

# Assignment 1B - Question 1

## Training and Adapting Deep Networks

In [1]:

```
import pandas
import numpy as np
import matplotlib.pyplot as plt
import statsmodels.api as sm
import scipy.stats as stats
from scipy.io import loadmat

import tensorflow as tf

from tensorflow import keras
from tensorflow.keras import layers
from tensorboard import notebook
from tensorflow.keras.preprocessing.image import Iterator

from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
import matplotlib.pyplot as plt
```

INFO:tensorflow:Enabling eager execution  
INFO:tensorflow:Enabling v2 tensorshape  
INFO:tensorflow:Enabling resource variables  
INFO:tensorflow:Enabling tensor equality  
INFO:tensorflow:Enabling control flow v2

### Load data from training and testing sets

Use scipy.io loadmat function

In [2]:

```
train = loadmat('Assessment 1B/Data/Q1/q1_train.mat')
test = loadmat('Assessment 1B/Data/Q1/q1_test.mat')
```

### Sanity check

In [3]:

```
(x_test, y_test) = (test['test_X'], test['test_Y'])
x_test = x_test.astype('float32') / 255
x_test = np.transpose(x_test, (3,0,1,2))
fig = plt.figure(figsize=[20, 20])
for i in range(100):
    ax = fig.add_subplot(10, 10, i + 1)
    ax.imshow(x_test[i,:,:,:])
```

## Question1



```
In [4]:  
    (x_train, y_train) = (train['train_X'], train['train_Y'])  
    x_train = x_train.astype('float32') / 255  
    x_train = np.transpose(x_train, (3,0,1,2))  
    fig = plt.figure(figsize=[20, 20])  
    for i in range(100):  
        ax = fig.add_subplot(10, 10, i + 1)  
        ax.imshow(x_train[i,:,:,:])
```

## Question1



## Keras Model

Taken from Week 4 example 2

In [7]:

```
def get_model():
    inputs = keras.Input(shape=(32, 32, 3, ), name='img')
    x = layers.Conv2D(filters=8, kernel_size=(3,3), activation='relu', padding='same')(inputs)
    x = layers.MaxPool2D(pool_size=(2, 2))(x)
    x = layers.Conv2D(filters=16, kernel_size=(3,3), activation='relu', padding='same')(x)
    x = layers.MaxPool2D(pool_size=(2, 2))(x)
    x = layers.Conv2D(filters=32, kernel_size=(3,3), activation='relu', padding='same')(x)
    x = layers.Flatten()(x)
    x = layers.Dense(64, activation='relu')(x)
    outputs = layers.Dense(11, activation='softmax')(x)

    model_cnn = keras.Model(inputs=inputs, outputs=outputs, name='SVHN_CNN_Model')

    return model_cnn
```

In [8]:

```
model_cnn = get_model()
model_cnn.compile(loss=keras.losses.SparseCategoricalCrossentropy(from_logits=False),
                  optimizer=keras.optimizers.RMSprop(),
                  metrics=['accuracy'])
history = model_cnn.fit(x_train, y_train,
```

```
batch_size=32,  
epochs=100,  
validation_split=0.2, verbose=True)
```

```
Epoch 1/100  
25/25 [=====] - 1s 12ms/step - loss: 2.3392 - accuracy: 0.1  
842 - val_loss: 2.2591 - val_accuracy: 0.1600  
Epoch 2/100  
25/25 [=====] - 0s 8ms/step - loss: 2.2829 - accuracy: 0.16  
01 - val_loss: 2.2361 - val_accuracy: 0.1600  
Epoch 3/100  
25/25 [=====] - 0s 7ms/step - loss: 2.2669 - accuracy: 0.16  
93 - val_loss: 2.2271 - val_accuracy: 0.1600  
Epoch 4/100  
25/25 [=====] - 0s 7ms/step - loss: 2.2311 - accuracy: 0.18  
52 - val_loss: 2.1957 - val_accuracy: 0.1850  
Epoch 5/100  
25/25 [=====] - 0s 7ms/step - loss: 2.1943 - accuracy: 0.21  
89 - val_loss: 2.2205 - val_accuracy: 0.1700  
Epoch 6/100  
25/25 [=====] - 0s 7ms/step - loss: 2.1290 - accuracy: 0.24  
07 - val_loss: 2.1540 - val_accuracy: 0.1900  
Epoch 7/100  
25/25 [=====] - 0s 7ms/step - loss: 2.0824 - accuracy: 0.28  
23 - val_loss: 2.1329 - val_accuracy: 0.2350  
Epoch 8/100  
25/25 [=====] - 0s 7ms/step - loss: 1.9888 - accuracy: 0.31  
46 - val_loss: 2.1094 - val_accuracy: 0.2700  
Epoch 9/100  
25/25 [=====] - 0s 7ms/step - loss: 1.9191 - accuracy: 0.35  
44 - val_loss: 2.0151 - val_accuracy: 0.3200  
Epoch 10/100  
25/25 [=====] - 0s 7ms/step - loss: 1.8385 - accuracy: 0.35  
35 - val_loss: 1.9130 - val_accuracy: 0.4050  
Epoch 11/100  
25/25 [=====] - 0s 7ms/step - loss: 1.6995 - accuracy: 0.41  
10 - val_loss: 1.9100 - val_accuracy: 0.3200  
Epoch 12/100  
25/25 [=====] - 0s 7ms/step - loss: 1.6047 - accuracy: 0.48  
85 - val_loss: 1.7891 - val_accuracy: 0.4100  
Epoch 13/100  
25/25 [=====] - 0s 7ms/step - loss: 1.4571 - accuracy: 0.52  
57 - val_loss: 1.7312 - val_accuracy: 0.4150  
Epoch 14/100  
25/25 [=====] - 0s 7ms/step - loss: 1.3687 - accuracy: 0.57  
31 - val_loss: 1.6379 - val_accuracy: 0.4650  
Epoch 15/100  
25/25 [=====] - 0s 7ms/step - loss: 1.2993 - accuracy: 0.61  
05 - val_loss: 1.6950 - val_accuracy: 0.4800  
Epoch 16/100  
25/25 [=====] - 0s 7ms/step - loss: 1.1661 - accuracy: 0.63  
79 - val_loss: 1.6146 - val_accuracy: 0.5100  
Epoch 17/100  
25/25 [=====] - 0s 6ms/step - loss: 1.0976 - accuracy: 0.66  
25 - val_loss: 1.6179 - val_accuracy: 0.5050  
Epoch 18/100  
25/25 [=====] - 0s 6ms/step - loss: 1.0123 - accuracy: 0.67  
89 - val_loss: 1.6076 - val_accuracy: 0.5200  
Epoch 19/100  
25/25 [=====] - 0s 7ms/step - loss: 0.8959 - accuracy: 0.73  
85 - val_loss: 1.5985 - val_accuracy: 0.4950  
Epoch 20/100  
25/25 [=====] - 0s 7ms/step - loss: 0.8545 - accuracy: 0.74  
17 - val_loss: 1.6301 - val_accuracy: 0.5350  
Epoch 21/100  
25/25 [=====] - 0s 6ms/step - loss: 0.7934 - accuracy: 0.75  
45 - val_loss: 1.6284 - val_accuracy: 0.5250  
Epoch 22/100  
25/25 [=====] - 0s 6ms/step - loss: 0.7433 - accuracy: 0.78
```

```
35 - val_loss: 1.7321 - val_accuracy: 0.5250
Epoch 23/100
25/25 [=====] - 0s 7ms/step - loss: 0.6867 - accuracy: 0.79
18 - val_loss: 1.5809 - val_accuracy: 0.5600
Epoch 24/100
25/25 [=====] - 0s 7ms/step - loss: 0.6205 - accuracy: 0.81
84 - val_loss: 1.5974 - val_accuracy: 0.5450
Epoch 25/100
25/25 [=====] - 0s 6ms/step - loss: 0.5628 - accuracy: 0.83
86 - val_loss: 1.5859 - val_accuracy: 0.5450
Epoch 26/100
25/25 [=====] - 0s 6ms/step - loss: 0.5082 - accuracy: 0.83
86 - val_loss: 1.6338 - val_accuracy: 0.5400
Epoch 27/100
25/25 [=====] - 0s 6ms/step - loss: 0.4736 - accuracy: 0.86
72 - val_loss: 1.7374 - val_accuracy: 0.5750
Epoch 28/100
25/25 [=====] - 0s 6ms/step - loss: 0.3597 - accuracy: 0.90
59 - val_loss: 1.7793 - val_accuracy: 0.5550
Epoch 29/100
25/25 [=====] - 0s 7ms/step - loss: 0.3229 - accuracy: 0.91
54 - val_loss: 1.6590 - val_accuracy: 0.5850
Epoch 30/100
25/25 [=====] - 0s 6ms/step - loss: 0.2849 - accuracy: 0.92
45 - val_loss: 1.8151 - val_accuracy: 0.5850
Epoch 31/100
25/25 [=====] - 0s 7ms/step - loss: 0.2735 - accuracy: 0.90
43 - val_loss: 1.9845 - val_accuracy: 0.5800
Epoch 32/100
25/25 [=====] - 0s 7ms/step - loss: 0.2474 - accuracy: 0.94
00 - val_loss: 1.8692 - val_accuracy: 0.5950
Epoch 33/100
25/25 [=====] - 0s 7ms/step - loss: 0.1882 - accuracy: 0.96
31 - val_loss: 1.9158 - val_accuracy: 0.5900
Epoch 34/100
25/25 [=====] - 0s 7ms/step - loss: 0.2097 - accuracy: 0.94
67 - val_loss: 1.9954 - val_accuracy: 0.6000
Epoch 35/100
25/25 [=====] - 0s 6ms/step - loss: 0.1757 - accuracy: 0.96
07 - val_loss: 2.0778 - val_accuracy: 0.6000
Epoch 36/100
25/25 [=====] - 0s 7ms/step - loss: 0.1155 - accuracy: 0.98
51 - val_loss: 2.0665 - val_accuracy: 0.6000
Epoch 37/100
25/25 [=====] - 0s 6ms/step - loss: 0.1074 - accuracy: 0.97
46 - val_loss: 2.3078 - val_accuracy: 0.6050
Epoch 38/100
25/25 [=====] - 0s 6ms/step - loss: 0.0901 - accuracy: 0.98
13 - val_loss: 2.3750 - val_accuracy: 0.5750
Epoch 39/100
25/25 [=====] - 0s 6ms/step - loss: 0.0796 - accuracy: 0.99
03 - val_loss: 2.3080 - val_accuracy: 0.6150
Epoch 40/100
25/25 [=====] - 0s 6ms/step - loss: 0.0757 - accuracy: 0.98
66 - val_loss: 2.3198 - val_accuracy: 0.6000
Epoch 41/100
25/25 [=====] - 0s 6ms/step - loss: 0.0479 - accuracy: 0.99
73 - val_loss: 2.5324 - val_accuracy: 0.6100
Epoch 42/100
25/25 [=====] - 0s 6ms/step - loss: 0.0483 - accuracy: 0.99
34 - val_loss: 2.4425 - val_accuracy: 0.6150
Epoch 43/100
25/25 [=====] - 0s 6ms/step - loss: 0.0384 - accuracy: 0.99
72 - val_loss: 2.8828 - val_accuracy: 0.5950
Epoch 44/100
25/25 [=====] - 0s 6ms/step - loss: 0.0429 - accuracy: 0.99
05 - val_loss: 2.8712 - val_accuracy: 0.5750
Epoch 45/100
25/25 [=====] - 0s 6ms/step - loss: 0.0446 - accuracy: 0.99
```

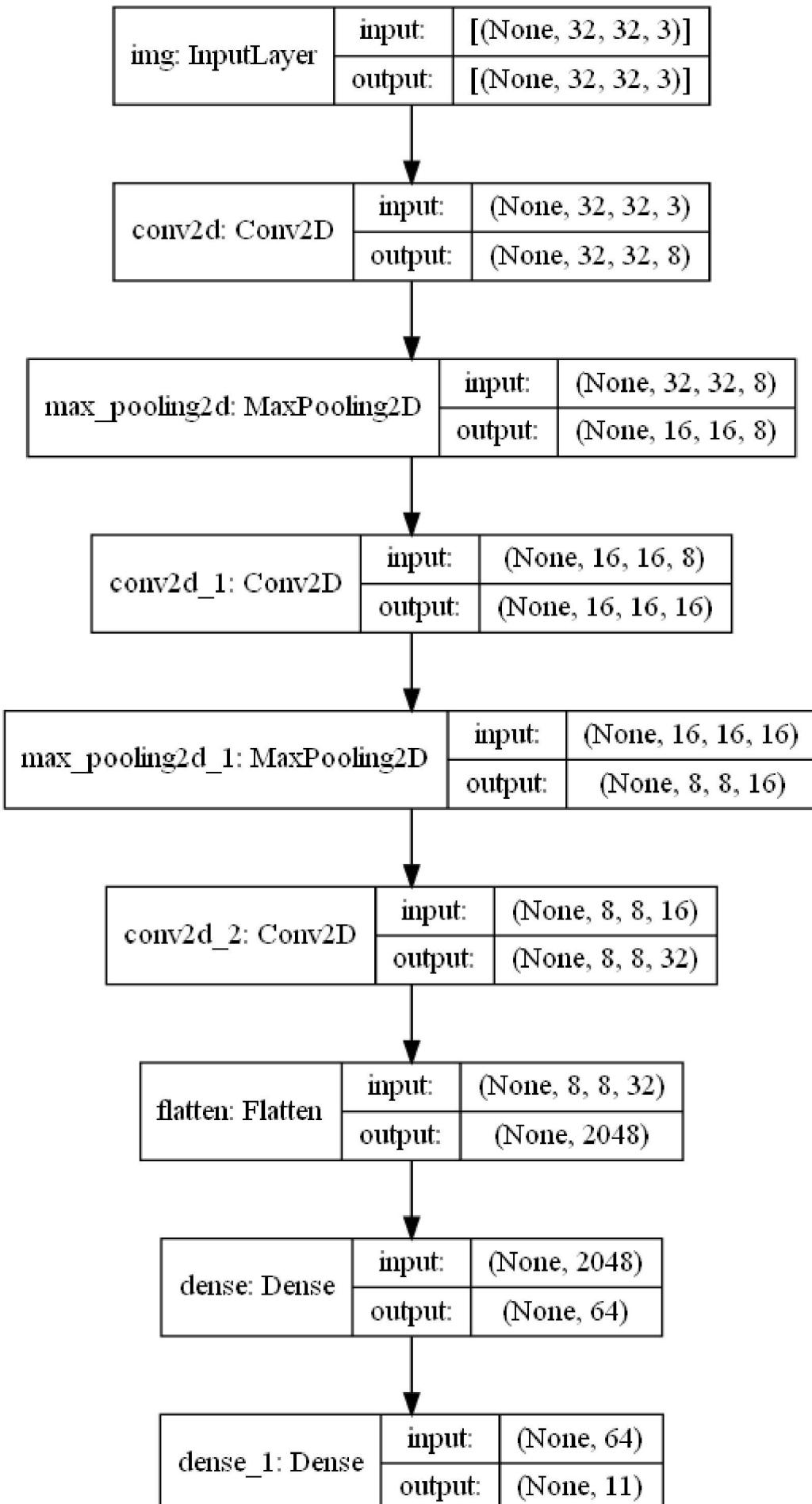
```
32 - val_loss: 2.8440 - val_accuracy: 0.5900
Epoch 46/100
25/25 [=====] - 0s 6ms/step - loss: 0.0485 - accuracy: 0.99
25 - val_loss: 2.6509 - val_accuracy: 0.6100
Epoch 47/100
25/25 [=====] - 0s 7ms/step - loss: 0.0262 - accuracy: 0.99
76 - val_loss: 2.8116 - val_accuracy: 0.6150
Epoch 48/100
25/25 [=====] - 0s 6ms/step - loss: 0.0107 - accuracy: 1.00
00 - val_loss: 3.4063 - val_accuracy: 0.6050
Epoch 49/100
25/25 [=====] - 0s 7ms/step - loss: 0.1114 - accuracy: 0.96
98 - val_loss: 2.9967 - val_accuracy: 0.6150
Epoch 50/100
25/25 [=====] - 0s 6ms/step - loss: 0.0078 - accuracy: 1.00
00 - val_loss: 3.1230 - val_accuracy: 0.6000
Epoch 51/100
25/25 [=====] - 0s 6ms/step - loss: 0.0568 - accuracy: 0.98
53 - val_loss: 2.9246 - val_accuracy: 0.6200
Epoch 52/100
25/25 [=====] - 0s 7ms/step - loss: 0.0062 - accuracy: 1.00
00 - val_loss: 3.5863 - val_accuracy: 0.6100
Epoch 53/100
25/25 [=====] - 0s 7ms/step - loss: 0.0118 - accuracy: 0.99
83 - val_loss: 3.2322 - val_accuracy: 0.6050
Epoch 54/100
25/25 [=====] - 0s 6ms/step - loss: 0.0088 - accuracy: 1.00
00 - val_loss: 3.1525 - val_accuracy: 0.6100
Epoch 55/100
25/25 [=====] - 0s 7ms/step - loss: 0.0042 - accuracy: 0.99
97 - val_loss: 3.9751 - val_accuracy: 0.5150
Epoch 56/100
25/25 [=====] - 0s 7ms/step - loss: 0.0427 - accuracy: 0.98
79 - val_loss: 3.1969 - val_accuracy: 0.6200
Epoch 57/100
25/25 [=====] - 0s 7ms/step - loss: 0.0027 - accuracy: 1.00
00 - val_loss: 3.2716 - val_accuracy: 0.6350
Epoch 58/100
25/25 [=====] - 0s 7ms/step - loss: 0.0021 - accuracy: 1.00
00 - val_loss: 3.4809 - val_accuracy: 0.6200
Epoch 59/100
25/25 [=====] - 0s 7ms/step - loss: 0.1551 - accuracy: 0.96
49 - val_loss: 3.2550 - val_accuracy: 0.6350
Epoch 60/100
25/25 [=====] - 0s 7ms/step - loss: 0.0017 - accuracy: 1.00
00 - val_loss: 3.3469 - val_accuracy: 0.6400
Epoch 61/100
25/25 [=====] - 0s 7ms/step - loss: 0.0011 - accuracy: 1.00
00 - val_loss: 3.5242 - val_accuracy: 0.6150
Epoch 62/100
25/25 [=====] - 0s 7ms/step - loss: 0.0253 - accuracy: 0.99
16 - val_loss: 3.4038 - val_accuracy: 0.5950
Epoch 63/100
25/25 [=====] - 0s 7ms/step - loss: 0.0011 - accuracy: 1.00
00 - val_loss: 3.3770 - val_accuracy: 0.6150
Epoch 64/100
25/25 [=====] - 0s 7ms/step - loss: 6.8874e-04 - accuracy: 1.0000
1 - val_loss: 3.7608 - val_accuracy: 0.6050
Epoch 65/100
25/25 [=====] - 0s 6ms/step - loss: 0.0422 - accuracy: 0.99
35 - val_loss: 3.3547 - val_accuracy: 0.6200
Epoch 66/100
25/25 [=====] - 0s 6ms/step - loss: 0.0014 - accuracy: 1.00
00 - val_loss: 3.4650 - val_accuracy: 0.6150
Epoch 67/100
25/25 [=====] - 0s 6ms/step - loss: 5.2853e-04 - accuracy: 1.0000
1 - val_loss: 3.6665 - val_accuracy: 0.6100
Epoch 68/100
25/25 [=====] - 0s 6ms/step - loss: 0.0176 - accuracy: 0.99
```

```
54 - val_loss: 3.5647 - val_accuracy: 0.6300
Epoch 69/100
25/25 [=====] - 0s 7ms/step - loss: 0.0018 - accuracy: 1.00
00 - val_loss: 3.6264 - val_accuracy: 0.6250
Epoch 70/100
25/25 [=====] - 0s 7ms/step - loss: 5.5660e-04 - accuracy: 1.0000
1.0000 - val_loss: 3.7398 - val_accuracy: 0.6250
Epoch 71/100
25/25 [=====] - 0s 7ms/step - loss: 2.7192e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.0987 - val_accuracy: 0.6100
Epoch 72/100
25/25 [=====] - 0s 6ms/step - loss: 0.0147 - accuracy: 0.99
72 - val_loss: 3.8884 - val_accuracy: 0.6150
Epoch 73/100
25/25 [=====] - 0s 7ms/step - loss: 0.0116 - accuracy: 0.99
58 - val_loss: 4.0240 - val_accuracy: 0.6150
Epoch 74/100
25/25 [=====] - 0s 7ms/step - loss: 4.4911e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.1002 - val_accuracy: 0.6150
Epoch 75/100
25/25 [=====] - 0s 6ms/step - loss: 2.3179e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.2516 - val_accuracy: 0.6150
Epoch 76/100
25/25 [=====] - 0s 7ms/step - loss: 0.0128 - accuracy: 0.99
76 - val_loss: 3.8321 - val_accuracy: 0.6100
Epoch 77/100
25/25 [=====] - 0s 7ms/step - loss: 0.0016 - accuracy: 1.00
00 - val_loss: 3.8717 - val_accuracy: 0.6100
Epoch 78/100
25/25 [=====] - 0s 7ms/step - loss: 2.8195e-04 - accuracy: 1.0000
1.0000 - val_loss: 3.9587 - val_accuracy: 0.6250
Epoch 79/100
25/25 [=====] - 0s 6ms/step - loss: 1.5004e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.1553 - val_accuracy: 0.6100
Epoch 80/100
25/25 [=====] - 0s 7ms/step - loss: 0.0037 - accuracy: 0.99
93 - val_loss: 4.0792 - val_accuracy: 0.6400
Epoch 81/100
25/25 [=====] - 0s 7ms/step - loss: 0.0031 - accuracy: 0.99
85 - val_loss: 4.2685 - val_accuracy: 0.6450
Epoch 82/100
25/25 [=====] - 0s 8ms/step - loss: 0.0121 - accuracy: 0.99
68 - val_loss: 4.2351 - val_accuracy: 0.6250
Epoch 83/100
25/25 [=====] - 0s 7ms/step - loss: 0.0070 - accuracy: 0.99
72 - val_loss: 3.7722 - val_accuracy: 0.6400
Epoch 84/100
25/25 [=====] - 0s 7ms/step - loss: 2.8698e-04 - accuracy: 1.0000
1.0000 - val_loss: 3.8851 - val_accuracy: 0.6400
Epoch 85/100
25/25 [=====] - 0s 7ms/step - loss: 1.5842e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.0996 - val_accuracy: 0.6200
Epoch 86/100
25/25 [=====] - 0s 7ms/step - loss: 8.9892e-05 - accuracy: 1.0000
1.0000 - val_loss: 4.3499 - val_accuracy: 0.6100
Epoch 87/100
25/25 [=====] - 0s 7ms/step - loss: 0.0149 - accuracy: 0.99
68 - val_loss: 5.0779 - val_accuracy: 0.5850
Epoch 88/100
25/25 [=====] - 0s 7ms/step - loss: 0.0048 - accuracy: 1.00
00 - val_loss: 4.2498 - val_accuracy: 0.6200
Epoch 89/100
25/25 [=====] - 0s 7ms/step - loss: 1.3800e-04 - accuracy: 1.0000
1.0000 - val_loss: 4.3040 - val_accuracy: 0.6300
Epoch 90/100
25/25 [=====] - 0s 7ms/step - loss: 8.5759e-05 - accuracy: 1.0000
1.0000 - val_loss: 4.4793 - val_accuracy: 0.6300
Epoch 91/100
25/25 [=====] - 0s 7ms/step - loss: 4.2072e-05 - accuracy:
```

```
1.0000 - val_loss: 4.6720 - val_accuracy: 0.6150
Epoch 92/100
25/25 [=====] - 0s 6ms/step - loss: 0.0318 - accuracy: 0.99
18 - val_loss: 4.6031 - val_accuracy: 0.6000
Epoch 93/100
25/25 [=====] - 0s 6ms/step - loss: 0.0067 - accuracy: 0.99
66 - val_loss: 4.3799 - val_accuracy: 0.6250
Epoch 94/100
25/25 [=====] - 0s 6ms/step - loss: 1.1916e-04 - accuracy:
1.0000 - val_loss: 4.3813 - val_accuracy: 0.6250
Epoch 95/100
25/25 [=====] - 0s 7ms/step - loss: 6.5398e-05 - accuracy:
1.0000 - val_loss: 4.4679 - val_accuracy: 0.6300
Epoch 96/100
25/25 [=====] - 0s 6ms/step - loss: 3.6226e-05 - accuracy:
1.0000 - val_loss: 4.6105 - val_accuracy: 0.6150
Epoch 97/100
25/25 [=====] - 0s 6ms/step - loss: 0.0027 - accuracy: 0.99
95 - val_loss: 4.3929 - val_accuracy: 0.6050
Epoch 98/100
25/25 [=====] - 0s 6ms/step - loss: 0.0089 - accuracy: 0.99
81 - val_loss: 4.2590 - val_accuracy: 0.6200
Epoch 99/100
25/25 [=====] - 0s 6ms/step - loss: 2.1359e-04 - accuracy:
1.0000 - val_loss: 4.4443 - val_accuracy: 0.6300
Epoch 100/100
25/25 [=====] - 0s 6ms/step - loss: 5.5059e-05 - accuracy:
1.0000 - val_loss: 4.5467 - val_accuracy: 0.6250
```

In [9]: `keras.utils.plot_model(model_cnn, show_shapes=True)`

Out[9]:



In [10]:

```

def plot_training(history, model, x_test, y_test):
    fig = plt.figure(figsize=[20, 6])
    ax = fig.add_subplot(1, 3, 1)
  
```

```

ax.plot(history.history['loss'], label="Training Loss")
ax.plot(history.history['val_loss'], label="Validation Loss")
ax.legend()

ax = fig.add_subplot(1, 3, 2)
ax.plot(history.history['accuracy'], label="Training Accuracy")
ax.plot(history.history['val_accuracy'], label="Validation Accuracy")
ax.legend()

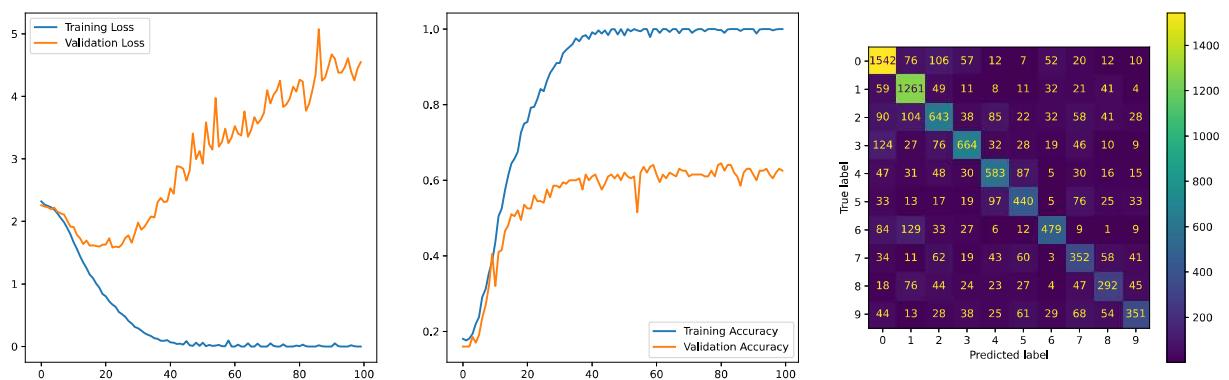
pred = model.predict(x_test)
indexes = tf.argmax(pred, axis=1)
i = tf.cast([], tf.int32)
indexes = tf.gather_nd(indexes, i)

cm = confusion_matrix(y_test, indexes)
ax = fig.add_subplot(1, 3, 3)
c = ConfusionMatrixDisplay(cm, display_labels=range(10))

c.plot(ax = ax)

plot_training(history, model_cnn, x_test, y_test)

```



## Data Augmentation

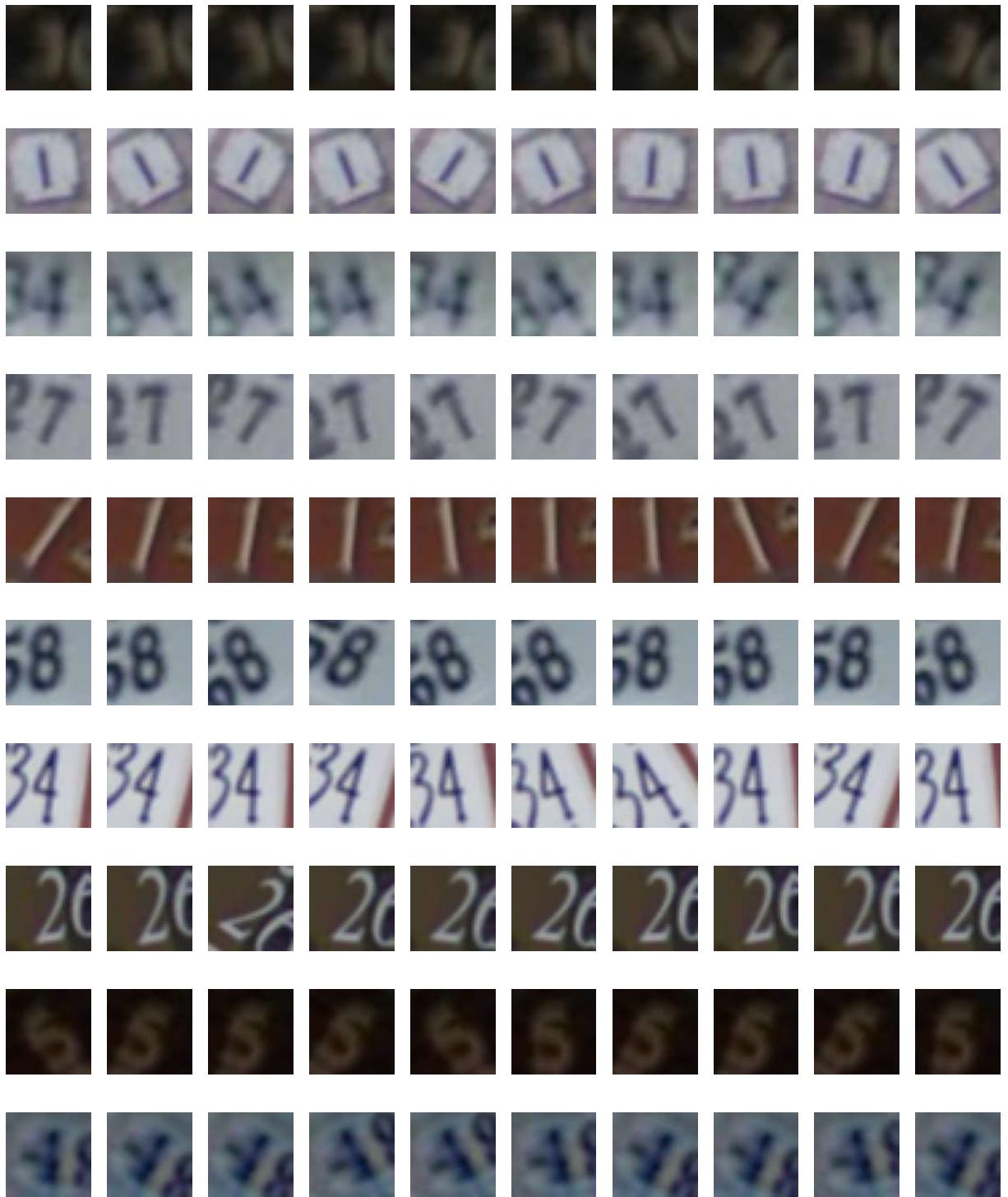
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```

In [11]: data_augmentation = keras.Sequential([
    layers.experimental.preprocessing.RandomRotation(0.1),
    layers.experimental.preprocessing.RandomZoom(0.03),
])

fig = plt.figure(figsize=[20, 25])
for i in range(10):
    for j in range(10):
        ax = fig.add_subplot(10, 10, i*10 + (j + 1))
        augmented_image = data_augmentation(tf.expand_dims(x_train[i,:,:,:],0))
        plt.imshow(augmented_image[0])
        plt.axis("off")

```



In [12]:

```
def get_model_augment():
    inputs = keras.Input(shape=(32, 32, 3, ), name='img')
    augmented = data_augmentation(inputs)
    x = layers.Conv2D(filters=8, kernel_size=(3,3), activation='relu', padding='same')(augmented)
    x = layers.MaxPool2D(pool_size=(2, 2))(x)
    x = layers.Conv2D(filters=16, kernel_size=(3,3), activation='relu', padding='same')(x)
    x = layers.MaxPool2D(pool_size=(2, 2))(x)
    x = layers.Conv2D(filters=32, kernel_size=(3,3), activation='relu', padding='same')(x)
    x = layers.Flatten()(x)
    x = layers.Dense(64, activation='relu')(x)
    outputs = layers.Dense(11, activation='softmax')(x)

    model_cnn_aug = keras.Model(inputs=inputs, outputs=outputs, name='SVHN_CNN_Model')

    return model_cnn_aug
```

```
In [13]: model_cnn_aug = get_model_augment()
model_cnn_aug.compile(loss=keras.losses.SparseCategoricalCrossentropy(from_logits=False,
                                                                     optimizer=keras.optimizers.RMSprop(),
                                                                     metrics=['accuracy']))
history = model_cnn_aug.fit(x_train, y_train,
                             batch_size=32,
                             epochs=100,
                             validation_split=0.2, verbose=True)
```

```
Epoch 1/100
25/25 [=====] - 1s 17ms/step - loss: 2.3611 - accuracy: 0.1
351 - val_loss: 2.2990 - val_accuracy: 0.1550
Epoch 2/100
25/25 [=====] - 0s 13ms/step - loss: 2.2841 - accuracy: 0.1
697 - val_loss: 2.2840 - val_accuracy: 0.1600
Epoch 3/100
25/25 [=====] - 0s 13ms/step - loss: 2.2784 - accuracy: 0.1
601 - val_loss: 2.2666 - val_accuracy: 0.1600
Epoch 4/100
25/25 [=====] - 0s 13ms/step - loss: 2.2597 - accuracy: 0.1
939 - val_loss: 2.2062 - val_accuracy: 0.1700
Epoch 5/100
25/25 [=====] - 0s 13ms/step - loss: 2.2449 - accuracy: 0.1
889 - val_loss: 2.2097 - val_accuracy: 0.1950
Epoch 6/100
25/25 [=====] - 0s 13ms/step - loss: 2.2137 - accuracy: 0.2
091 - val_loss: 2.1801 - val_accuracy: 0.2150
Epoch 7/100
25/25 [=====] - 0s 13ms/step - loss: 2.1927 - accuracy: 0.2
111 - val_loss: 2.1471 - val_accuracy: 0.2250
Epoch 8/100
25/25 [=====] - 0s 13ms/step - loss: 2.1468 - accuracy: 0.2
146 - val_loss: 2.1513 - val_accuracy: 0.2100
Epoch 9/100
25/25 [=====] - 0s 13ms/step - loss: 2.0988 - accuracy: 0.2
675 - val_loss: 2.0972 - val_accuracy: 0.2650
Epoch 10/100
25/25 [=====] - 0s 13ms/step - loss: 2.0544 - accuracy: 0.2
617 - val_loss: 2.0659 - val_accuracy: 0.2550
Epoch 11/100
25/25 [=====] - 0s 13ms/step - loss: 1.9974 - accuracy: 0.2
939 - val_loss: 1.9888 - val_accuracy: 0.2700
Epoch 12/100
25/25 [=====] - 0s 12ms/step - loss: 1.9378 - accuracy: 0.3
270 - val_loss: 2.0238 - val_accuracy: 0.3000
Epoch 13/100
25/25 [=====] - 0s 12ms/step - loss: 1.9018 - accuracy: 0.3
729 - val_loss: 1.9429 - val_accuracy: 0.2900
Epoch 14/100
25/25 [=====] - 0s 12ms/step - loss: 1.8419 - accuracy: 0.3
723 - val_loss: 1.8821 - val_accuracy: 0.2750
Epoch 15/100
25/25 [=====] - 0s 13ms/step - loss: 1.7679 - accuracy: 0.3
810 - val_loss: 1.8009 - val_accuracy: 0.3550
Epoch 16/100
25/25 [=====] - 0s 13ms/step - loss: 1.7114 - accuracy: 0.4
357 - val_loss: 1.6978 - val_accuracy: 0.3950
Epoch 17/100
25/25 [=====] - 0s 13ms/step - loss: 1.6610 - accuracy: 0.4
688 - val_loss: 1.7075 - val_accuracy: 0.3950
Epoch 18/100
25/25 [=====] - 0s 12ms/step - loss: 1.5225 - accuracy: 0.4
864 - val_loss: 1.5675 - val_accuracy: 0.4200
Epoch 19/100
25/25 [=====] - 0s 12ms/step - loss: 1.4689 - accuracy: 0.5
288 - val_loss: 1.5136 - val_accuracy: 0.5250
Epoch 20/100
25/25 [=====] - 0s 13ms/step - loss: 1.3610 - accuracy: 0.5
```

```
550 - val_loss: 1.5028 - val_accuracy: 0.4850
Epoch 21/100
25/25 [=====] - 0s 12ms/step - loss: 1.4306 - accuracy: 0.5
386 - val_loss: 1.5604 - val_accuracy: 0.4950
Epoch 22/100
25/25 [=====] - 0s 12ms/step - loss: 1.2617 - accuracy: 0.5
918 - val_loss: 1.4098 - val_accuracy: 0.5400
Epoch 23/100
25/25 [=====] - 0s 12ms/step - loss: 1.2355 - accuracy: 0.5
933 - val_loss: 1.4327 - val_accuracy: 0.5250
Epoch 24/100
25/25 [=====] - 0s 12ms/step - loss: 1.2325 - accuracy: 0.6
020 - val_loss: 1.3720 - val_accuracy: 0.5900
Epoch 25/100
25/25 [=====] - 0s 13ms/step - loss: 1.1795 - accuracy: 0.6
256 - val_loss: 1.3202 - val_accuracy: 0.5950
Epoch 26/100
25/25 [=====] - 0s 13ms/step - loss: 1.1790 - accuracy: 0.6
112 - val_loss: 1.2624 - val_accuracy: 0.6200
Epoch 27/100
25/25 [=====] - 0s 13ms/step - loss: 1.1255 - accuracy: 0.6
421 - val_loss: 1.1893 - val_accuracy: 0.6350
Epoch 28/100
25/25 [=====] - 0s 12ms/step - loss: 1.1297 - accuracy: 0.6
381 - val_loss: 1.2111 - val_accuracy: 0.6400
Epoch 29/100
25/25 [=====] - 0s 13ms/step - loss: 1.0262 - accuracy: 0.6
829 - val_loss: 1.3689 - val_accuracy: 0.5200
Epoch 30/100
25/25 [=====] - 0s 13ms/step - loss: 0.9644 - accuracy: 0.6
912 - val_loss: 1.1946 - val_accuracy: 0.6400
Epoch 31/100
25/25 [=====] - 0s 13ms/step - loss: 0.8941 - accuracy: 0.7
296 - val_loss: 1.2556 - val_accuracy: 0.6500
Epoch 32/100
25/25 [=====] - 0s 13ms/step - loss: 0.9476 - accuracy: 0.6
893 - val_loss: 1.2855 - val_accuracy: 0.5900
Epoch 33/100
25/25 [=====] - 0s 12ms/step - loss: 0.8226 - accuracy: 0.7
434 - val_loss: 1.1242 - val_accuracy: 0.6650
Epoch 34/100
25/25 [=====] - 0s 13ms/step - loss: 0.8941 - accuracy: 0.7
185 - val_loss: 1.1683 - val_accuracy: 0.6700
Epoch 35/100
25/25 [=====] - 0s 13ms/step - loss: 0.7546 - accuracy: 0.7
673 - val_loss: 1.1871 - val_accuracy: 0.6250
Epoch 36/100
25/25 [=====] - 0s 13ms/step - loss: 0.7312 - accuracy: 0.7
719 - val_loss: 1.2313 - val_accuracy: 0.6450
Epoch 37/100
25/25 [=====] - 0s 13ms/step - loss: 0.7554 - accuracy: 0.7
787 - val_loss: 1.1204 - val_accuracy: 0.6750
Epoch 38/100
25/25 [=====] - 0s 13ms/step - loss: 0.7248 - accuracy: 0.7
749 - val_loss: 1.1022 - val_accuracy: 0.6850
Epoch 39/100
25/25 [=====] - 0s 13ms/step - loss: 0.6571 - accuracy: 0.7
889 - val_loss: 1.1894 - val_accuracy: 0.6650
Epoch 40/100
25/25 [=====] - 0s 12ms/step - loss: 0.6257 - accuracy: 0.8
054 - val_loss: 1.1935 - val_accuracy: 0.6550
Epoch 41/100
25/25 [=====] - 0s 13ms/step - loss: 0.6476 - accuracy: 0.8
090 - val_loss: 1.1927 - val_accuracy: 0.6800
Epoch 42/100
25/25 [=====] - 0s 13ms/step - loss: 0.6240 - accuracy: 0.8
108 - val_loss: 1.2340 - val_accuracy: 0.6250
Epoch 43/100
25/25 [=====] - 0s 13ms/step - loss: 0.6196 - accuracy: 0.7
```

```
961 - val_loss: 1.1613 - val_accuracy: 0.7100
Epoch 44/100
25/25 [=====] - 0s 13ms/step - loss: 0.6307 - accuracy: 0.8
157 - val_loss: 1.1673 - val_accuracy: 0.7050
Epoch 45/100
25/25 [=====] - 0s 13ms/step - loss: 0.5386 - accuracy: 0.8
390 - val_loss: 1.2400 - val_accuracy: 0.6500
Epoch 46/100
25/25 [=====] - 0s 12ms/step - loss: 0.5174 - accuracy: 0.8
565 - val_loss: 1.3123 - val_accuracy: 0.6550
Epoch 47/100
25/25 [=====] - 0s 12ms/step - loss: 0.5909 - accuracy: 0.8
348 - val_loss: 1.1346 - val_accuracy: 0.6800
Epoch 48/100
25/25 [=====] - 0s 13ms/step - loss: 0.4638 - accuracy: 0.8
633 - val_loss: 1.1399 - val_accuracy: 0.7100
Epoch 49/100
25/25 [=====] - 0s 12ms/step - loss: 0.4080 - accuracy: 0.8
856 - val_loss: 1.2560 - val_accuracy: 0.6600
Epoch 50/100
25/25 [=====] - 0s 12ms/step - loss: 0.4919 - accuracy: 0.8
366 - val_loss: 1.2873 - val_accuracy: 0.6750
Epoch 51/100
25/25 [=====] - 0s 12ms/step - loss: 0.4688 - accuracy: 0.8
480 - val_loss: 1.1972 - val_accuracy: 0.7050
Epoch 52/100
25/25 [=====] - 0s 12ms/step - loss: 0.4252 - accuracy: 0.8
738 - val_loss: 1.1997 - val_accuracy: 0.7000
Epoch 53/100
25/25 [=====] - 0s 12ms/step - loss: 0.3951 - accuracy: 0.8
919 - val_loss: 1.2330 - val_accuracy: 0.6900
Epoch 54/100
25/25 [=====] - 0s 13ms/step - loss: 0.3920 - accuracy: 0.8
849 - val_loss: 1.3015 - val_accuracy: 0.6750
Epoch 55/100
25/25 [=====] - 0s 13ms/step - loss: 0.3720 - accuracy: 0.8
802 - val_loss: 1.3337 - val_accuracy: 0.6800
Epoch 56/100
25/25 [=====] - 0s 14ms/step - loss: 0.3506 - accuracy: 0.8
950 - val_loss: 1.1962 - val_accuracy: 0.7200
Epoch 57/100
25/25 [=====] - 0s 13ms/step - loss: 0.3355 - accuracy: 0.9
087 - val_loss: 1.1292 - val_accuracy: 0.7150
Epoch 58/100
25/25 [=====] - 0s 13ms/step - loss: 0.3536 - accuracy: 0.9
140 - val_loss: 1.3237 - val_accuracy: 0.7000
Epoch 59/100
25/25 [=====] - 0s 13ms/step - loss: 0.3047 - accuracy: 0.9
103 - val_loss: 1.3170 - val_accuracy: 0.7050
Epoch 60/100
25/25 [=====] - 0s 13ms/step - loss: 0.3079 - accuracy: 0.9
126 - val_loss: 1.2977 - val_accuracy: 0.6900
Epoch 61/100
25/25 [=====] - 0s 13ms/step - loss: 0.2741 - accuracy: 0.9
209 - val_loss: 1.3036 - val_accuracy: 0.7050
Epoch 62/100
25/25 [=====] - 0s 13ms/step - loss: 0.2834 - accuracy: 0.9
246 - val_loss: 1.3426 - val_accuracy: 0.7200
Epoch 63/100
25/25 [=====] - 0s 12ms/step - loss: 0.2669 - accuracy: 0.9
231 - val_loss: 1.3743 - val_accuracy: 0.7000
Epoch 64/100
25/25 [=====] - 0s 12ms/step - loss: 0.2634 - accuracy: 0.9
115 - val_loss: 1.3927 - val_accuracy: 0.6900
Epoch 65/100
25/25 [=====] - 0s 13ms/step - loss: 0.2946 - accuracy: 0.9
225 - val_loss: 1.3578 - val_accuracy: 0.6700
Epoch 66/100
25/25 [=====] - 0s 13ms/step - loss: 0.2473 - accuracy: 0.9
```

```
326 - val_loss: 1.3773 - val_accuracy: 0.7050
Epoch 67/100
25/25 [=====] - 0s 13ms/step - loss: 0.2471 - accuracy: 0.9
232 - val_loss: 1.4303 - val_accuracy: 0.7100
Epoch 68/100
25/25 [=====] - 0s 13ms/step - loss: 0.2375 - accuracy: 0.9
362 - val_loss: 1.3506 - val_accuracy: 0.7000
Epoch 69/100
25/25 [=====] - 0s 13ms/step - loss: 0.1810 - accuracy: 0.9
456 - val_loss: 1.4504 - val_accuracy: 0.7000
Epoch 70/100
25/25 [=====] - 0s 12ms/step - loss: 0.2962 - accuracy: 0.8
992 - val_loss: 1.3268 - val_accuracy: 0.7050
Epoch 71/100
25/25 [=====] - 0s 13ms/step - loss: 0.2347 - accuracy: 0.9
168 - val_loss: 1.3500 - val_accuracy: 0.7050
Epoch 72/100
25/25 [=====] - 0s 13ms/step - loss: 0.2230 - accuracy: 0.9
516 - val_loss: 1.2757 - val_accuracy: 0.7550
Epoch 73/100
25/25 [=====] - 0s 13ms/step - loss: 0.1789 - accuracy: 0.9
443 - val_loss: 1.7832 - val_accuracy: 0.6700
Epoch 74/100
25/25 [=====] - 0s 12ms/step - loss: 0.2107 - accuracy: 0.9
375 - val_loss: 1.4771 - val_accuracy: 0.7200
Epoch 75/100
25/25 [=====] - 0s 12ms/step - loss: 0.1355 - accuracy: 0.9
624 - val_loss: 1.7759 - val_accuracy: 0.6850
Epoch 76/100
25/25 [=====] - 0s 12ms/step - loss: 0.2285 - accuracy: 0.9
338 - val_loss: 1.4263 - val_accuracy: 0.7200
Epoch 77/100
25/25 [=====] - 0s 12ms/step - loss: 0.1778 - accuracy: 0.9
497 - val_loss: 1.3853 - val_accuracy: 0.7250
Epoch 78/100
25/25 [=====] - 0s 13ms/step - loss: 0.1616 - accuracy: 0.9
470 - val_loss: 1.5406 - val_accuracy: 0.7150
Epoch 79/100
25/25 [=====] - 0s 12ms/step - loss: 0.2607 - accuracy: 0.9
206 - val_loss: 1.4975 - val_accuracy: 0.7250
Epoch 80/100
25/25 [=====] - 0s 13ms/step - loss: 0.1402 - accuracy: 0.9
608 - val_loss: 1.6311 - val_accuracy: 0.7050
Epoch 81/100
25/25 [=====] - 0s 12ms/step - loss: 0.1586 - accuracy: 0.9
590 - val_loss: 1.7252 - val_accuracy: 0.6900
Epoch 82/100
25/25 [=====] - 0s 13ms/step - loss: 0.1110 - accuracy: 0.9
736 - val_loss: 1.5538 - val_accuracy: 0.7100
Epoch 83/100
25/25 [=====] - 0s 13ms/step - loss: 0.1684 - accuracy: 0.9
472 - val_loss: 1.5221 - val_accuracy: 0.7350
Epoch 84/100
25/25 [=====] - 0s 13ms/step - loss: 0.1252 - accuracy: 0.9
568 - val_loss: 1.5246 - val_accuracy: 0.7150
Epoch 85/100
25/25 [=====] - 0s 13ms/step - loss: 0.1303 - accuracy: 0.9
678 - val_loss: 1.5745 - val_accuracy: 0.7250
Epoch 86/100
25/25 [=====] - 0s 13ms/step - loss: 0.1054 - accuracy: 0.9
707 - val_loss: 1.5936 - val_accuracy: 0.7100
Epoch 87/100
25/25 [=====] - 0s 13ms/step - loss: 0.1447 - accuracy: 0.9
502 - val_loss: 1.6659 - val_accuracy: 0.7200
Epoch 88/100
25/25 [=====] - 0s 13ms/step - loss: 0.1511 - accuracy: 0.9
558 - val_loss: 1.8055 - val_accuracy: 0.6700
Epoch 89/100
25/25 [=====] - 0s 12ms/step - loss: 0.1422 - accuracy: 0.9
```

```

537 - val_loss: 1.6116 - val_accuracy: 0.7200
Epoch 90/100
25/25 [=====] - 0s 13ms/step - loss: 0.0746 - accuracy: 0.9
812 - val_loss: 1.7322 - val_accuracy: 0.6850
Epoch 91/100
25/25 [=====] - 0s 12ms/step - loss: 0.0920 - accuracy: 0.9
796 - val_loss: 1.6639 - val_accuracy: 0.7350
Epoch 92/100
25/25 [=====] - 0s 13ms/step - loss: 0.1302 - accuracy: 0.9
571 - val_loss: 1.9906 - val_accuracy: 0.7150
Epoch 93/100
25/25 [=====] - 0s 12ms/step - loss: 0.1002 - accuracy: 0.9
718 - val_loss: 1.7114 - val_accuracy: 0.7200
Epoch 94/100
25/25 [=====] - 0s 13ms/step - loss: 0.0629 - accuracy: 0.9
796 - val_loss: 1.9540 - val_accuracy: 0.6950
Epoch 95/100
25/25 [=====] - 0s 12ms/step - loss: 0.1128 - accuracy: 0.9
688 - val_loss: 1.8018 - val_accuracy: 0.7150
Epoch 96/100
25/25 [=====] - 0s 12ms/step - loss: 0.1132 - accuracy: 0.9
748 - val_loss: 1.7821 - val_accuracy: 0.7200
Epoch 97/100
25/25 [=====] - 0s 13ms/step - loss: 0.0605 - accuracy: 0.9
845 - val_loss: 1.8031 - val_accuracy: 0.7050
Epoch 98/100
25/25 [=====] - 0s 13ms/step - loss: 0.1006 - accuracy: 0.9
696 - val_loss: 1.8132 - val_accuracy: 0.7700
Epoch 99/100
25/25 [=====] - 0s 13ms/step - loss: 0.0673 - accuracy: 0.9
723 - val_loss: 1.9831 - val_accuracy: 0.7400
Epoch 100/100
25/25 [=====] - 0s 13ms/step - loss: 0.0806 - accuracy: 0.9
814 - val_loss: 1.7520 - val_accuracy: 0.7550

```

In [14]:

```

def plot_training(history, model, x_test, y_test):
    fig = plt.figure(figsize=[20, 6])
    ax = fig.add_subplot(1, 3, 1)
    ax.plot(history.history['loss'], label="Training Loss")
    ax.plot(history.history['val_loss'], label="Validation Loss")
    ax.legend()

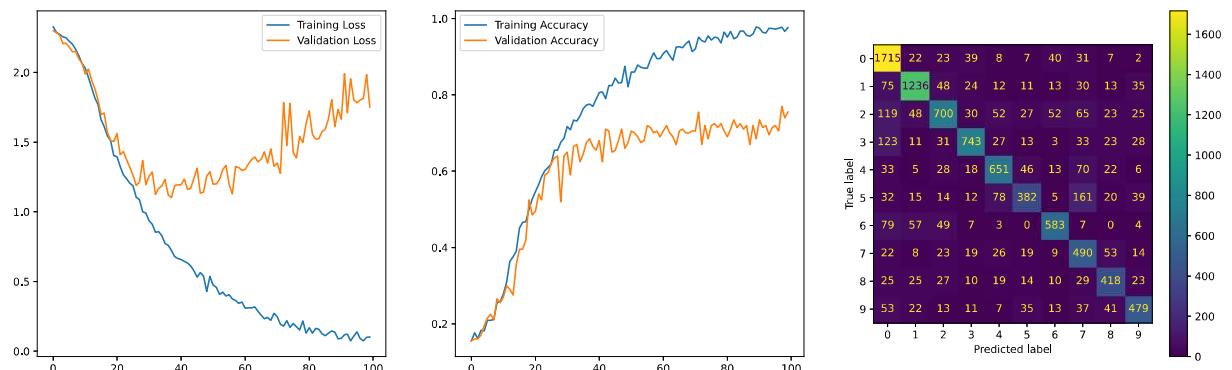
    ax = fig.add_subplot(1, 3, 2)
    ax.plot(history.history['accuracy'], label="Training Accuracy")
    ax.plot(history.history['val_accuracy'], label="Validation Accuracy")
    ax.legend()

    pred = model.predict(x_test)
    indexes = tf.argmax(pred, axis=1)
    i = tf.cast([], tf.int32)
    indexes = tf.gather_nd(indexes, i)

    cm = confusion_matrix(y_test, indexes)
    ax = fig.add_subplot(1, 3, 3)
    c = ConfusionMatrixDisplay(cm, display_labels=range(10))
    c.plot(ax = ax)

plot_training(history, model_cnn_aug, x_test, y_test)

```



## Fine Tuning on vgg

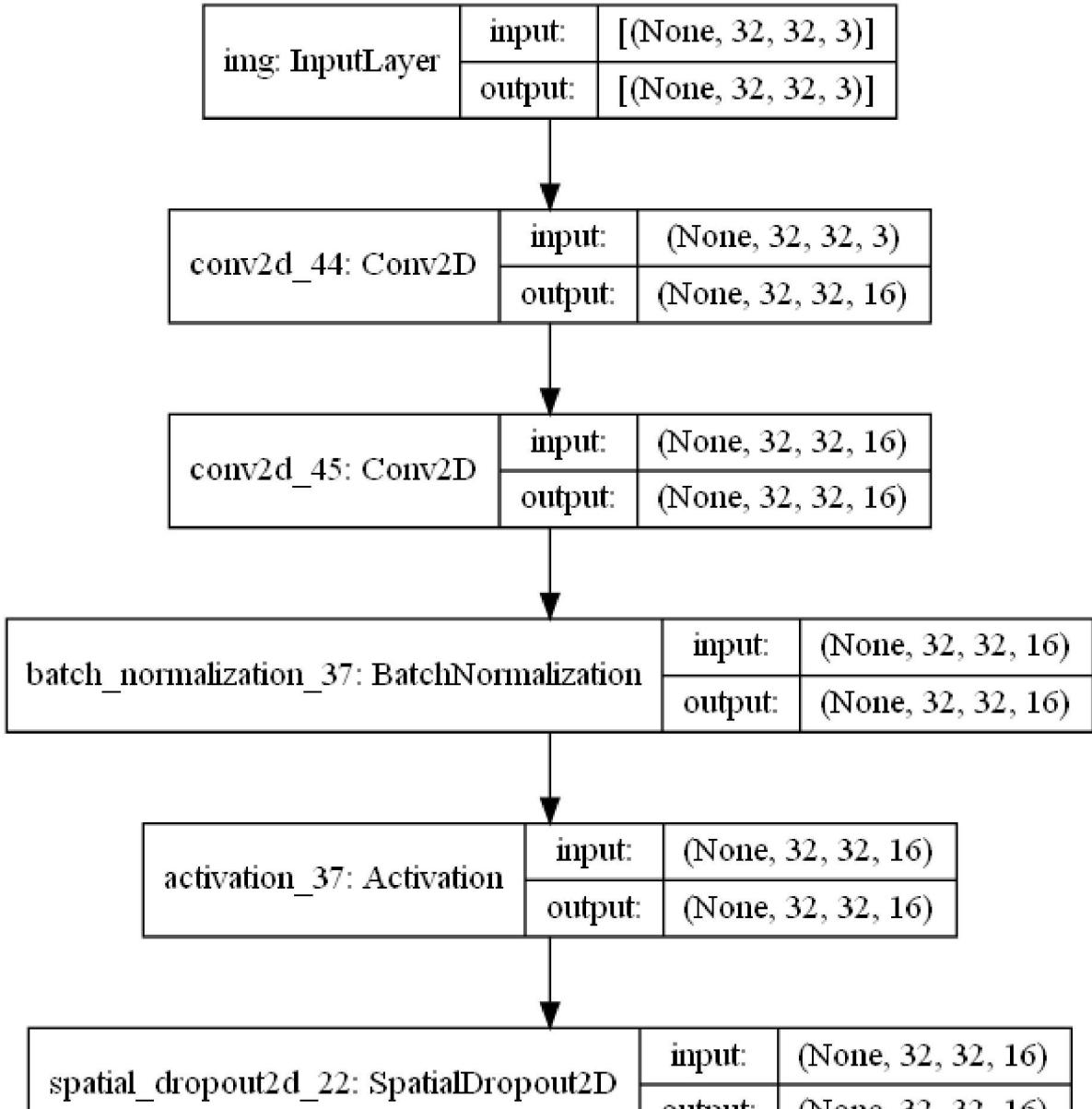
Week 5 example 3

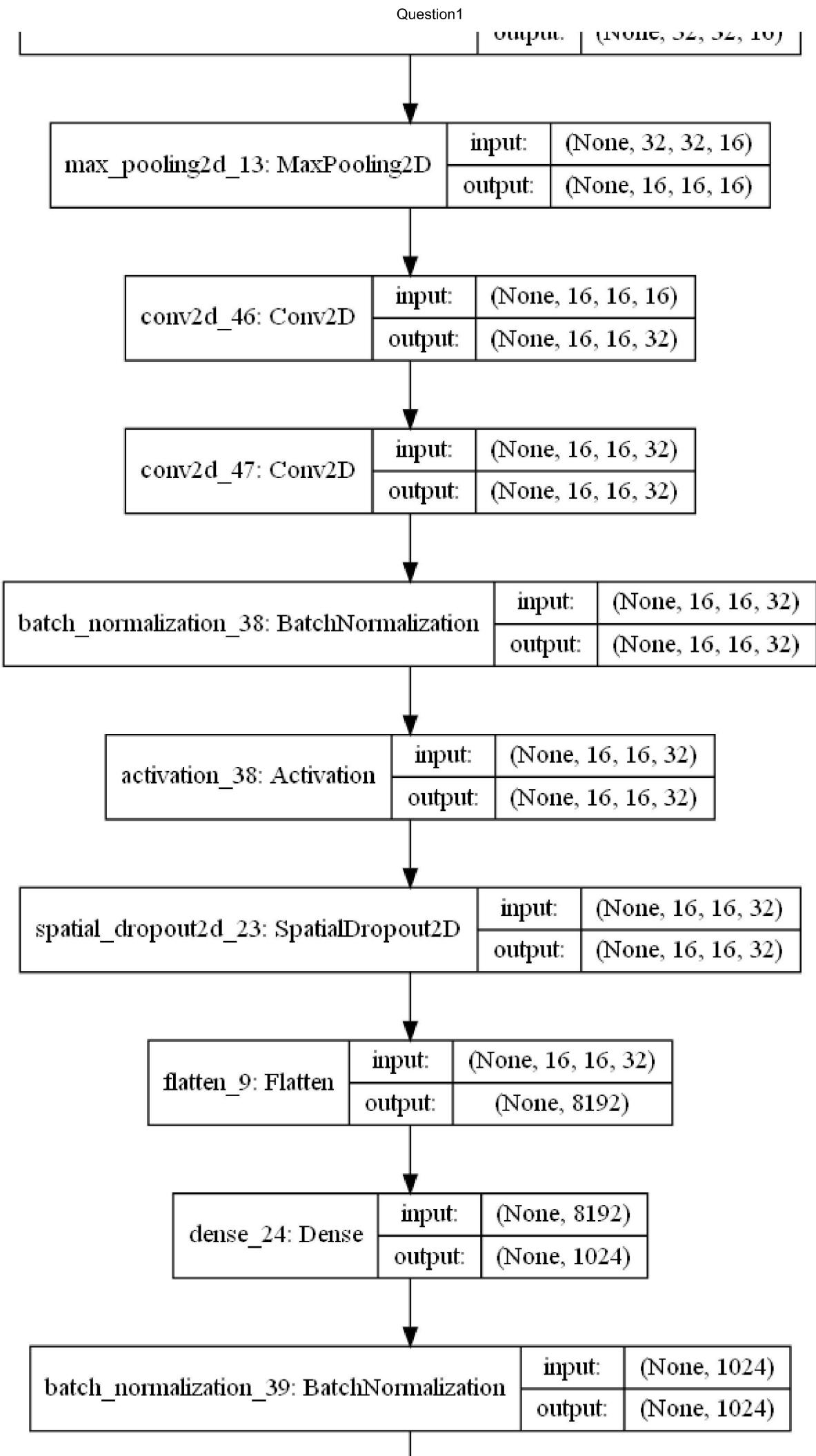
```
In [12]: model = keras.models.load_model('Assessment 1B/vgg_2stage_CIFAR_bigger.h5')

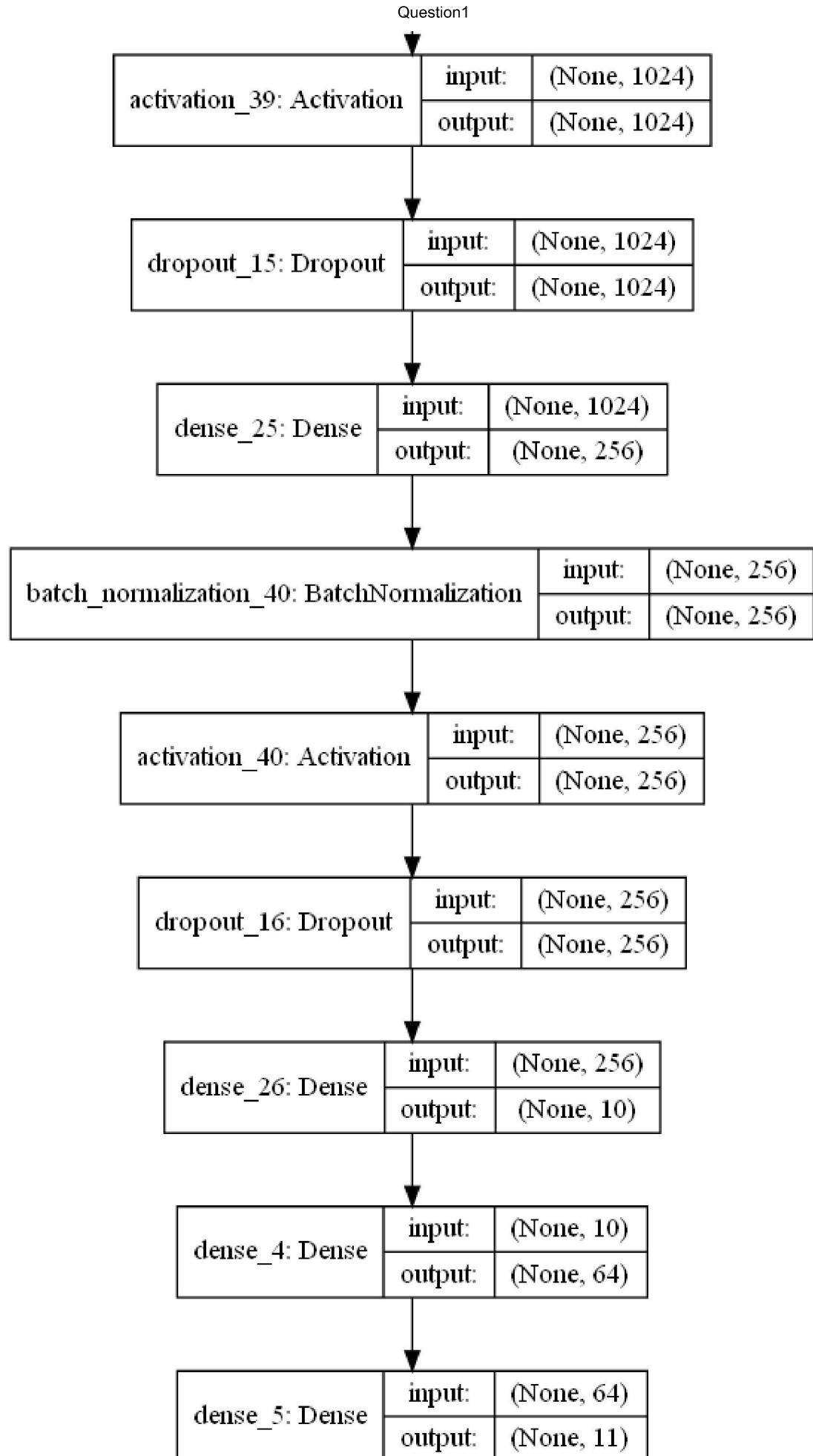
x = layers.Dense(64, activation='relu')(model.layers[-1].output)
# output layer, single value, as we only have 1 output - the
outputs = layers.Dense(11)(x)

new_model = keras.Model(inputs=model.input, outputs=outputs)
keras.utils.plot_model(new_model, show_shapes=True)
```

Out[12]:







In [11]:

```
# train the model
new_model.compile(loss=keras.losses.SparseCategoricalCrossentropy(from_logits=False),
                    optimizer=keras.optimizers.RMSprop(),
```

```
metrics=['accuracy'])

history = new_model.fit(x_train, y_train,
                        batch_size=32,
                        epochs=100,
                        validation_split=0.2, verbose=True)
```

```
Epoch 1/100
25/25 [=====] - 4s 92ms/step - loss: 5.9352 - accuracy: 0.1
232 - val_loss: 5.5801 - val_accuracy: 0.1750
Epoch 2/100
25/25 [=====] - 2s 86ms/step - loss: 4.9253 - accuracy: 0.1
695 - val_loss: 5.8066 - val_accuracy: 0.2100
Epoch 3/100
25/25 [=====] - 2s 86ms/step - loss: 4.1194 - accuracy: 0.2
139 - val_loss: 5.8597 - val_accuracy: 0.2100
Epoch 4/100
25/25 [=====] - 2s 85ms/step - loss: 4.0632 - accuracy: 0.1
967 - val_loss: 6.5230 - val_accuracy: 0.1600
Epoch 5/100
25/25 [=====] - 2s 85ms/step - loss: 3.8324 - accuracy: 0.2
203 - val_loss: 5.5341 - val_accuracy: 0.1900
Epoch 6/100
25/25 [=====] - 2s 85ms/step - loss: 3.5539 - accuracy: 0.2
458 - val_loss: 5.6826 - val_accuracy: 0.2150
Epoch 7/100
25/25 [=====] - 2s 86ms/step - loss: 3.4527 - accuracy: 0.3
122 - val_loss: 6.0353 - val_accuracy: 0.1650
Epoch 8/100
25/25 [=====] - 2s 86ms/step - loss: 3.4701 - accuracy: 0.2
952 - val_loss: 6.5614 - val_accuracy: 0.1700
Epoch 9/100
25/25 [=====] - 2s 87ms/step - loss: 3.0635 - accuracy: 0.3
305 - val_loss: 5.6132 - val_accuracy: 0.2150
Epoch 10/100
25/25 [=====] - 2s 87ms/step - loss: 2.8268 - accuracy: 0.3
660 - val_loss: 5.0943 - val_accuracy: 0.2900
Epoch 11/100
25/25 [=====] - 2s 85ms/step - loss: 3.0488 - accuracy: 0.3
758 - val_loss: 6.3208 - val_accuracy: 0.2850
Epoch 12/100
25/25 [=====] - 2s 85ms/step - loss: 3.6904 - accuracy: 0.3
332 - val_loss: 5.7211 - val_accuracy: 0.2550
Epoch 13/100
25/25 [=====] - 2s 86ms/step - loss: 3.5569 - accuracy: 0.3
682 - val_loss: 10.1054 - val_accuracy: 0.2050
Epoch 14/100
25/25 [=====] - 2s 88ms/step - loss: 3.8160 - accuracy: 0.3
289 - val_loss: 10.2844 - val_accuracy: 0.1550
Epoch 15/100
25/25 [=====] - 2s 88ms/step - loss: 3.1901 - accuracy: 0.3
148 - val_loss: 5.7288 - val_accuracy: 0.1650
Epoch 16/100
25/25 [=====] - 2s 86ms/step - loss: 2.5232 - accuracy: 0.2
516 - val_loss: 3.2861 - val_accuracy: 0.1150
Epoch 17/100
25/25 [=====] - 2s 85ms/step - loss: 2.3934 - accuracy: 0.2
013 - val_loss: 3.1159 - val_accuracy: 0.1650
Epoch 18/100
25/25 [=====] - 2s 86ms/step - loss: 2.3929 - accuracy: 0.2
358 - val_loss: 3.0206 - val_accuracy: 0.2200
Epoch 19/100
25/25 [=====] - 2s 88ms/step - loss: 2.4584 - accuracy: 0.2
222 - val_loss: 2.9889 - val_accuracy: 0.2400
Epoch 20/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
897 - val_loss: 2.7053 - val_accuracy: 0.2300
Epoch 21/100
25/25 [=====] - 2s 85ms/step - loss: 2.3990 - accuracy: 0.2
```

```
029 - val_loss: 2.3979 - val_accuracy: 0.0850
Epoch 22/100
25/25 [=====] - 2s 88ms/step - loss: 2.3979 - accuracy: 0.1
025 - val_loss: 2.3979 - val_accuracy: 0.0750
Epoch 23/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
431 - val_loss: 2.4440 - val_accuracy: 0.1050
Epoch 24/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
407 - val_loss: 2.3979 - val_accuracy: 0.1200
Epoch 25/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
457 - val_loss: 2.3979 - val_accuracy: 0.1400
Epoch 26/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
201 - val_loss: 2.3859 - val_accuracy: 0.1150
Epoch 27/100
25/25 [=====] - 2s 88ms/step - loss: 2.3979 - accuracy: 0.1
162 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 28/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
769 - val_loss: 2.3979 - val_accuracy: 0.1050
Epoch 29/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
389 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 30/100
25/25 [=====] - 2s 89ms/step - loss: 2.3979 - accuracy: 0.1
537 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 31/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
461 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 32/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
149 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 33/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
303 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 34/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
657 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 35/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
344 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 36/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
390 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 37/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
373 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 38/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
337 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 39/100
25/25 [=====] - 2s 88ms/step - loss: 2.4045 - accuracy: 0.1
659 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 40/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
396 - val_loss: 2.3979 - val_accuracy: 0.1050
Epoch 41/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
544 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 42/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
526 - val_loss: 2.3979 - val_accuracy: 0.1050
Epoch 43/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
552 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 44/100
25/25 [=====] - 2s 86ms/step - loss: 2.3891 - accuracy: 0.1
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454 - val_loss: 2.3979 - val_accuracy: 0.1200
Epoch 45/100
25/25 [=====] - 2s 84ms/step - loss: 2.3928 - accuracy: 0.1
642 - val_loss: 2.3979 - val_accuracy: 0.1200
Epoch 46/100
25/25 [=====] - 2s 85ms/step - loss: 2.4049 - accuracy: 0.1
474 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 47/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
475 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 48/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
413 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 49/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
635 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 50/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
505 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 51/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
327 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 52/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
484 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 53/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
476 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 54/100
25/25 [=====] - 2s 85ms/step - loss: 2.3921 - accuracy: 0.1
736 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 55/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
510 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 56/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
559 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 57/100
25/25 [=====] - 2s 86ms/step - loss: 2.3911 - accuracy: 0.1
611 - val_loss: 2.3979 - val_accuracy: 0.0850
Epoch 58/100
25/25 [=====] - 2s 88ms/step - loss: 2.3909 - accuracy: 0.1
433 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 59/100
25/25 [=====] - 2s 86ms/step - loss: 2.4093 - accuracy: 0.1
187 - val_loss: 2.3979 - val_accuracy: 0.1450
Epoch 60/100
25/25 [=====] - 2s 86ms/step - loss: 2.3970 - accuracy: 0.1
423 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 61/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
329 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 62/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
489 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 63/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
311 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 64/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
227 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 65/100
25/25 [=====] - 2s 88ms/step - loss: 2.3946 - accuracy: 0.1
512 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 66/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
412 - val_loss: 2.3979 - val_accuracy: 0.0950
Epoch 67/100
25/25 [=====] - 2s 86ms/step - loss: 2.3951 - accuracy: 0.1
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586 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 68/100
25/25 [=====] - 2s 85ms/step - loss: 2.3934 - accuracy: 0.1
297 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 69/100
25/25 [=====] - 2s 85ms/step - loss: 2.3956 - accuracy: 0.1
464 - val_loss: 2.3979 - val_accuracy: 0.1400
Epoch 70/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
398 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 71/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
381 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 72/100
25/25 [=====] - 2s 87ms/step - loss: 2.3979 - accuracy: 0.1
329 - val_loss: 2.3979 - val_accuracy: 0.0900
Epoch 73/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
255 - val_loss: 2.3979 - val_accuracy: 0.0800
Epoch 74/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
260 - val_loss: 2.3979 - val_accuracy: 0.0750
Epoch 75/100
25/25 [=====] - 2s 86ms/step - loss: 2.3979 - accuracy: 0.1
215 - val_loss: 2.3979 - val_accuracy: 0.0800
Epoch 76/100
25/25 [=====] - 2s 85ms/step - loss: 2.3979 - accuracy: 0.1
156 - val_loss: 2.3979 - val_accuracy: 0.0800
Epoch 77/100
25/25 [=====] - 2s 84ms/step - loss: 2.3973 - accuracy: 0.1
322 - val_loss: 2.3739 - val_accuracy: 0.2150
Epoch 78/100
25/25 [=====] - 2s 83ms/step - loss: 2.3951 - accuracy: 0.1
928 - val_loss: 2.3979 - val_accuracy: 0.1600
Epoch 79/100
25/25 [=====] - 2s 87ms/step - loss: 2.3938 - accuracy: 0.1
532 - val_loss: 2.3979 - val_accuracy: 0.1700
Epoch 80/100
25/25 [=====] - 2s 87ms/step - loss: 2.4052 - accuracy: 0.1
523 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 81/100
25/25 [=====] - 2s 88ms/step - loss: 2.3959 - accuracy: 0.1
243 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 82/100
25/25 [=====] - 2s 87ms/step - loss: 2.3911 - accuracy: 0.1
630 - val_loss: 2.3979 - val_accuracy: 0.1050
Epoch 83/100
25/25 [=====] - 2s 86ms/step - loss: 2.3975 - accuracy: 0.1
452 - val_loss: 2.3979 - val_accuracy: 0.1150
Epoch 84/100
25/25 [=====] - 2s 84ms/step - loss: 2.3972 - accuracy: 0.1
569 - val_loss: 2.3979 - val_accuracy: 0.1000
Epoch 85/100
25/25 [=====] - 2s 84ms/step - loss: 2.3944 - accuracy: 0.1
473 - val_loss: 2.3979 - val_accuracy: 0.1050
Epoch 86/100
25/25 [=====] - 2s 85ms/step - loss: 2.3862 - accuracy: 0.1
401 - val_loss: 2.3979 - val_accuracy: 0.1100
Epoch 87/100
25/25 [=====] - 2s 84ms/step - loss: 2.3895 - accuracy: 0.1
349 - val_loss: 2.3859 - val_accuracy: 0.1350
Epoch 88/100
25/25 [=====] - 2s 87ms/step - loss: 2.3886 - accuracy: 0.1
152 - val_loss: 2.5131 - val_accuracy: 0.1000
Epoch 89/100
25/25 [=====] - 2s 84ms/step - loss: 2.3985 - accuracy: 0.1
415 - val_loss: 2.3859 - val_accuracy: 0.1200
Epoch 90/100
25/25 [=====] - 2s 85ms/step - loss: 2.3999 - accuracy: 0.1
```

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412 - val_loss: 2.3979 - val_accuracy: 0.1400
Epoch 91/100
25/25 [=====] - 2s 85ms/step - loss: 2.3922 - accuracy: 0.1
655 - val_loss: 2.3979 - val_accuracy: 0.1250
Epoch 92/100
25/25 [=====] - 2s 86ms/step - loss: 2.3962 - accuracy: 0.1
260 - val_loss: 2.4353 - val_accuracy: 0.1200
Epoch 93/100
25/25 [=====] - 2s 84ms/step - loss: 2.3979 - accuracy: 0.1
517 - val_loss: 2.3979 - val_accuracy: 0.1250
Epoch 94/100
25/25 [=====] - 2s 83ms/step - loss: 2.3962 - accuracy: 0.1
521 - val_loss: 2.3979 - val_accuracy: 0.1200
Epoch 95/100
25/25 [=====] - 2s 86ms/step - loss: 2.3938 - accuracy: 0.1
571 - val_loss: 2.3979 - val_accuracy: 0.1300
Epoch 96/100
25/25 [=====] - 2s 85ms/step - loss: 2.3936 - accuracy: 0.1
475 - val_loss: 2.4559 - val_accuracy: 0.1200
Epoch 97/100
25/25 [=====] - 2s 85ms/step - loss: 2.3811 - accuracy: 0.1
528 - val_loss: 2.4554 - val_accuracy: 0.1200
Epoch 98/100
25/25 [=====] - 2s 86ms/step - loss: 2.3970 - accuracy: 0.1
445 - val_loss: 2.4551 - val_accuracy: 0.1250
Epoch 99/100
25/25 [=====] - 2s 85ms/step - loss: 2.3815 - accuracy: 0.1
426 - val_loss: 2.4437 - val_accuracy: 0.1450
Epoch 100/100
25/25 [=====] - 2s 86ms/step - loss: 2.3955 - accuracy: 0.1
492 - val_loss: 2.3979 - val_accuracy: 0.0950

```

In [13]:

```

def plot_training(history, model, x_test, y_test):
    fig = plt.figure(figsize=[20, 6])
    ax = fig.add_subplot(1, 3, 1)
    ax.plot(history.history['loss'], label="Training Loss")
    ax.plot(history.history['val_loss'], label="Validation Loss")
    ax.legend()

    ax = fig.add_subplot(1, 3, 2)
    ax.plot(history.history['accuracy'], label="Training Accuracy")
    ax.plot(history.history['val_accuracy'], label="Validation Accuracy")
    ax.legend()

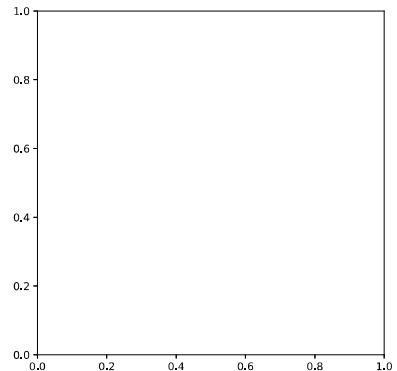
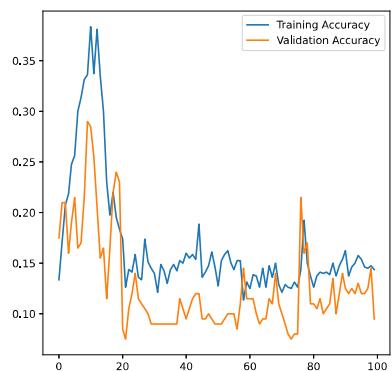
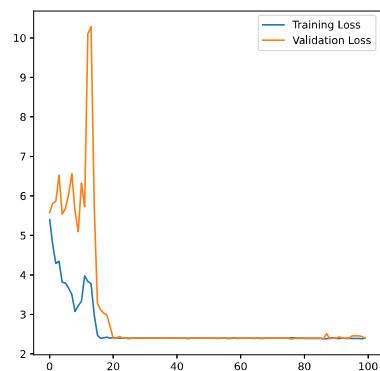
    pred = model.predict(x_test)
    indexes = tf.argmax(pred, axis=1)
    i = tf.cast([], tf.int32)
    indexes = tf.gather_nd(indexes, i)

    cm = confusion_matrix(y_test, indexes)
    ax = fig.add_subplot(1, 3, 3)
    c = ConfusionMatrixDisplay(cm, display_labels=range(10))

    #c.plot(ax = ax)
    plot_training(history, new_model, x_test, y_test)

```

## Question1



In [ ]: