6523
Epoch 5/20
79/79 [==============================] - 16s 194ms/step - loss: 0.6641 - accuracy: 0.7536 - precision: 0.8061 - recall: 0.661
5 - val_loss: 0.6936 - val_accuracy: 0.7289 - val_precision: 0.8032 - val_recall: 0.6380
Epoch 6/20
79/79 [==============================] - 14s 172ms/step - loss: 0.6412 - accuracy: 0.7560 - precision: 0.8192 - recall: 0.679
4 - val_loss: 0.6385 - val_accuracy: 0.7464 - val_precision: 0.8164 - val_recall: 0.6667
Epoch 7/20
79/79 [==============================] - 14s 172ms/step - loss: 0.6235 - accuracy: 0.7612 - precision: 0.8217 - recall: 0.687
4 - val_loss: 0.6440 - val_accuracy: 0.7400 - val_precision: 0.8227 - val_recall: 0.6587
Epoch 8/20
79/79 [==============================] - 14s 171ms/step - loss: 0.5985 - accuracy: 0.7695 - precision: 0.8252 - recall: 0.700
2 - val_loss: 0.6211 - val_accuracy: 0.7400 - val_precision: 0.8074 - val_recall: 0.6619
Epoch 9/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5940 - accuracy: 0.7751 - precision: 0.8265 - recall: 0.706
5 - val_loss: 0.5813 - val_accuracy: 0.7703 - val_precision: 0.8295 - val_recall: 0.6906
Epoch 10/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5820 - accuracy: 0.7795 - precision: 0.8241 - recall: 0.713
7 - val_loss: 0.6012 - val_accuracy: 0.7528 - val_precision: 0.8222 - val_recall: 0.6858
Epoch 11/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5748 - accuracy: 0.7687 - precision: 0.8240 - recall: 0.712
9 - val_loss: 0.5765 - val_accuracy: 0.7640 - val_precision: 0.8159 - val_recall: 0.7209
Epoch 12/20
79/79 [==============================] - 14s 175ms/step - loss: 0.5585 - accuracy: 0.7827 - precision: 0.8338 - recall: 0.728
1 - val_loss: 0.5883 - val_accuracy: 0.7703 - val_precision: 0.8112 - val_recall: 0.7193
Epoch 13/20
79/79 [==============================] - 15s 177ms/step - loss: 0.5474 - accuracy: 0.7887 - precision: 0.8319 - recall: 0.728
1 - val_loss: 0.5622 - val_accuracy: 0.7703 - val_precision: 0.8246 - val_recall: 0.7049
Epoch 14/20
79/79 [==============================] - 14s 170ms/step - loss: 0.5457 - accuracy: 0.7919 - precision: 0.8327 - recall: 0.736
0 - val_loss: 0.5508 - val_accuracy: 0.7927 - val_precision: 0.8355 - val_recall: 0.7209
Epoch 15/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5491 - accuracy: 0.7879 - precision: 0.8314 - recall: 0.737
2 - val_loss: 0.5545 - val_accuracy: 0.7895 - val_precision: 0.8403 - val_recall: 0.7384
Epoch 16/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5393 - accuracy: 0.7947 - precision: 0.8382 - recall: 0.739
6 - val_loss: 0.5854 - val_accuracy: 0.7735 - val_precision: 0.8378 - val_recall: 0.7002
Epoch 17/20
79/79 [==============================] - 14s 174ms/step - loss: 0.5187 - accuracy: 0.7982 - precision: 0.8444 - recall: 0.748
4 - val_loss: 0.5949 - val_accuracy: 0.7624 - val_precision: 0.8199 - val_recall: 0.7113
Epoch 18/20
79/79 [==============================] - 14s 174ms/step - loss: 0.5165 - accuracy: 0.8002 - precision: 0.8385 - recall: 0.741
2 - val_loss: 0.5498 - val_accuracy: 0.7799 - val_precision: 0.8127 - val_recall: 0.7337
Epoch 19/20
79/79 [==============================] - 14s 172ms/step - loss: 0.5211 - accuracy: 0.7899 - precision: 0.8356 - recall: 0.748
0 - val_loss: 0.5604 - val_accuracy: 0.7767 - val_precision: 0.8297 - val_recall: 0.7305
Epoch 20/20
79/79 [==============================] - 14s 173ms/step - loss: 0.5062 - accuracy: 0.7978 - precision: 0.8457 - recall: 0.745
2 - val_loss: 0.5250 - val_accuracy: 0.8086 - val_precision: 0.8482 - val_recall: 0.7576
```

In [24]:
```
%tensorboard --logdir={log_folder} --port=6007
```

In [25]:
```
# Plot the loss graph and accuracy graph
h = history.history
plt.style.use('ggplot')
plt.figure(figsize=(10, 5))
plt.plot(h['loss'], c='red', label='Training Loss')
plt.plot(h['val_loss'], c='red', linestyle='--', label='Validation Loss')
plt.plot(h['accuracy'], c='blue', label='Training Accuracy')
plt.plot(h['val_accuracy'], c='blue', linestyle='--', label='Validation Accuracy')
plt.xlabel("Number of Epochs")
plt.title('Model Performance of base CNN model', fontsize=15)
plt.ylabel("Accuracy / Loss")
plt.legend(loc='best')
plt.show()
```



In [26]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling (Rescaling)       (None, 256, 256, 3)       0

 input_1 (InputLayer)        multiple                  0

 conv2d (Conv2D)             (None, 256, 256, 32)      896

 conv2d_1 (Conv2D)           (None, 256, 256, 32)      9248

 max_pooling2d (MaxPooling2  (None, 128, 128, 32)      0
 D)

 conv2d_2 (Conv2D)           (None, 128, 128, 64)      18496

 conv2d_3 (Conv2D)           (None, 128, 128, 64)      36928

 max_pooling2d_1 (MaxPoolin  (None, 64, 64, 64)        0
 g2D)

 conv2d_4 (Conv2D)           (None, 64, 64, 128)       73856

 global_average_pooling2d (  (None, 128)               0
 GlobalAveragePooling2D)

 dense (Dense)               (None, 4)                 516

=================================================================
Total params: 139940 (546.64 KB)
Trainable params: 139940 (546.64 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [27]:
```
# Predict the accuracy for the test set
result = model.evaluate(test_ds)
dict(zip(model.metrics_names, result))
```

```
11/11 [==============================] - 3s 173ms/step - loss: 0.5383 - accuracy: 0.7493 - precision: 0.8000 - recall: 0.7066
```

Out[27]:
```
{'loss': 0.5382717251777649,
 'accuracy': 0.7492877244949341,
 'precision': 0.800000011920929,
 'recall': 0.7065526843070984}
```

In [28]:
```
l1,l2,l3,l4 = [],[],[],[]
sns.set(rc={'figure.figsize':(6, 6)})
sns.set(font_scale=1.2)
```

In [29]:
```
noise_path = '/content/ninjacart_data/test/indian market'
onion_path = '/content/ninjacart_data/test/onion'
potato_path = '/content/ninjacart_data/test/potato'
tomato_path = '/content/ninjacart_data/test/tomato'
```

In [30]:

```
def conf_mat(class_path, pred_list, model_name) :
    noise, tomato, potato, onion = 0, 0, 0, 0
    for i in os.listdir(class_path):

        img = tf.keras.utils.load_img(class_path + "/" + str(i))
        img = tf.keras.utils.img_to_array(img)
        img = tf.image.resize(img, (256, 256))
        img = tf.expand_dims(img, axis = 0)

        pred = model_name.predict(img)
        predicted = tf.argmax(pred, 1).numpy().item()

        if predicted == 0:
            noise+= 1
        elif predicted == 1:
            onion+= 1
        elif predicted == 2:
            potato+= 1
        else:
            tomato+= 1


    for item in noise, onion, potato, tomato :
        pred_list.append(item)

conf_mat(noise_path, l1, model)
conf_mat(onion_path, l2, model)
conf_mat(potato_path, l3, model)
conf_mat(tomato_path, l4, model)

ax = sns.heatmap([l1, l2, l3, l4], xticklabels=class_names, yticklabels=class_names, annot=True, fmt='g')
ax.set(xlabel='Predicted label', ylabel='True label',title = 'Confusion matrix for base model')
plt.show()
```

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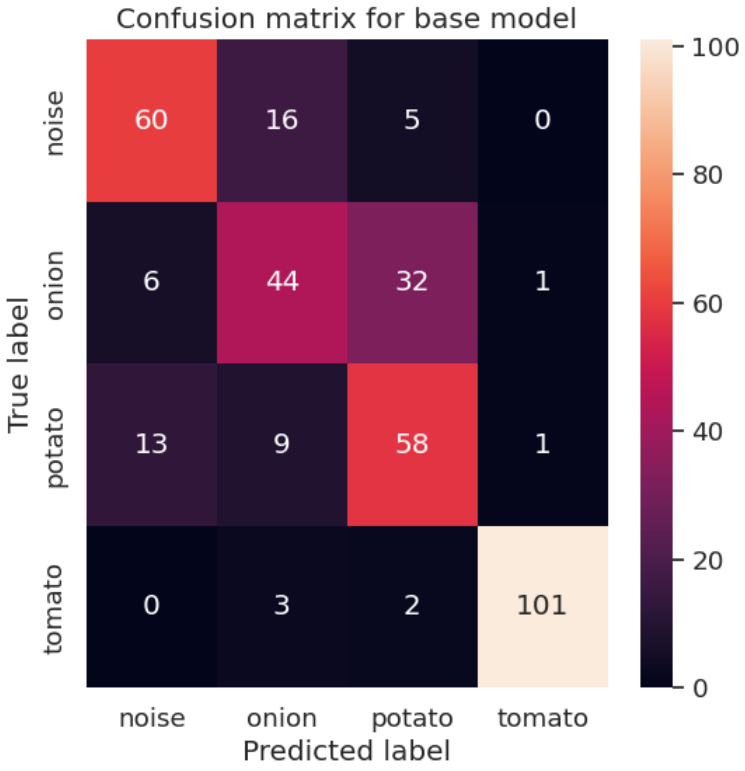

In [31]:
```
test_images = []

for folder in os.listdir(test_dir):
  for image in os.listdir(test_dir + '/' + folder):
    test_images.append(os.path.join(test_dir, folder, image))
```

In [32]:
```
def grid_test_model(model_name):

  fig = plt.figure(1, figsize=(17, 11))
  plt.axis('off')
  n = 0
  for i in range(8):
    n += 1

    img_0 = tf.keras.utils.load_img(random.choice(test_images))
    img_0 = tf.keras.utils.img_to_array(img_0)
    img_0 = tf.image.resize(img_0, (256, 256))
    img_1 = tf.expand_dims(img_0, axis = 0)

    pred = model_name.predict(img_1)
    predicted_label = tf.argmax(pred, 1).numpy().item()

    for item in pred :
      item = tf.round((item*100))

    plt.subplot(2, 4, n)
    plt.axis('off')
    plt.title(f'prediction : {class_names[predicted_label]}\n\n'
              f'{item[0]} % {class_names[0]}\n'
              f'{item[1]} % {class_names[1]}\n'
              f'{item[2]} % {class_names[2]}\n'
              f'{item[3]} % {class_names[3]}\n'
              )
    plt.imshow(img_0/255)
  plt.show()
```

In [33]:
```
grid_test_model(model)
```

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prediction : tomato

1.0 % noise
2.0 % onion
2.0 % potato
96.0 % tomato

prediction : tomato

0.0 % noise
0.0 % onion
1.0 % potato
99.0 % tomato

prediction : potato

8.0 % noise
18.0 % onion
74.0 % potato
0.0 % tomato

prediction : tomato

0.0 % noise
0.0 % onion
0.0 % potato
99.0 % tomato

prediction : potato

18.0 % noise
23.0 % onion
59.0 % potato
0.0 % tomato

prediction : onion

7.0 % noise
93.0 % onion
0.0 % potato
0.0 % tomato

prediction : noise

78.0 % noise
18.0 % onion
5.0 % potato
0.0 % tomato

prediction : potato

15.0 % noise
26.0 % onion
45.0 % potato
14.0 % tomato

In [34]:
```python
def classwise_accuracy(class_path, class_name, model_name) :
    paths = []
    for i in os.listdir(class_path):
        paths.append(class_path + "/" + str(i))

    correct = 0
    total = 0

    for i in range(len(paths)):
        total+= 1

        img = tf.keras.utils.load_img(paths[i])
        img = tf.keras.utils.img_to_array(img)
        img = tf.image.resize(img, (256, 256))
        img = tf.expand_dims(img, axis = 0)

        pred = model_name.predict(img)
        if tf.argmax(pred[0]) == class_names.index(f"{class_name}"):
            correct+= 1

    print(f"\n --> Accuracy for class {class_name} is {round((correct/total)*100, 2)}% consisting of {len(paths)} images \n"
    print('------------'*50)
```

In [35]:
```python
classwise_accuracy(noise_path, 'noise', model)
classwise_accuracy(onion_path, 'onion', model)
classwise_accuracy(potato_path, 'potato', model)
classwise_accuracy(tomato_path, 'tomato', model)
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 --> Accuracy for class noise is 74.07% consisting of 81 images

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--> Accuracy for class onion is 53.01% consisting of 83 images

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 --> Accuracy for class potato is 71.6% consisting of 81 images

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 --> Accuracy for class tomato is 95.28% consisting of 106 images

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```

Observations :

- With base CNN model we get a test accuracy of 74% and train accuracy of 80%.
- Also, there are many misclassifications in predictions to actual labels in the dataset.

2) Revamped CNN model

The base model is overfitting as there is variation in training vs validation accuracy. Hence we try to tune our model by applying - :

- BatchNormalization and Dropout
- Callbacks : EarlyStopping, ModelCheckpoint and TensorBoard callback
- Data Augmentation

In [37]:
```
augmentation = tf.keras.Sequential([
    tf.keras.layers.RandomFlip("horizontal_and_vertical"),
    tf.keras.layers.RandomRotation(0.2),
    tf.keras.layers.RandomTranslation(height_factor = 0.2, width_factor=0.2)
])

aug_ds = train_ds

for image, label in aug_ds :
  image = augmentation(image)
```

In [38]:
```
model_revamp = tf.keras.Sequential([

tf.keras.layers.Rescaling(1./255),
tf.keras.layers.InputLayer(input_shape = [image_size[0], image_size[1], 3]),

tf.keras.layers.Conv2D(filters = 32, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.Conv2D(filters = 32, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.BatchNormalization(),
tf.keras.layers.MaxPool2D(pool_size = (2,2)),

tf.keras.layers.Conv2D(filters = 64, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.Conv2D(filters = 64, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.BatchNormalization(),
tf.keras.layers.MaxPool2D(pool_size = (2,2)),

tf.keras.layers.Conv2D(filters = 128, kernel_size = (3,3), padding = 'Same', activation = 'relu'),
tf.keras.layers.BatchNormalization(),
```

```
tf.keras.layers.GlobalAveragePooling2D(),
tf.keras.layers.Dropout(rate = 0.2),

tf.keras.layers.Dense(4, activation = 'softmax')
])
```

In [39]:
```
model_revamp.compile(optimizer = tf.keras.optimizers.Adam(learning_rate = 1e-4),
                     loss = tf.keras.losses.CategoricalCrossentropy(),
                     metrics = ['accuracy', 'Precision', 'Recall'])
```

In [40]:
```
log_dir_revamp = "logs/basemodel_revamp"

tensorboard_cb = tf.keras.callbacks.TensorBoard(log_dir = log_dir_revamp, histogram_freq = 1)

checkpoint_cb = tf.keras.callbacks.ModelCheckpoint("CNN_best.h5", save_best_only = True)

early_stopping_cb = tf.keras.callbacks.EarlyStopping(
    monitor = 'val_loss', patience = 5, restore_best_weights = True
)
```

In [41]:
```
history_revamp= model_revamp.fit(
train_ds,
epochs=20,
validation_data = valid_ds,
callbacks=[tensorboard_cb, checkpoint_cb, early_stopping_cb])
```

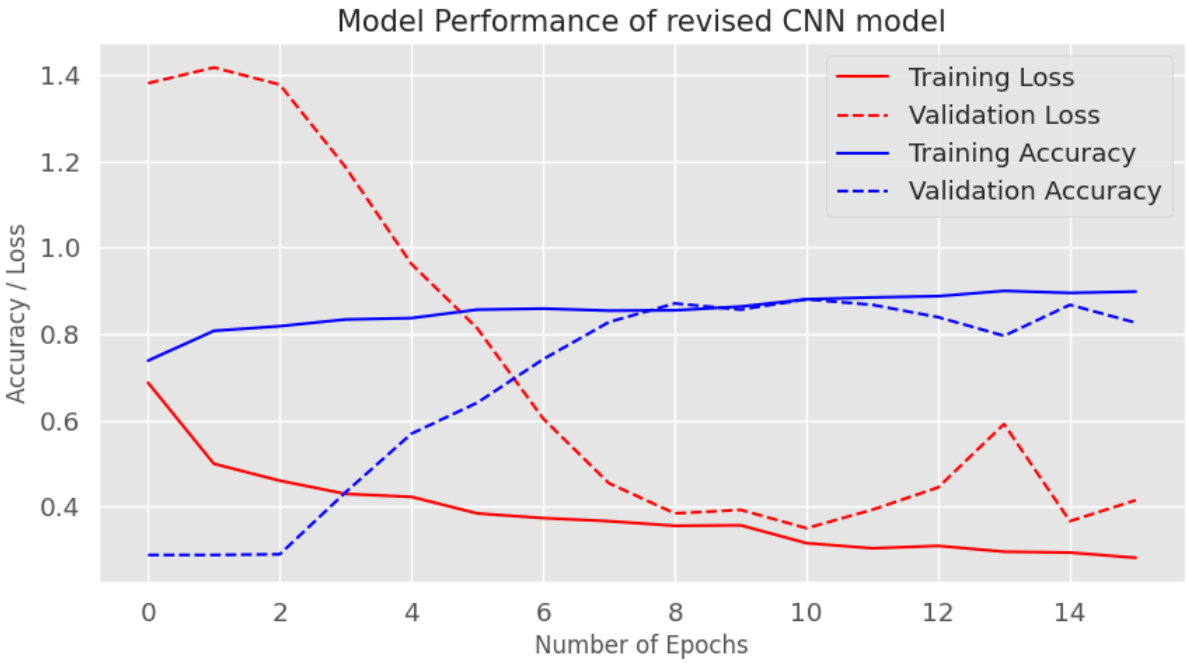
```
Epoch 1/20
79/79 [==============================] - 21s 190ms/step - loss: 0.6873 - accuracy: 0.7384 - precision: 0.8214 - recall: 0.630
8 - val_loss: 1.3805 - val_accuracy: 0.2887 - val_precision: 1.0000 - val_recall: 0.0048
Epoch 2/20
79/79 [==============================] - 15s 182ms/step - loss: 0.4996 - accuracy: 0.8074 - precision: 0.8539 - recall: 0.757
6 - val_loss: 1.4169 - val_accuracy: 0.2887 - val_precision: 0.2987 - val_recall: 0.2887
Epoch 3/20
79/79 [==============================] - 15s 186ms/step - loss: 0.4606 - accuracy: 0.8182 - precision: 0.8525 - recall: 0.769
5 - val_loss: 1.3772 - val_accuracy: 0.2903 - val_precision: 0.3237 - val_recall: 0.2871
Epoch 4/20
79/79 [==============================] - 15s 187ms/step - loss: 0.4300 - accuracy: 0.8337 - precision: 0.8659 - recall: 0.793
1 - val_loss: 1.1859 - val_accuracy: 0.4338 - val_precision: 0.4551 - val_recall: 0.3477
Epoch 5/20
79/79 [==============================] - 16s 199ms/step - loss: 0.4232 - accuracy: 0.8369 - precision: 0.8661 - recall: 0.791
9 - val_loss: 0.9621 - val_accuracy: 0.5694 - val_precision: 0.6605 - val_recall: 0.5120
Epoch 6/20
79/79 [==============================] - 16s 188ms/step - loss: 0.3848 - accuracy: 0.8565 - precision: 0.8865 - recall: 0.828
1 - val_loss: 0.8132 - val_accuracy: 0.6411 - val_precision: 0.7148 - val_recall: 0.5997
Epoch 7/20
79/79 [==============================] - 17s 198ms/step - loss: 0.3741 - accuracy: 0.8589 - precision: 0.8845 - recall: 0.827
8 - val_loss: 0.6044 - val_accuracy: 0.7416 - val_precision: 0.7801 - val_recall: 0.7018
Epoch 8/20
79/79 [==============================] - 16s 187ms/step - loss: 0.3668 - accuracy: 0.8541 - precision: 0.8872 - recall: 0.825
0 - val_loss: 0.4546 - val_accuracy: 0.8278 - val_precision: 0.8586 - val_recall: 0.7847
Epoch 9/20
79/79 [==============================] - 16s 188ms/step - loss: 0.3563 - accuracy: 0.8549 - precision: 0.8811 - recall: 0.830
5 - val_loss: 0.3849 - val_accuracy: 0.8708 - val_precision: 0.9064 - val_recall: 0.8182
Epoch 10/20
79/79 [==============================] - 16s 189ms/step - loss: 0.3574 - accuracy: 0.8636 - precision: 0.8890 - recall: 0.836
5 - val_loss: 0.3931 - val_accuracy: 0.8565 - val_precision: 0.8827 - val_recall: 0.8278
Epoch 11/20
79/79 [==============================] - 17s 198ms/step - loss: 0.3160 - accuracy: 0.8804 - precision: 0.8989 - recall: 0.854
5 - val_loss: 0.3506 - val_accuracy: 0.8804 - val_precision: 0.9024 - val_recall: 0.8405
Epoch 12/20
79/79 [==============================] - 19s 221ms/step - loss: 0.3041 - accuracy: 0.8848 - precision: 0.9035 - recall: 0.862
0 - val_loss: 0.3934 - val_accuracy: 0.8676 - val_precision: 0.8823 - val_recall: 0.8485
Epoch 13/20
79/79 [==============================] - 15s 186ms/step - loss: 0.3097 - accuracy: 0.8876 - precision: 0.8999 - recall: 0.860
4 - val_loss: 0.4451 - val_accuracy: 0.8389 - val_precision: 0.8603 - val_recall: 0.8054
Epoch 14/20
79/79 [==============================] - 16s 188ms/step - loss: 0.2962 - accuracy: 0.8999 - precision: 0.9175 - recall: 0.877
6 - val_loss: 0.5917 - val_accuracy: 0.7959 - val_precision: 0.8190 - val_recall: 0.7719
Epoch 15/20
79/79 [==============================] - 15s 187ms/step - loss: 0.2943 - accuracy: 0.8951 - precision: 0.9084 - recall: 0.866
0 - val_loss: 0.3669 - val_accuracy: 0.8676 - val_precision: 0.8791 - val_recall: 0.8469
Epoch 16/20
79/79 [==============================] - 19s 221ms/step - loss: 0.2822 - accuracy: 0.8983 - precision: 0.9159 - recall: 0.882
0 - val_loss: 0.4155 - val_accuracy: 0.8262 - val_precision: 0.8423 - val_recall: 0.8006
```

In [42]:
```
model_revamp.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling_1 (Rescaling)     (None, 256, 256, 3)       0

 input_2 (InputLayer)        multiple                  0

 conv2d_5 (Conv2D)           (None, 256, 256, 32)      896

 conv2d_6 (Conv2D)           (None, 256, 256, 32)      9248

 batch_normalization (Batch  (None, 256, 256, 32)      128
 Normalization)

 max_pooling2d_2 (MaxPoolin  (None, 128, 128, 32)      0
 g2D)

 conv2d_7 (Conv2D)           (None, 128, 128, 64)      18496

 conv2d_8 (Conv2D)           (None, 128, 128, 64)      36928

 batch_normalization_1 (Bat  (None, 128, 128, 64)      256
 chNormalization)

 max_pooling2d_3 (MaxPoolin  (None, 64, 64, 64)        0
 g2D)

 conv2d_9 (Conv2D)           (None, 64, 64, 128)       73856

 batch_normalization_2 (Bat  (None, 64, 64, 128)       512
 chNormalization)

 global_average_pooling2d_1  (None, 128)               0
  (GlobalAveragePooling2D)

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 4)                 516

=================================================================
Total params: 140836 (550.14 KB)
Trainable params: 140388 (548.39 KB)
Non-trainable params: 448 (1.75 KB)
_________________________________________________________________
```

In [43]:

```python
# Plot the loss graph and accuracy graph
h = history_revamp.history
plt.style.use('ggplot')
plt.figure(figsize=(10, 5))
plt.plot(h['loss'], c='red', label='Training Loss')
plt.plot(h['val_loss'], c='red', linestyle='--', label='Validation Loss')
plt.plot(h['accuracy'], c='blue', label='Training Accuracy')
plt.plot(h['val_accuracy'], c='blue', linestyle='--', label='Validation Accuracy')
plt.xlabel("Number of Epochs")
plt.title('Model Performance of revised CNN model', fontsize=15)
plt.ylabel("Accuracy / Loss")
plt.legend(loc='best')
plt.show()
```



In [44]:
```
grid_test_model(model_revamp)
```

```
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1/1 [==============================] - 0s 22ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 18ms/step
```
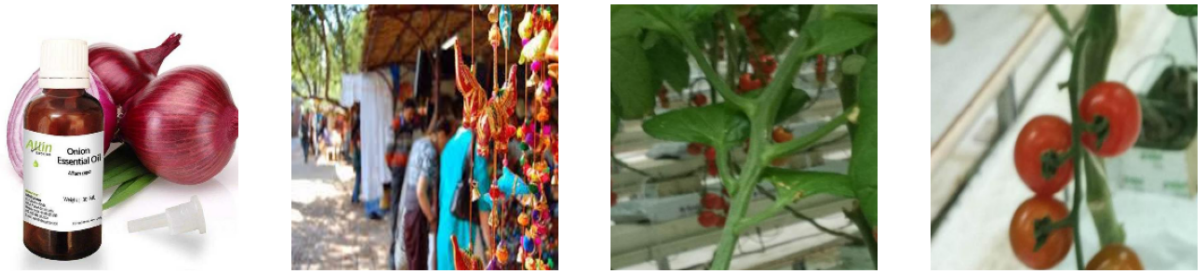

prediction : onion	prediction : noise	prediction : tomato	prediction : tomato
5.0 % noise 92.0 % onion 3.0 % potato 1.0 % tomato	93.0 % noise 6.0 % onion 1.0 % potato 0.0 % tomato	0.0 % noise 0.0 % onion 0.0 % potato 100.0 % tomato	1.0 % noise 1.0 % onion 1.0 % potato 97.0 % tomato



prediction : onion	prediction : tomato	prediction : onion	prediction : noise
1.0 % noise 88.0 % onion 10.0 % potato 0.0 % tomato	0.0 % noise 1.0 % onion 1.0 % potato 97.0 % tomato	38.0 % noise 61.0 % onion 0.0 % potato 0.0 % tomato	63.0 % noise 35.0 % onion 2.0 % potato 0.0 % tomato

In [45]:
```
result = model_revamp.evaluate(test_ds)
dict(zip(model_revamp.metrics_names, result))
```

```
11/11 [==============================] - 2s 59ms/step - loss: 0.3183 - accuracy: 0.8889 - precision: 0.9121 - recall: 0.8575
```

Out[45]:
```
{'loss': 0.3182925879955292,
 'accuracy': 0.8888888955116272,
 'precision': 0.9121212363243103,
 'recall': 0.8575498461723328}
```

In [91]:

```
l1 = []
l2 = []
l3 = []
l4 = []

conf_mat(noise_path, l1, model_revamp)
conf_mat(onion_path, l2, model_revamp)
conf_mat(potato_path, l3, model_revamp)
conf_mat(tomato_path, l4, model_revamp)

ax = sns.heatmap([l1, l2, l3, l4], xticklabels = class_names, yticklabels = class_names, annot = True, fmt = 'g')
ax.set(xlabel = 'Predicted label', ylabel = 'True label',title = ' Confusion matrix for revised CNN model')
plt.show()
```

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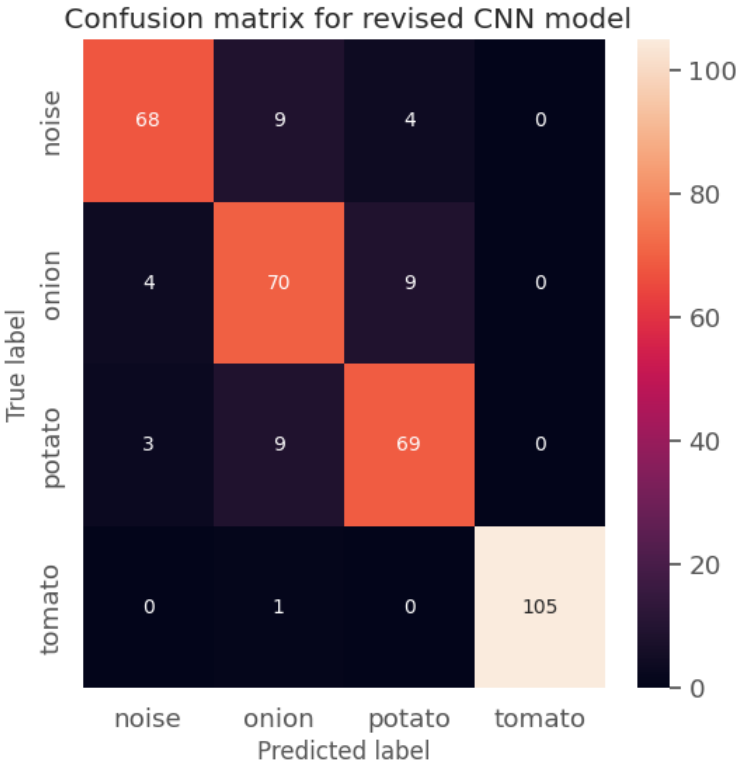

In [47]:
```
classwise_accuracy(noise_path, 'noise', model_revamp)
classwise_accuracy(onion_path, 'onion', model_revamp)
classwise_accuracy(potato_path, 'potato', model_revamp)
classwise_accuracy(tomato_path, 'tomato', model_revamp)
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 --> Accuracy for class noise is 83.95% consisting of 81 images

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 --> Accuracy for class onion is 84.34% consisting of 83 images

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 --> Accuracy for class potato is 85.19% consisting of 81 images

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 --> Accuracy for class tomato is 99.06% consisting of 106 images

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```

> Transfer Learning

Next we will train 3 of the most efficient and accurate pretrained models on the ImageNet dataset using :

- VGG-19
- ResNet
- MobileNet

and compare the model performance to choose the best model from them.

3) VGG19 Model

In [48]:
```python
# VGG19
base_model_vgg = tf.keras.applications.vgg19.VGG19(input_shape=(256, 256, 3), include_top = False)
model_vgg = base_model_vgg.output
model_vgg = tf.keras.Sequential([
            tf.keras.layers.Rescaling(1./255),
            tf.keras.layers.InputLayer(input_shape=[image_size[0], image_size[1], 3]),
            base_model_vgg,
            tf.keras.layers.GlobalAveragePooling2D(),
            tf.keras.layers.Dropout(rate = 0.1),
            tf.keras.layers.Dense(4, activation = 'softmax')
        ])
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kernels_notop.h5
80134624/80134624 [==============================] - 5s 0us/step
```

In [49]:
```python
model_vgg.compile(optimizer = tf.keras.optimizers.Adam(learning_rate = 1e-4),
              loss = tf.keras.losses.CategoricalCrossentropy(),
              metrics = ['accuracy', 'Precision', 'Recall'])
```

In [50]:
```python
log_dir_vgg = "logs/model_vgg"

tensorboard_cb = tf.keras.callbacks.TensorBoard(log_dir=log_dir_vgg, histogram_freq=1)

checkpoint_cb = tf.keras.callbacks.ModelCheckpoint("VGG19", save_best_only=True)

early_stopping_cb = tf.keras.callbacks.EarlyStopping(
    monitor = 'val_loss', patience = 5, restore_best_weights=True
)
```

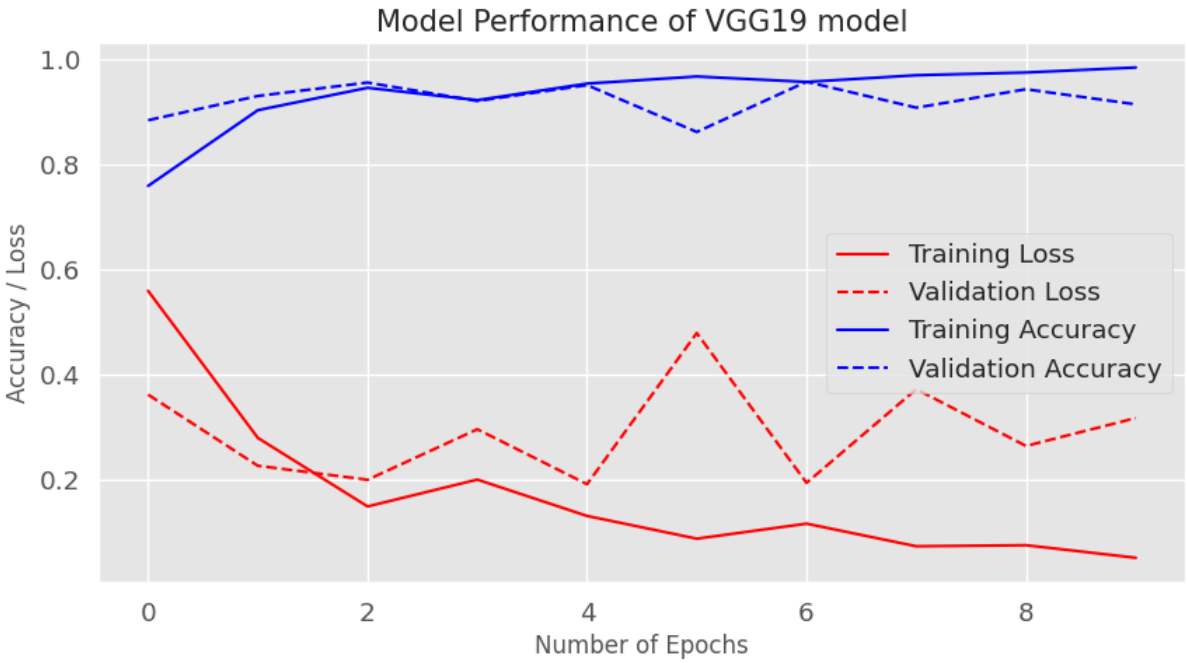
In [51]:
```
history_vgg = model_vgg.fit(aug_ds, validation_data = valid_ds, epochs = 20, callbacks=[tensorboard_cb, checkpoint_cb, early
```

```
Epoch 1/20
79/79 [==============================] - 89s 894ms/step - loss: 0.5601 - accuracy: 0.7600 - precision: 0.8046 - recall: 0.712
5 - val_loss: 0.3625 - val_accuracy: 0.8852 - val_precision: 0.8898 - val_recall: 0.8756
Epoch 2/20
79/79 [==============================] - 63s 791ms/step - loss: 0.2801 - accuracy: 0.9043 - precision: 0.9162 - recall: 0.893
9 - val_loss: 0.2269 - val_accuracy: 0.9314 - val_precision: 0.9399 - val_recall: 0.9234
Epoch 3/20
79/79 [==============================] - 64s 801ms/step - loss: 0.1494 - accuracy: 0.9470 - precision: 0.9517 - recall: 0.942
6 - val_loss: 0.2003 - val_accuracy: 0.9569 - val_precision: 0.9615 - val_recall: 0.9553
Epoch 4/20
79/79 [==============================] - 60s 748ms/step - loss: 0.2006 - accuracy: 0.9234 - precision: 0.9308 - recall: 0.917
1 - val_loss: 0.2965 - val_accuracy: 0.9219 - val_precision: 0.9291 - val_recall: 0.9203
Epoch 5/20
79/79 [==============================] - 62s 772ms/step - loss: 0.1314 - accuracy: 0.9549 - precision: 0.9582 - recall: 0.951
4 - val_loss: 0.1918 - val_accuracy: 0.9522 - val_precision: 0.9583 - val_recall: 0.9522
Epoch 6/20
79/79 [==============================] - 58s 731ms/step - loss: 0.0880 - accuracy: 0.9685 - precision: 0.9723 - recall: 0.966
9 - val_loss: 0.4798 - val_accuracy: 0.8628 - val_precision: 0.8656 - val_recall: 0.8628
Epoch 7/20
79/79 [==============================] - 59s 741ms/step - loss: 0.1167 - accuracy: 0.9581 - precision: 0.9626 - recall: 0.953
7 - val_loss: 0.1944 - val_accuracy: 0.9585 - val_precision: 0.9599 - val_recall: 0.9537
Epoch 8/20
79/79 [==============================] - 59s 736ms/step - loss: 0.0736 - accuracy: 0.9709 - precision: 0.9748 - recall: 0.970
5 - val_loss: 0.3728 - val_accuracy: 0.9091 - val_precision: 0.9145 - val_recall: 0.9043
Epoch 9/20
79/79 [==============================] - 58s 733ms/step - loss: 0.0756 - accuracy: 0.9761 - precision: 0.9776 - recall: 0.974
9 - val_loss: 0.2646 - val_accuracy: 0.9442 - val_precision: 0.9442 - val_recall: 0.9442
Epoch 10/20
79/79 [==============================] - 59s 735ms/step - loss: 0.0517 - accuracy: 0.9856 - precision: 0.9868 - recall: 0.983
7 - val_loss: 0.3179 - val_accuracy: 0.9155 - val_precision: 0.9195 - val_recall: 0.9107
```

In [52]:
```
model_vgg.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling_2 (Rescaling)     (None, 256, 256, 3)       0

 input_4 (InputLayer)        multiple                  0

 vgg19 (Functional)          (None, 8, 8, 512)         20024384

 global_average_pooling2d_2  (None, 512)               0
  (GlobalAveragePooling2D)

 dropout_1 (Dropout)         (None, 512)               0

 dense_2 (Dense)             (None, 4)                 2052

=================================================================
Total params: 20026436 (76.39 MB)
Trainable params: 20026436 (76.39 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [53]:
```
# Plot the loss graph and accuracy graph
h = history_vgg.history
plt.style.use('ggplot')
plt.figure(figsize=(10, 5))
plt.plot(h['loss'], c='red', label='Training Loss')
plt.plot(h['val_loss'], c='red', linestyle='--', label='Validation Loss')
plt.plot(h['accuracy'], c='blue', label='Training Accuracy')
plt.plot(h['val_accuracy'], c='blue', linestyle='--', label='Validation Accuracy')
plt.xlabel("Number of Epochs")
plt.title('Model Performance of VGG19 model', fontsize=15)
plt.ylabel("Accuracy / Loss")
plt.legend(loc='best')
plt.show()
```



In [54]:
```
classwise_accuracy(noise_path, 'noise', model_vgg)
classwise_accuracy(onion_path, 'onion', model_vgg)
classwise_accuracy(potato_path, 'potato', model_vgg)
classwise_accuracy(tomato_path, 'tomato', model_vgg)
```

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 --> Accuracy for class noise is 64.2% consisting of 81 images

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--> Accuracy for class onion is 100.0% consisting of 83 images

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 --> Accuracy for class potato is 88.89% consisting of 81 images

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 --> Accuracy for class tomato is 100.0% consisting of 106 images

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In [55]:
```
grid_test_model(model_vgg)
```

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prediction : noise	prediction : potato	prediction : onion	prediction : onion
100.0 % noise 0.0 % onion 0.0 % potato 0.0 % tomato	0.0 % noise 4.0 % onion 96.0 % potato 0.0 % tomato	0.0 % noise 100.0 % onion 0.0 % potato 0.0 % tomato	0.0 % noise 100.0 % onion 0.0 % potato 0.0 % tomato
			
prediction : tomato	prediction : noise	prediction : potato	prediction : noise
0.0 % noise 0.0 % onion 0.0 % potato 100.0 % tomato	88.0 % noise 12.0 % onion 0.0 % potato 0.0 % tomato	2.0 % noise 32.0 % onion 66.0 % potato 0.0 % tomato	100.0 % noise 0.0 % onion 0.0 % potato 0.0 % tomato
			

In [56]:
```
result = model_vgg.evaluate(test_ds)
dict(zip(model_vgg.metrics_names, result))
```

```
11/11 [==============================] - 7s 550ms/step - loss: 0.3601 - accuracy: 0.9003 - precision: 0.8997 - recall: 0.8946
```

Out[56]:
```
{'loss': 0.36014044284820557,
 'accuracy': 0.9002848863601685,
 'precision': 0.8997134566307068,
 'recall': 0.8945869207382202}
```

In [57]:
```
l1 = []
l2 = []
l3 = []
l4 = []

conf_mat(noise_path, l1, model_vgg)
conf_mat(onion_path, l2, model_vgg)
conf_mat(potato_path, l3, model_vgg)
conf_mat(tomato_path, l4, model_vgg)

ax = sns.heatmap([l1, l2, l3, l4], xticklabels=class_names, yticklabels=class_names, annot=True, fmt='g')
ax.set(xlabel='Predicted label', ylabel='True label',title = ' Confusion Matrix for VGG19 model')
plt.show()
```

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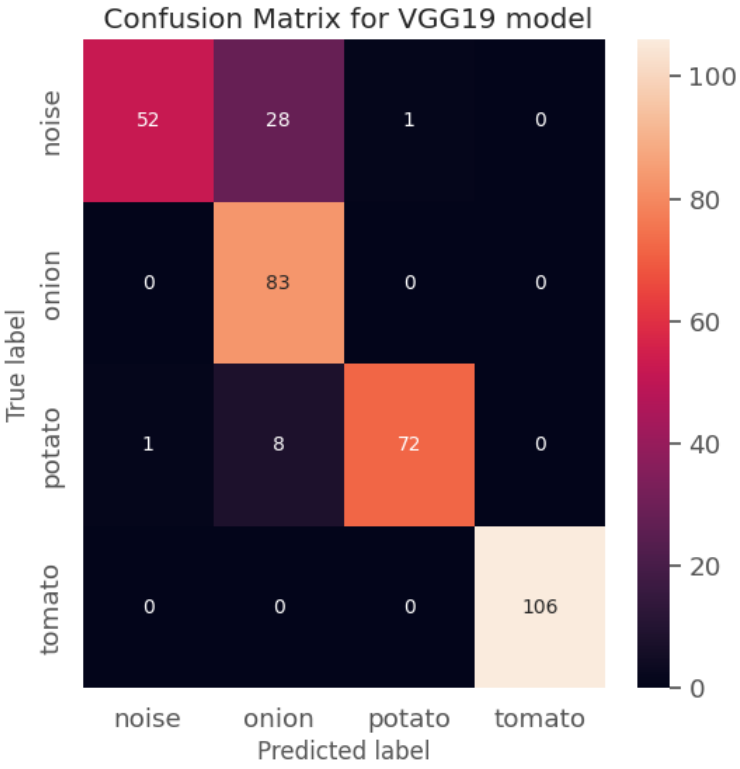
```



Observations :

- With VGG19 model we get a test accuracy of 90% and train accuracy of 99%.
- Also, the predictions are nearly 95% to actual labels in the dataset with some misclassifications.

4) ResNet Model

In [58]:
```
# ResNet
base_model_res = tf.keras.applications.resnet50.ResNet50(input_shape=(256, 256, 3), include_top = False)
model_res = base_model_res.output

model_res = tf.keras.Sequential([

            tf.keras.layers.Rescaling(1./255),
            tf.keras.layers.InputLayer(input_shape=[image_size[0], image_size[1], 3]),
            base_model_res,
            tf.keras.layers.GlobalAveragePooling2D(),
            tf.keras.layers.Dropout(rate = 0.1),
            tf.keras.layers.Dense(4, activation = 'softmax')
        ])
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50_weights_tf_dim_ordering_tf
_kernels_notop.h5
94765736/94765736 [==============================] - 6s 0us/step
```

In [59]:
```
model_res.compile(optimizer = tf.keras.optimizers.Adam(learning_rate = 1e-4),
              loss = tf.keras.losses.CategoricalCrossentropy(),
              metrics = ['accuracy', 'Precision', 'Recall'])
```

In [60]:
```
log_dir_res = "logs/model_resnet"

tensorboard_cb = tf.keras.callbacks.TensorBoard(log_dir=log_dir_res, histogram_freq=1)

checkpoint_cb = tf.keras.callbacks.ModelCheckpoint("ResNet.h5", save_best_only=True)

early_stopping_cb = tf.keras.callbacks.EarlyStopping(
    monitor = 'val_loss', patience = 5, restore_best_weights=True
)
```

In [61]:
```
history_res = model_res.fit(aug_ds, validation_data = valid_ds, epochs = 20, callbacks=[tensorboard_cb, checkpoint_cb, early
```

```
Epoch 1/20
79/79 [==============================] - 81s 582ms/step - loss: 0.1704 - accuracy: 0.9378 - precision: 0.9558 - recall: 0.921
9 - val_loss: 2.5773 - val_accuracy: 0.2121 - val_precision: 0.2121 - val_recall: 0.2121
Epoch 2/20
79/79 [==============================] - 41s 517ms/step - loss: 0.0229 - accuracy: 0.9924 - precision: 0.9924 - recall: 0.992
4 - val_loss: 2.6748 - val_accuracy: 0.2105 - val_precision: 0.2077 - val_recall: 0.2057
Epoch 3/20
79/79 [==============================] - 42s 527ms/step - loss: 0.0235 - accuracy: 0.9928 - precision: 0.9932 - recall: 0.992
4 - val_loss: 2.4560 - val_accuracy: 0.2153 - val_precision: 0.1971 - val_recall: 0.1707
Epoch 4/20
79/79 [==============================] - 42s 529ms/step - loss: 0.0092 - accuracy: 0.9972 - precision: 0.9976 - recall: 0.997
2 - val_loss: 1.6379 - val_accuracy: 0.2360 - val_precision: 0.1411 - val_recall: 0.0542
Epoch 5/20
79/79 [==============================] - 44s 546ms/step - loss: 0.0147 - accuracy: 0.9964 - precision: 0.9968 - recall: 0.996
0 - val_loss: 1.6250 - val_accuracy: 0.3780 - val_precision: 0.4190 - val_recall: 0.2887
Epoch 6/20
79/79 [==============================] - 41s 517ms/step - loss: 0.0186 - accuracy: 0.9952 - precision: 0.9956 - recall: 0.995
2 - val_loss: 1.6817 - val_accuracy: 0.4131 - val_precision: 0.4577 - val_recall: 0.3541
Epoch 7/20
79/79 [==============================] - 42s 523ms/step - loss: 0.0206 - accuracy: 0.9940 - precision: 0.9944 - recall: 0.993
6 - val_loss: 0.9446 - val_accuracy: 0.6619 - val_precision: 0.7082 - val_recall: 0.5534
Epoch 8/20
79/79 [==============================] - 42s 525ms/step - loss: 0.0454 - accuracy: 0.9896 - precision: 0.9904 - recall: 0.989
2 - val_loss: 0.9214 - val_accuracy: 0.6380 - val_precision: 0.6565 - val_recall: 0.6188
Epoch 9/20
79/79 [==============================] - 43s 531ms/step - loss: 0.0078 - accuracy: 0.9980 - precision: 0.9980 - recall: 0.997
6 - val_loss: 0.4854 - val_accuracy: 0.8102 - val_precision: 0.8283 - val_recall: 0.7847
Epoch 10/20
79/79 [==============================] - 43s 535ms/step - loss: 0.0156 - accuracy: 0.9948 - precision: 0.9948 - recall: 0.994
8 - val_loss: 0.2516 - val_accuracy: 0.9107 - val_precision: 0.9237 - val_recall: 0.8884
Epoch 11/20
79/79 [==============================] - 43s 532ms/step - loss: 0.0099 - accuracy: 0.9968 - precision: 0.9968 - recall: 0.996
4 - val_loss: 0.1587 - val_accuracy: 0.9426 - val_precision: 0.9498 - val_recall: 0.9362
Epoch 12/20
79/79 [==============================] - 43s 533ms/step - loss: 0.0046 - accuracy: 0.9992 - precision: 0.9992 - recall: 0.999
2 - val_loss: 0.1138 - val_accuracy: 0.9665 - val_precision: 0.9711 - val_recall: 0.9649
Epoch 13/20
79/79 [==============================] - 45s 561ms/step - loss: 0.0035 - accuracy: 0.9992 - precision: 0.9992 - recall: 0.999
2 - val_loss: 0.0920 - val_accuracy: 0.9745 - val_precision: 0.9760 - val_recall: 0.9729
Epoch 14/20
79/79 [==============================] - 43s 541ms/step - loss: 0.0014 - accuracy: 1.0000 - precision: 1.0000 - recall: 1.000
0 - val_loss: 0.0691 - val_accuracy: 0.9841 - val_precision: 0.9856 - val_recall: 0.9825
Epoch 15/20
79/79 [==============================] - 42s 520ms/step - loss: 0.0166 - accuracy: 0.9956 - precision: 0.9960 - recall: 0.995
6 - val_loss: 0.1186 - val_accuracy: 0.9681 - val_precision: 0.9696 - val_recall: 0.9681
Epoch 16/20
79/79 [==============================] - 42s 520ms/step - loss: 0.0082 - accuracy: 0.9972 - precision: 0.9972 - recall: 0.996
8 - val_loss: 0.0824 - val_accuracy: 0.9729 - val_precision: 0.9760 - val_recall: 0.9729
Epoch 17/20
79/79 [==============================] - 41s 516ms/step - loss: 0.0040 - accuracy: 0.9988 - precision: 0.9988 - recall: 0.998
8 - val_loss: 0.2363 - val_accuracy: 0.9490 - val_precision: 0.9566 - val_recall: 0.9490
Epoch 18/20
79/79 [==============================] - 43s 540ms/step - loss: 0.0091 - accuracy: 0.9968 - precision: 0.9972 - recall: 0.996
8 - val_loss: 0.1134 - val_accuracy: 0.9681 - val_precision: 0.9712 - val_recall: 0.9665
Epoch 19/20
79/79 [==============================] - 43s 533ms/step - loss: 0.0247 - accuracy: 0.9944 - precision: 0.9948 - recall: 0.994
0 - val_loss: 0.2557 - val_accuracy: 0.9474 - val_precision: 0.9503 - val_recall: 0.9458
```

In [62]:
```
model_res.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling_3 (Rescaling)     (None, 256, 256, 3)       0

 input_6 (InputLayer)        multiple                  0

 resnet50 (Functional)       (None, 8, 8, 2048)        23587712

 global_average_pooling2d_3  (None, 2048)              0
  (GlobalAveragePooling2D)

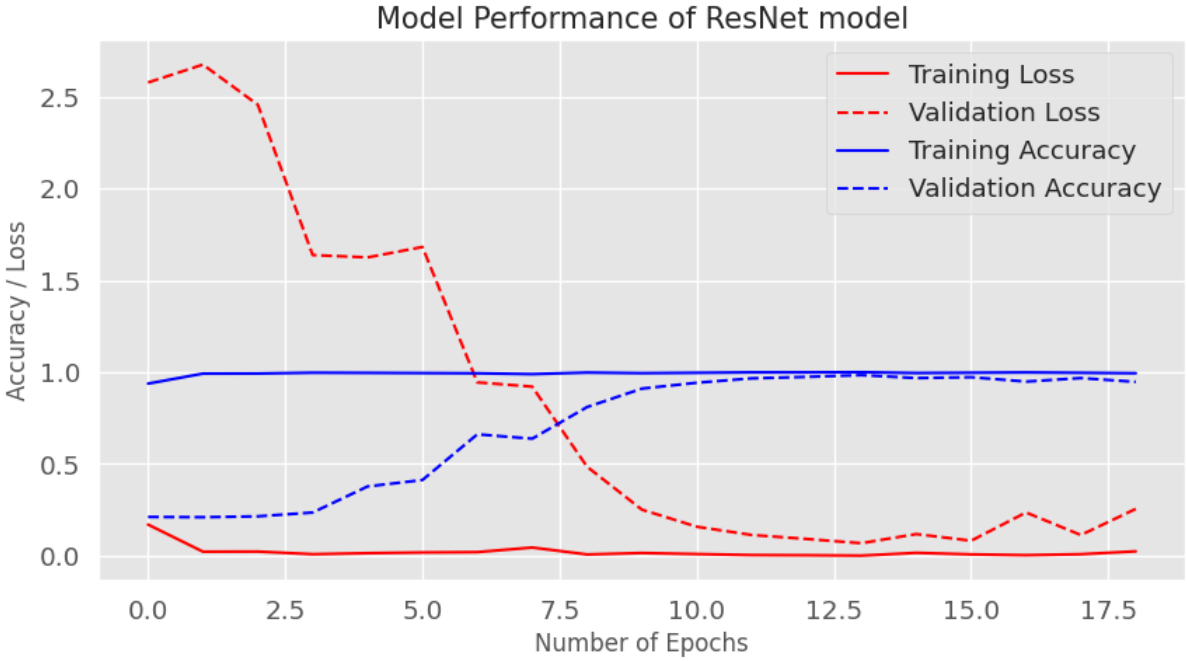
 dropout_2 (Dropout)         (None, 2048)              0

 dense_3 (Dense)             (None, 4)                 8196

=================================================================
Total params: 23595908 (90.01 MB)
Trainable params: 23542788 (89.81 MB)
Non-trainable params: 53120 (207.50 KB)
_________________________________________________________________
```

In [63]:
```
# Plot the loss graph and accuracy graph
h = history_res.history
plt.style.use('ggplot')
```

```
plt.figure(figsize=(10, 5))
plt.plot(h['loss'], c='red', label='Training Loss')
plt.plot(h['val_loss'], c='red', linestyle='--', label='Validation Loss')
plt.plot(h['accuracy'], c='blue', label='Training Accuracy')
plt.plot(h['val_accuracy'], c='blue', linestyle='--', label='Validation Accuracy')
plt.xlabel("Number of Epochs")
plt.title('Model Performance of ResNet model', fontsize=15)
plt.ylabel("Accuracy / Loss")
plt.legend(loc='best')
plt.show()
```



In [64]:
```
classwise_accuracy(noise_path, 'noise', model_res)
classwise_accuracy(onion_path, 'onion', model_res)
classwise_accuracy(potato_path, 'potato', model_res)
classwise_accuracy(tomato_path, 'tomato', model_res)
```

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 --> Accuracy for class noise is 83.95% consisting of 81 images

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```
 --> Accuracy for class onion is 98.8% consisting of 83 images

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 --> Accuracy for class potato is 86.42% consisting of 81 images

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 --> Accuracy for class tomato is 100.0% consisting of 106 images

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```

In [65]:
```
grid_test_model(model_res)
```

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prediction : onion

32.0 % noise
55.0 % onion
11.0 % potato
2.0 % tomato

prediction : onion

0.0 % noise
99.0 % onion
0.0 % potato
0.0 % tomato

prediction : onion

44.0 % noise
56.0 % onion
0.0 % potato
0.0 % tomato

prediction : tomato

0.0 % noise
0.0 % onion
0.0 % potato
100.0 % tomato

prediction : potato

0.0 % noise
0.0 % onion
100.0 % potato
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prediction : onion

0.0 % noise
100.0 % onion
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prediction : potato

0.0 % noise
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100.0 % potato
0.0 % tomato

prediction : potato

0.0 % noise
0.0 % onion
100.0 % potato
0.0 % tomato

In [66]:
```
result = model_res.evaluate(test_ds)
dict(zip(model_res.metrics_names, result))
```

```
11/11 [==============================] - 4s 250ms/step - loss: 0.2921 - accuracy: 0.9259 - precision: 0.9366 - recall: 0.9259
```

Out[66]:
```
{'loss': 0.2921386957168579,
 'accuracy': 0.9259259104728699,
 'precision': 0.9365994334220886,
 'recall': 0.9259259104728699}
```

In [67]:
```
l1 = []
l2 = []
l3 = []
l4 = []

conf_mat(noise_path, l1, model_res)
conf_mat(onion_path, l2, model_res)
conf_mat(potato_path, l3, model_res)
conf_mat(tomato_path, l4, model_res)

ax = sns.heatmap([l1, l2, l3, l4], xticklabels=class_names, yticklabels=class_names, annot=True, fmt='g')
ax.set(xlabel='Predicted label', ylabel='True label',title = ' Confusion Matrix for ResNet model')
plt.show()
```

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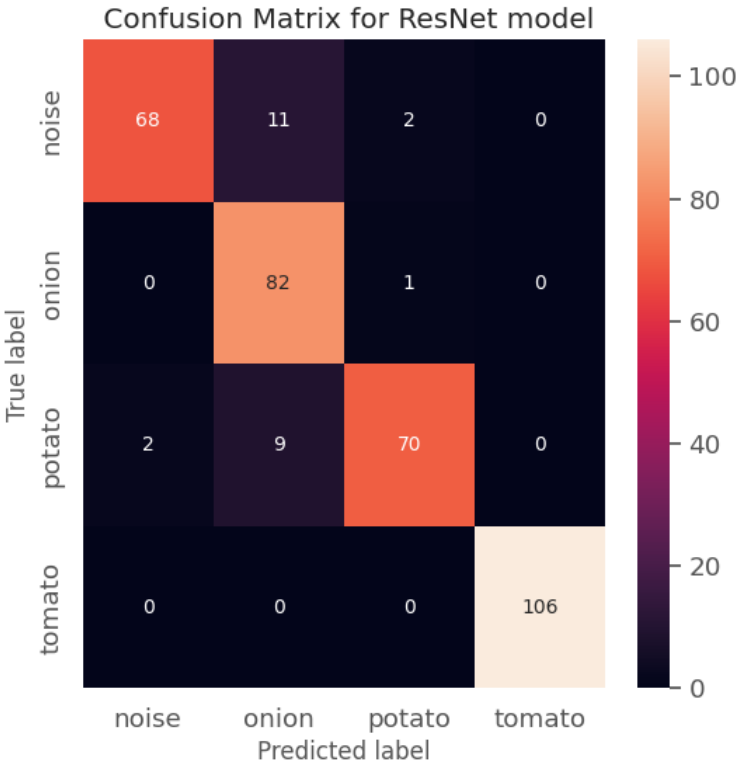


Observations :

- With ResNet model we get a test accuracy of 93% and train accuracy of 99.63%.
- Also, the predictions are nearly 100% to actual labels in the dataset.

5) MobileNet Model

In [68]:
```
# MobileNet
base_model_mob = tf.keras.applications.mobilenet.MobileNet(input_shape=(256, 256, 3), include_top = False)
model_mob = base_model_mob.output

model_mob = tf.keras.Sequential([
            tf.keras.layers.Rescaling(1./255),
            tf.keras.layers.InputLayer(input_shape=[image_size[0], image_size[1], 3]),
            base_model_mob,
            tf.keras.layers.GlobalAveragePooling2D(),
            tf.keras.layers.Dropout(rate = 0.1),
            tf.keras.layers.Dense(4, activation = 'softmax')
        ])
```

```
WARNING:tensorflow:`input_shape` is undefined or non-square, or `rows` is not in [128, 160, 192, 224]. Weights for input shap
e (224, 224) will be loaded as the default.
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/mobilenet/mobilenet_1_0_224_tf_no_top.h5
17225924/17225924 [==============================] - 2s 0us/step
```

In [69]:
```
log_dir_mob = "logs/model_mob"

tensorboard_cb = tf.keras.callbacks.TensorBoard(log_dir=log_dir_mob, histogram_freq=1)

checkpoint_cb = tf.keras.callbacks.ModelCheckpoint("MobileNet.h5", save_best_only=True)

early_stopping_cb = tf.keras.callbacks.EarlyStopping(
    monitor = 'val_loss', patience = 5, restore_best_weights=True
)
```

In [80]:
```
model_mob.compile(optimizer = tf.keras.optimizers.Adam(learning_rate = 1e-4),
              loss = tf.keras.losses.CategoricalCrossentropy(),
              metrics = ['accuracy', 'Precision', 'Recall'])
```

In [82]:
```
history_mob = model_mob.fit(aug_ds, validation_data = valid_ds, epochs = 20,
                            callbacks=[tensorboard_cb, checkpoint_cb, early_stopping_cb])
```

```
Epoch 1/20
79/79 [==============================] - 18s 214ms/step - loss: 0.0100 - accuracy: 0.9972 - precision: 0.9972 - recall: 0.997
2 - val_loss: 0.2185 - val_accuracy: 0.9490 - val_precision: 0.9490 - val_recall: 0.9490
Epoch 2/20
79/79 [==============================] - 17s 204ms/step - loss: 0.0152 - accuracy: 0.9968 - precision: 0.9968 - recall: 0.996
8 - val_loss: 0.2470 - val_accuracy: 0.9490 - val_precision: 0.9490 - val_recall: 0.9490
Epoch 3/20
79/79 [==============================] - 16s 198ms/step - loss: 0.0160 - accuracy: 0.9924 - precision: 0.9924 - recall: 0.992
4 - val_loss: 0.1164 - val_accuracy: 0.9729 - val_precision: 0.9758 - val_recall: 0.9665
Epoch 4/20
79/79 [==============================] - 16s 197ms/step - loss: 0.0043 - accuracy: 0.9984 - precision: 0.9988 - recall: 0.998
4 - val_loss: 0.0997 - val_accuracy: 0.9729 - val_precision: 0.9729 - val_recall: 0.9729
Epoch 5/20
79/79 [==============================] - 16s 200ms/step - loss: 0.0073 - accuracy: 0.9972 - precision: 0.9976 - recall: 0.997
2 - val_loss: 0.0981 - val_accuracy: 0.9809 - val_precision: 0.9824 - val_recall: 0.9793
Epoch 6/20
79/79 [==============================] - 16s 200ms/step - loss: 0.0031 - accuracy: 0.9996 - precision: 0.9996 - recall: 0.999
6 - val_loss: 0.1038 - val_accuracy: 0.9777 - val_precision: 0.9777 - val_recall: 0.9777
Epoch 7/20
79/79 [==============================] - 16s 200ms/step - loss: 0.0012 - accuracy: 1.0000 - precision: 1.0000 - recall: 1.000
0 - val_loss: 0.1356 - val_accuracy: 0.9713 - val_precision: 0.9713 - val_recall: 0.9713
Epoch 8/20
79/79 [==============================] - 16s 198ms/step - loss: 6.0777e-04 - accuracy: 1.0000 - precision: 1.0000 - recall:
1.0000 - val_loss: 0.1204 - val_accuracy: 0.9745 - val_precision: 0.9745 - val_recall: 0.9745
Epoch 9/20
79/79 [==============================] - 16s 199ms/step - loss: 2.5592e-04 - accuracy: 1.0000 - precision: 1.0000 - recall:
1.0000 - val_loss: 0.1067 - val_accuracy: 0.9777 - val_precision: 0.9777 - val_recall: 0.9777
Epoch 10/20
79/79 [==============================] - 17s 200ms/step - loss: 2.4627e-04 - accuracy: 1.0000 - precision: 1.0000 - recall:
1.0000 - val_loss: 0.0936 - val_accuracy: 0.9809 - val_precision: 0.9809 - val_recall: 0.9809
Epoch 11/20
79/79 [==============================] - 16s 199ms/step - loss: 0.0050 - accuracy: 0.9984 - precision: 0.9984 - recall: 0.998
4 - val_loss: 0.1233 - val_accuracy: 0.9745 - val_precision: 0.9745 - val_recall: 0.9745
Epoch 12/20
79/79 [==============================] - 16s 197ms/step - loss: 7.4578e-04 - accuracy: 1.0000 - precision: 1.0000 - recall:
1.0000 - val_loss: 0.1050 - val_accuracy: 0.9713 - val_precision: 0.9713 - val_recall: 0.9713
Epoch 13/20
79/79 [==============================] - 16s 197ms/step - loss: 0.0024 - accuracy: 0.9992 - precision: 0.9992 - recall: 0.999
2 - val_loss: 0.1381 - val_accuracy: 0.9713 - val_precision: 0.9713 - val_recall: 0.9713
Epoch 14/20
79/79 [==============================] - 17s 201ms/step - loss: 0.0017 - accuracy: 0.9996 - precision: 0.9996 - recall: 0.999
6 - val_loss: 0.1252 - val_accuracy: 0.9713 - val_precision: 0.9713 - val_recall: 0.9713
Epoch 15/20
79/79 [==============================] - 16s 200ms/step - loss: 0.0043 - accuracy: 0.9984 - precision: 0.9984 - recall: 0.998
4 - val_loss: 0.1254 - val_accuracy: 0.9713 - val_precision: 0.9713 - val_recall: 0.9713
```

In [83]:
```
model_mob.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 rescaling_4 (Rescaling)     (None, 256, 256, 3)       0

 input_8 (InputLayer)        multiple                  0

 mobilenet_1.00_224 (Functi  (None, 8, 8, 1024)        3228864
 onal)

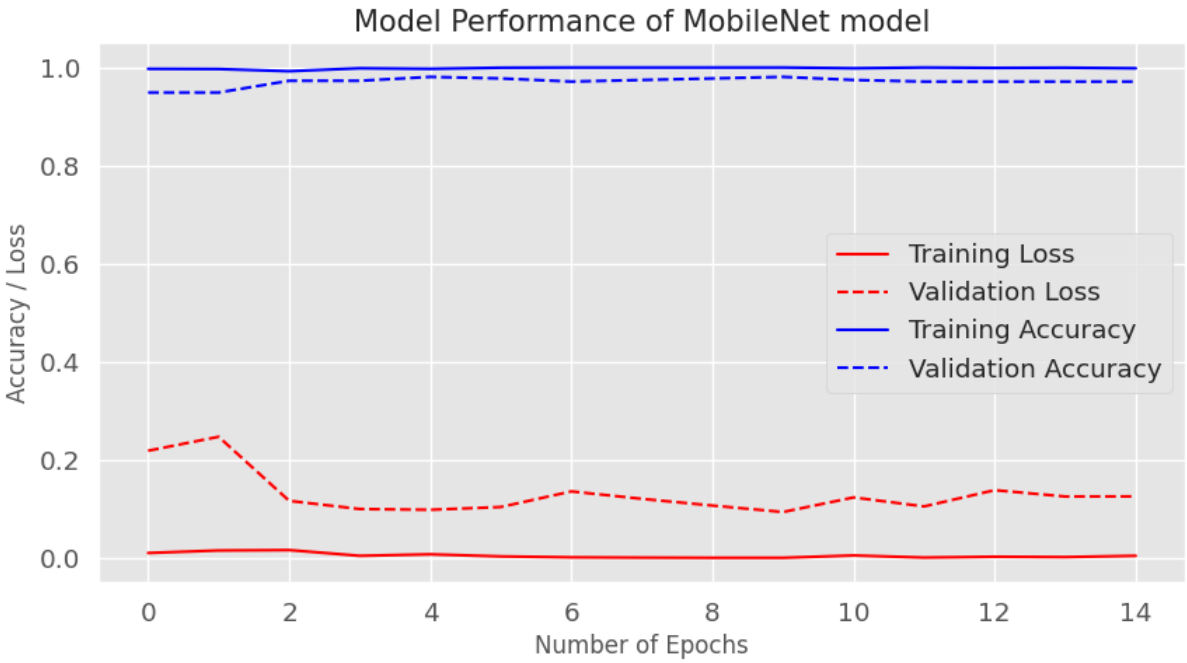
 global_average_pooling2d_4  (None, 1024)              0
  (GlobalAveragePooling2D)

 dropout_3 (Dropout)         (None, 1024)              0

 dense_4 (Dense)             (None, 4)                 4100

=================================================================
Total params: 3232964 (12.33 MB)
Trainable params: 3211076 (12.25 MB)
Non-trainable params: 21888 (85.50 KB)
_________________________________________________________________
```

In [84]:
```
# Plot the loss graph and accuracy graph
h = history_mob.history
plt.style.use('ggplot')
plt.figure(figsize=(10, 5))
plt.plot(h['loss'], c='red', label='Training Loss')
plt.plot(h['val_loss'], c='red', linestyle='--', label='Validation Loss')
plt.plot(h['accuracy'], c='blue', label='Training Accuracy')
plt.plot(h['val_accuracy'], c='blue', linestyle='--', label='Validation Accuracy')
plt.xlabel("Number of Epochs")
plt.title('Model Performance of MobileNet model', fontsize=15)
plt.ylabel("Accuracy / Loss")
plt.legend(loc='best')
plt.show()
```



In [85]:
```
classwise_accuracy(noise_path, 'noise', model_mob)
classwise_accuracy(onion_path, 'onion', model_mob)
classwise_accuracy(potato_path, 'potato', model_mob)
classwise_accuracy(tomato_path, 'tomato', model_mob)
```

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 --> Accuracy for class noise is 82.72% consisting of 81 images

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```
 --> Accuracy for class onion is 98.8% consisting of 83 images

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 --> Accuracy for class potato is 81.48% consisting of 81 images

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 --> Accuracy for class tomato is 100.0% consisting of 106 images

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----------------------------------------------------------------------------------------------------
```

In [86]:
```
grid_test_model(model_mob)
```

```
1/1 [==============================] - 0s 19ms/step
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1/1 [==============================] - 0s 20ms/step
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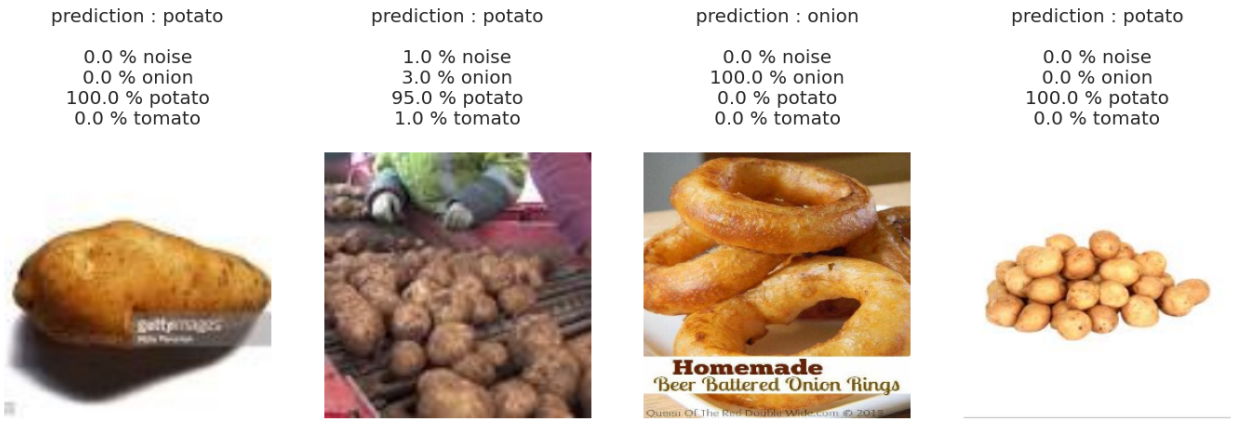
1/1 [==============================] - 0s 20ms/step
1/1 [==============================] - 0s 24ms/step
```



In [87]:
```
result = model_mob.evaluate(test_ds)
dict(zip(model_mob.metrics_names, result))
```

```
11/11 [==============================] - 2s 62ms/step - loss: 0.4683 - accuracy: 0.9145 - precision: 0.9145 - recall: 0.9145
```

Out[87]:
```
{'loss': 0.46834248304367065,
 'accuracy': 0.9145299196243286,
 'precision': 0.9145299196243286,
 'recall': 0.9145299196243286}
```

In [88]:
```
l1 = []
l2 = []
l3 = []
l4 = []

conf_mat(noise_path, l1, model_mob)
conf_mat(onion_path, l2, model_mob)
conf_mat(potato_path, l3, model_mob)
conf_mat(tomato_path, l4, model_mob)

ax = sns.heatmap([l1, l2, l3, l4], xticklabels=class_names, yticklabels=class_names, annot=True, fmt='g')
ax.set(xlabel='Predicted label', ylabel='True label',title = 'Confusion matrix for MobileNet model')
plt.show()
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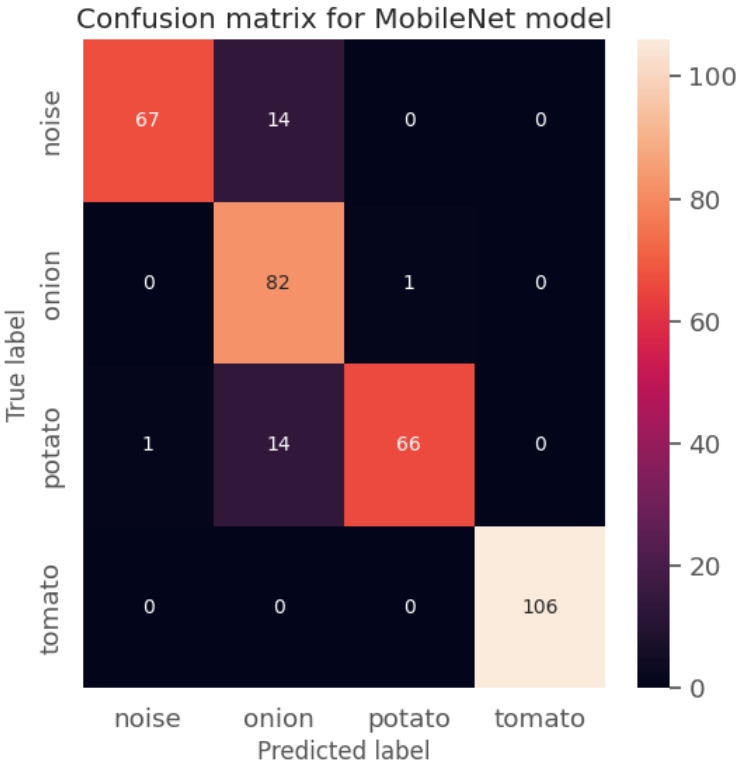

Observations :

- With MobileNet model we get a test accuracy of 91% and train accuracy of 99.89%.
- Also, the predictions are nearly 100% to actual labels in the dataset.

Comparison of Trained Model Results

In [90]:
```
%load_ext tensorboard
%tensorboard --logdir /content/logs
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
Reusing TensorBoard on port 6006 (pid 38210), started 0:37:52 ago. (Use '!kill 38210' to kill it.)
```

Conclusions :

> **Evaluation Results of Trained Models**

Model Name	Test Accuracy	Train Accuracy	Precision	Recall
Base CNN	74.93%	79.78%	0.8000	0.7066
Revised CNN	88.88%	89.83%	0.9121	0.8575
VGG19	90%	99.84%	0.8997	0.8946
ResNet	93%	99.63%	0.9366	0.9259
MobileNet	91.45%	100%	0.9145	0.9145

- After training all of our models, we found **ResNet** model to be the most accurate model on our dataset.
- Also, Resnet model gave us the highest test accuracy among all models and the base CNN model has the lowest test accuracy.

- ResNet Model is nearly 100% sure of the correct class in every image we plotted above, indicating a very good choice for our classfication task.

Submitted by : Mrudula A P