Tasks ¶

1. Build and train the model with the **minimum number** of parameters and performance F1 > 0.985
    - consider convolution layers, max pooling layers, dense layers after flattening, batch normalization layers
    - consider different activation functions (linear, sigmoid, tanh, relu)
    - consider different optimizers (adam, rmsprop, sgd, adadelta, ...)
2. Change the input image size, consider 8x8, 12x12, 16x16, 28x28, 32x32. How performances of your best model from p.1 changes as a function of image size?

Description: SEM images of the metal-nitrides thin films, depending on the metals concentrations and processing conditions

In [1]:

```
import seaborn as sns
from skimage import color
from skimage import io
import matplotlib.image as mpimg
from sklearn.preprocessing import OneHotEncoder
import numpy as np
```

In [2]:

```
import matplotlib.pyplot as plt
from matplotlib import rcParams
%matplotlib inline
sns.set()
```

Read the images

Read the JPG files

In [3]:

```
img1=mpimg.imread('class1.jpg')
img2=mpimg.imread('class2.jpg')
img3=mpimg.imread('class3.jpg')
```

and show it

In [4]:

```
fig, axs = plt.subplots(1,3, figsize=(15,5), sharex=True, sharey=True)

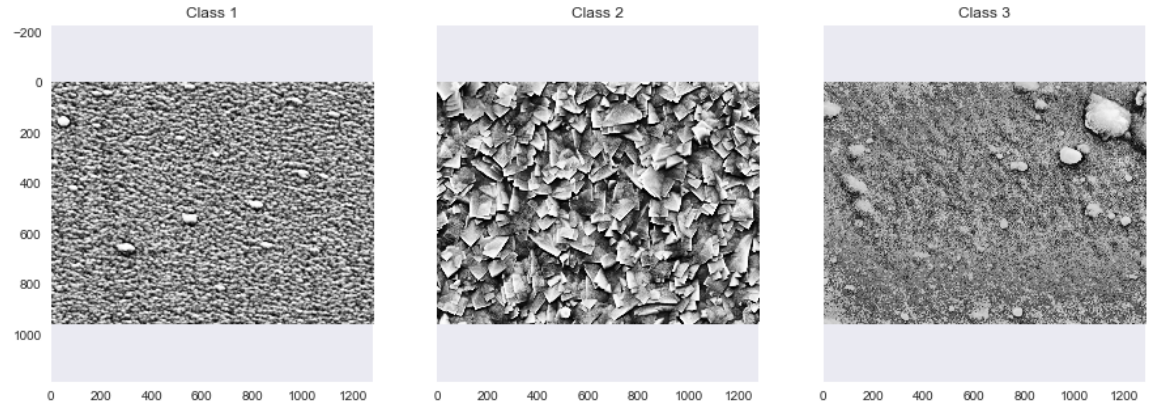
axs[0].imshow(img1)
axs[0].grid(False)
axs[0].set_title("Class 1")

axs[1].imshow(img2)
axs[1].grid(False)
axs[1].set_title("Class 2")


axs[2].imshow(img3)
axs[2].grid(False)
axs[2].set_title("Class 3")
```

Out[4]:

```
Text(0.5,1,'Class 3')
```



In [5]:

```
class_names=["Class 1","Class 2","Class 3"]
```

Check the shape of the data

In [6]:

```
img1.shape
```

Out[6]:

```
(959, 1280, 3)
```

In [7]:

```
img2.shape
```

Out[7]:

```
(959, 1280, 3)
```

In [8]:

```
img3.shape
```

Out[8]:

```
(959, 1280, 3)
```

We have 1280 x 959 px images. Last dimension with 3 numbers corresponds to RGB channels. Let us convert the images to gray scale, i.e. with a single grey channel only

In [9]:

```
img1_gr=color.rgb2gray(img1)
img2_gr=color.rgb2gray(img2)
img3_gr=color.rgb2gray(img3)
```

In [10]:

```
img1_gr.shape
```

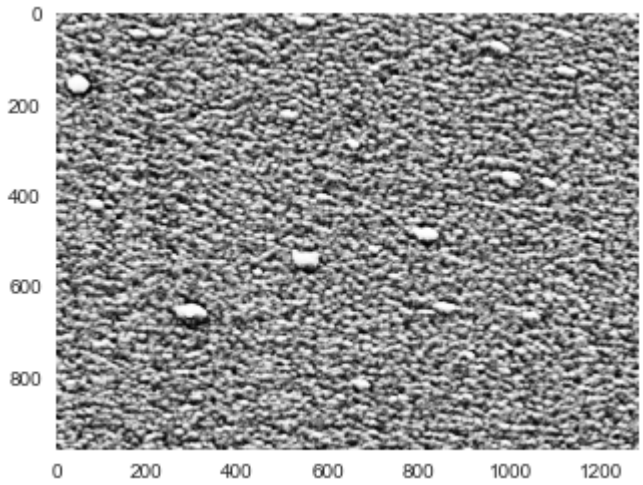
Out[10]:

```
(959, 1280)
```

Now the shape is correct, as only one element per each pixel

In [11]:

```
plt.imshow(img1_gr, cmap="gray")
plt.grid(False)
```



Just for your information:

if you compute the histogram of the grey color intensity, it has a name "Intensity Histogram"

In [12]:

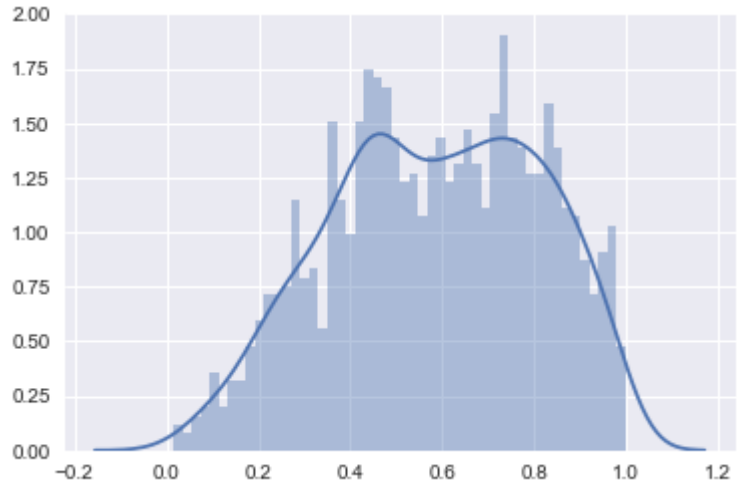
```
img1_gr[0]
```

Out[12]:

```
array([0.47843137, 0.4745098 , 0.46666667, ..., 0.69019608, 0.666666
67,
       0.65098039])
```

In [13]:

```
sns.distplot(img1_gr[0], bins=50);
```



An example workout

We will crop the images onto 28*28 pixel squares

In [14]:

```
sx=28
sy=28
```

In [15]:

```
MAX_X = img1_gr.shape[0]
MAX_Y = img1_gr.shape[1]
```

In [16]:

```
class1_data=[]
class2_data=[]
class3_data=[]

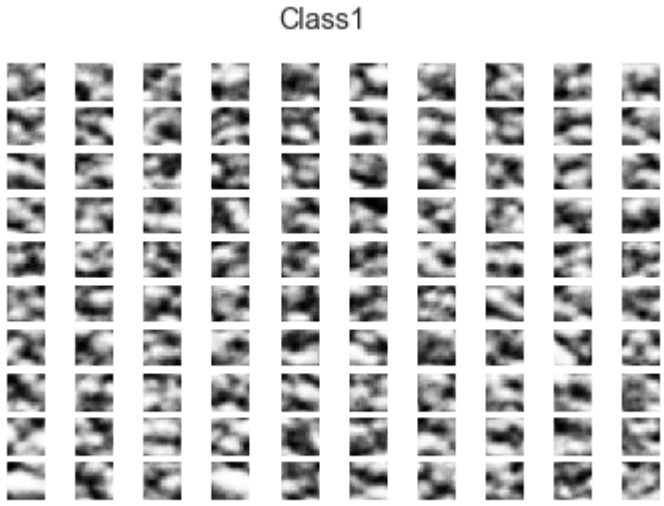
for x_coord in np.arange(0,MAX_X-sx,sx):
    for y_coord in np.arange(0,MAX_Y-sy,sy):
        class1_data.append(img1_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
        class2_data.append(img2_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
        class3_data.append(img3_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
```

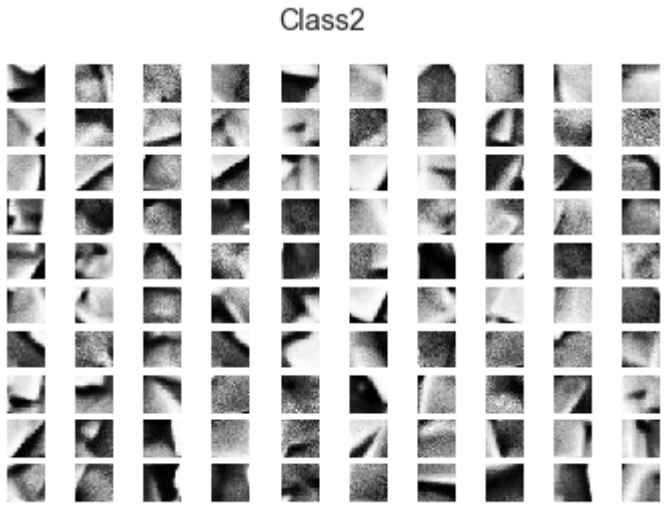
In [17]:

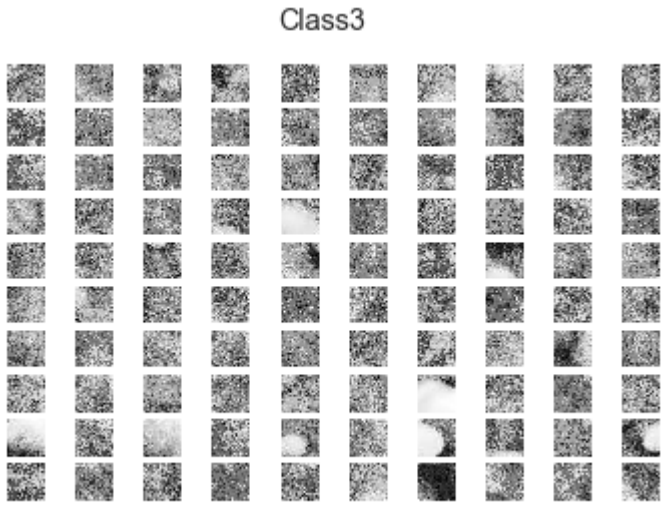
```
for i in range(100):
    plt.suptitle('Class1')
    plt.subplot(10,10,i+1)
    plt.imshow(class1_data[np.random.randint(0,len(class1_data))], cmap="gray")
    plt.axis('off')
    plt.grid(False)
#plt.savefig('Class1_1.png', dpi=150)
plt.show()

for i in range(100):
    plt.suptitle('Class2')
    plt.subplot(10,10,i+1)
    plt.imshow(class2_data[np.random.randint(0,len(class1_data))], cmap="gray")
    plt.axis('off')
    plt.grid(False)
#plt.savefig('Class2_1.png', dpi=150)
plt.show()

for i in range(100):
    plt.suptitle('Class3')
    plt.subplot(10,10,i+1)
    plt.imshow(class3_data[np.random.randint(0,len(class1_data))], cmap="gray")
    plt.axis('off')
    plt.grid(False)
#plt.savefig('Class3_1.png', dpi=150)
plt.show()
```







In [18]:

```
X = np.vstack([class1_data, class2_data, class3_data])
```

Create a corresponding labels and

In [19]:

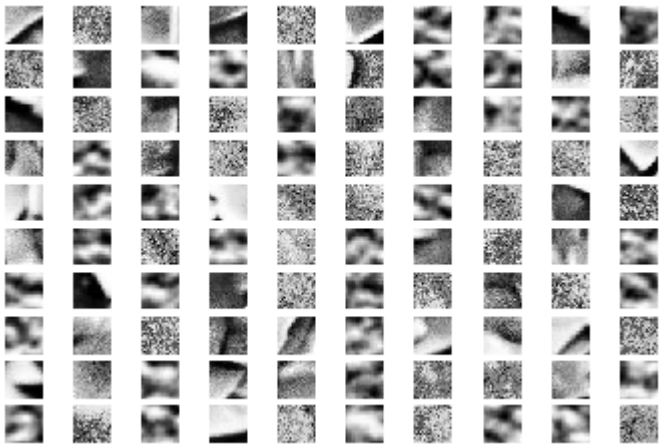
```
labels = np.array([0]*len(class1_data) + [1]*len(class2_data) + [2]*len(class3_d
ata))
```

In [20]:

```
color_dict={0:"red",1:"lightgreen",2:"blue"}
```

In [21]:

```
for i in range(100):
    plt.subplot(10,10,i+1)
    ind=np.random.randint(0,len(X))
    plt.imshow(X[ind], cmap="gray")
    ax = plt.gca()
    c=color_dict[labels[ind]]
    plt.setp(ax.spines.values(), color=c)
    #plt.axis('off')
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
    plt.grid(False)
#plt.savefig('channels.png', dpi = 300)
plt.show()
```



perform a one-hot encoding

In [22]:

```
from sklearn.preprocessing import OneHotEncoder
```

In [23]:

```
y = OneHotEncoder().fit_transform(labels.reshape(-1,1))
```

Finally, our data

In [24]:

```
X.shape
```

Out[24]:

```
(4590, 28, 28)
```

In [25]:

```
y.shape
```

Out[25]:

```
(4590, 3)
```

Routines for model validation

!!! Read more here on the confusion matrix, precision, recall and F1 score:

https://towardsdatascience.com/accuracy-precision-recall-or-f1-331fb37c5cb9 (https://towardsdatascience.com/accuracy-precision-recall-or-f1-331fb37c5cb9)

In [26]:

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix, accuracy_score, precision_score, r
ecall_score, f1_score
from keras import backend as K
```

```
/opt/netapps/thermocalc/2018/anaconda/lib/python3.6/site-packages/h5
py/__init__.py:36: FutureWarning: Conversion of the second argument
of issubdtype from `float` to `np.floating` is deprecated. In futur
e, it will be treated as `np.float64 == np.dtype(float).type`.
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

In [27]:

```
def prob_to_class(y):
     return np.argmax(y,axis=1).reshape(-1,1)
```

In [28]:

```
def probabilities_to_class_converter(func):
    def f(y_true,y_pred,*args,**kwargs):
        return func(prob_to_class(y_true), prob_to_class(y_pred),*args,**kwargs)
    return f
```

In [29]:

```
def max_probability_confusion_matrix(y_true, y_pred):
    return confusion_matrix(
        prob_to_class(y_true),
        prob_to_class(y_pred)
    )
```

In [30]:

```
accuracy_score=probabilities_to_class_converter(accuracy_score)
precision_score=probabilities_to_class_converter(precision_score)
recall_score=probabilities_to_class_converter(recall_score)
f1_score = probabilities_to_class_converter(f1_score)
```

In [31]:

```
def recall(y_true, y_pred):
    """Recall metric.

    Only computes a batch-wise average of recall.

    Computes the recall, a metric for multi-label classification of
    how many relevant items are selected.
    """
    true_positives = K.sum(K.round(K.clip(y_true * y_pred, 0, 1)))
    possible_positives = K.sum(K.round(K.clip(y_true, 0, 1)))
    recall = true_positives / (possible_positives + K.epsilon())
    return recall
def precision(y_true, y_pred):
    """Precision metric.

    Only computes a batch-wise average of precision.

    Computes the precision, a metric for multi-label classification of
    how many selected items are relevant.
    """
    true_positives = K.sum(K.round(K.clip(y_true * y_pred, 0, 1)))
    predicted_positives = K.sum(K.round(K.clip(y_pred, 0, 1)))
    precision = true_positives / (predicted_positives + K.epsilon())
    return precision

def f1(y_true, y_pred):
    p = precision(y_true, y_pred)
    r = recall(y_true, y_pred)
    return 2*((p*r)/(p+r+K.epsilon()))
```

In [32]:

```
def plot_confusion_matrix(conf_matrix,
                          normalize=False,
                          title=None,
                          cmap=plt.cm.Blues):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    if not title:
        if normalize:
            title = 'Normalized confusion matrix'
        else:
            title = 'Confusion matrix, without normalization'

    # Compute confusion matrix
    cm = conf_matrix
    # Only use the labels that appear in the data
    classes = class_names
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    fig, ax = plt.subplots()
    im = ax.imshow(cm, interpolation='nearest', cmap=cmap)
    ax.figure.colorbar(im, ax=ax)
    # We want to show all ticks...
    ax.set(xticks=np.arange(cm.shape[1]),
           yticks=np.arange(cm.shape[0]),
           # ... and label them with the respective list entries
           xticklabels=classes, yticklabels=classes,
           title=title,
           ylabel='True label',
           xlabel='Predicted label')

    # Rotate the tick labels and set their alignment.
    plt.setp(ax.get_xticklabels(), rotation=45, ha="right",
             rotation_mode="anchor")

    # Loop over data dimensions and create text annotations.
    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i in range(cm.shape[0]):
        for j in range(cm.shape[1]):
            ax.text(j, i, format(cm[i, j], fmt),
                    ha="center", va="center",
                    color="white" if cm[i, j] > thresh else "black")
    fig.tight_layout()
    plt.grid(False)
    return ax
```

In [33]:

```
def plot_train_history(history):
    metrics=["acc","precision","recall","f1"]

    plt.figure(figsize=(6,6))

    for i,metric in enumerate(metrics):
        plt.subplot(2,2,i+1)
        plt.plot(history.history[metric], label="Train")
        plt.plot(history.history['val_'+metric], label="Test")
        plt.xlabel("Epoch")
        plt.ylabel(metric)
        plt.legend()
        plt.suptitle('Training History', x = 0.5, y = 1.0, fontsize = 11)
    #rcParams['axes.titlepad'] = 2.5
        plt.tight_layout()
```

In [34]:

```
def model_predict(model):
    return model.predict(X_test_ch)
```

In [35]:

```
def model_test_summary(model):
    y_pred = model_predict(model)
    cm=max_probability_confusion_matrix(y_test,y_pred)
    cm_df=pd.DataFrame(cm, columns=class_names, index=class_names)
    plot_confusion_matrix(cm,normalize=True)
    plt.title("Precision: {}\nAccuracy: {}\nRecall: {}\nF1-score: {}\n\n".format
(
        precision_score(y_test, y_pred, average="macro"),
        accuracy_score(y_test, y_pred),
        recall_score(y_test, y_pred, average="macro"),
        f1_score(y_test, y_pred, average="macro")), fontsize = 10, loc='left')
    rcParams['axes.titlepad'] = 2.5
    plt.tight_layout()
```

In [36]:

```
def model_wrong_predictions(model):
    y_pred = model_predict(model)

    y_pred_class=prob_to_class(y_pred)
    y_t=np.array(y_test_class.reshape(-1))[0]
    y_p=np.array(y_pred_class.reshape(-1))

    pred_df=pd.DataFrame({"True":y_t, "Pred":y_p})

    pred_df["Error"]=pred_df["True"]!=pred_df["Pred"]

    err_df=pred_df[pred_df["Error"]]

    for cl in range(3):
        print("True class: ",cl+1)
        subdf=err_df[err_df["True"]==cl]


        other_cl=list(range(3))
        other_cl.remove(cl)

        for pred_cl in other_cl:
            wrong_pred=subdf[subdf["Pred"]==pred_cl].index
            if len(wrong_pred)>0:
                wrong_predicted_indices=np.random.choice(subdf[subdf["Pred"]==pr
ed_cl].index,size=4)

                print("Wrongly predicted as Class "+str(pred_cl+1))
                for ax_i,ind in enumerate(wrong_predicted_indices):
                    plt.subplot(2,2,ax_i+1)
                    plt.imshow(X_test[ind],cmap="gray")
                    plt.axis("off")
                    plt.grid(False)
                plt.show()
```

Model validation strategy

train/test split

In [37]:

```
X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.15, random_stat
e=42, shuffle=True)
```

In [38]:

```
y_test_class=prob_to_class(y_test)
```

In [39]:

```
X_train.shape
```

Out[39]:

```
(3901, 28, 28)
```

In [40]:

```
X_test.shape
```

Out[40]:

```
(689, 28, 28)
```

change the shape of the input images, to add one gray chanel

In [41]:

```
X_train_ch=X_train.reshape(-1,sx,sy,1)
X_test_ch=X_test.reshape(-1,sx,sy,1)
```

In [42]:

```
input_shape = (sx,sy,1)
```

Task: create a neural network classifier to identify the class of the images

https://machinelearningmastery.com/multi-class-classification-tutorial-keras-deep-learning-library/ (https://machinelearningmastery.com/multi-class-classification-tutorial-keras-deep-learning-library/)

In [43]:

```
from keras.models import Sequential
from keras.layers import Dense, InputLayer,Flatten
```

Baseline model

In [44]:

```
model=Sequential()

model.add(InputLayer(input_shape=input_shape))
model.add(Flatten())
model.add(Dense(10,input_shape=input_shape, activation="relu"))
model.add(Dense(3,activation="softmax"))

model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accur
acy', precision,recall,f1])
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 784)               0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                7850
_________________________________________________________________
dense_2 (Dense)              (None, 3)                 33
=================================================================
Total params: 7,883
Trainable params: 7,883
Non-trainable params: 0
_________________________________________________________________
```

Train the model

In [45]:

```
history=model.fit(X_train_ch,y_train, validation_data=(X_test_ch,y_test), batch_
size=1024, epochs=100)
```

```
Train on 3901 samples, validate on 689 samples
Epoch 1/100
3901/3901 [==============================] - 0s 52us/step - loss: 1.
1085 - acc: 0.3509 - precision: 0.3024 - recall: 0.0215 - f1: 0.0393
- val_loss: 1.1056 - val_acc: 0.3774 - val_precision: 0.0000e+00 - v
al_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 2/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
924 - acc: 0.3850 - precision: 0.0000e+00 - recall: 0.0000e+00 - f1:
0.0000e+00 - val_loss: 1.0791 - val_acc: 0.4485 - val_precision: 0.6
429 - val_recall: 0.0131 - val_f1: 0.0256
Epoch 3/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
783 - acc: 0.3950 - precision: 0.6374 - recall: 0.0336 - f1: 0.0631
- val_loss: 1.0706 - val_acc: 0.4456 - val_precision: 0.5455 - val_r
ecall: 0.0174 - val_f1: 0.0338
Epoch 4/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
698 - acc: 0.4089 - precision: 0.5302 - recall: 0.0074 - f1: 0.0146
- val_loss: 1.0736 - val_acc: 0.3817 - val_precision: 0.8333 - val_r
ecall: 0.0073 - val_f1: 0.0144
Epoch 5/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
635 - acc: 0.4294 - precision: 0.5092 - recall: 0.0056 - f1: 0.0111
- val_loss: 1.0636 - val_acc: 0.4369 - val_precision: 0.5455 - val_r
ecall: 0.0174 - val_f1: 0.0338
Epoch 6/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
514 - acc: 0.4368 - precision: 0.6767 - recall: 0.0369 - f1: 0.0698
- val_loss: 1.0508 - val_acc: 0.4311 - val_precision: 0.8000 - val_r
ecall: 0.0464 - val_f1: 0.0878
Epoch 7/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
419 - acc: 0.4591 - precision: 0.8003 - recall: 0.0379 - f1: 0.0723
- val_loss: 1.0443 - val_acc: 0.4499 - val_precision: 0.7568 - val_r
ecall: 0.0406 - val_f1: 0.0771
Epoch 8/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
317 - acc: 0.4599 - precision: 0.7482 - recall: 0.0549 - f1: 0.1020
- val_loss: 1.0365 - val_acc: 0.4615 - val_precision: 0.7885 - val_r
ecall: 0.0595 - val_f1: 0.1107
Epoch 9/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
248 - acc: 0.4847 - precision: 0.7792 - recall: 0.0543 - f1: 0.1015
- val_loss: 1.0306 - val_acc: 0.4862 - val_precision: 0.8200 - val_r
ecall: 0.0595 - val_f1: 0.1110
Epoch 10/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
138 - acc: 0.4909 - precision: 0.7785 - recall: 0.0718 - f1: 0.1314
- val_loss: 1.0271 - val_acc: 0.4906 - val_precision: 0.7818 - val_r
ecall: 0.0624 - val_f1: 0.1156
Epoch 11/100
3901/3901 [==============================] - 0s 8us/step - loss: 1.0
056 - acc: 0.5109 - precision: 0.7980 - recall: 0.0672 - f1: 0.1237
- val_loss: 1.0160 - val_acc: 0.5065 - val_precision: 0.7541 - val_r
ecall: 0.0668 - val_f1: 0.1227
Epoch 12/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
949 - acc: 0.5240 - precision: 0.8048 - recall: 0.0751 - f1: 0.1373
- val_loss: 1.0064 - val_acc: 0.5094 - val_precision: 0.7794 - val_r
ecall: 0.0769 - val_f1: 0.1400
```

```
Epoch 13/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
858 - acc: 0.5337 - precision: 0.7774 - recall: 0.0879 - f1: 0.1578
- val_loss: 1.0015 - val_acc: 0.5370 - val_precision: 0.8387 - val_r
ecall: 0.0755 - val_f1: 0.1385
Epoch 14/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
762 - acc: 0.5460 - precision: 0.7942 - recall: 0.0818 - f1: 0.1482
- val_loss: 0.9916 - val_acc: 0.5210 - val_precision: 0.7471 - val_r
ecall: 0.0943 - val_f1: 0.1675
Epoch 15/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
681 - acc: 0.5393 - precision: 0.7735 - recall: 0.1015 - f1: 0.1793
- val_loss: 0.9886 - val_acc: 0.5457 - val_precision: 0.8000 - val_r
ecall: 0.0813 - val_f1: 0.1476
Epoch 16/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
573 - acc: 0.5614 - precision: 0.7914 - recall: 0.0992 - f1: 0.1759
- val_loss: 0.9739 - val_acc: 0.5573 - val_precision: 0.7670 - val_r
ecall: 0.1147 - val_f1: 0.1995
Epoch 17/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
489 - acc: 0.5660 - precision: 0.7876 - recall: 0.1115 - f1: 0.1950
- val_loss: 0.9694 - val_acc: 0.5602 - val_precision: 0.7742 - val_r
ecall: 0.1045 - val_f1: 0.1841
Epoch 18/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
394 - acc: 0.5763 - precision: 0.7953 - recall: 0.1182 - f1: 0.2056
- val_loss: 0.9598 - val_acc: 0.5747 - val_precision: 0.7624 - val_r
ecall: 0.1118 - val_f1: 0.1949
Epoch 19/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.9
316 - acc: 0.5886 - precision: 0.7669 - recall: 0.1269 - f1: 0.2177
- val_loss: 0.9582 - val_acc: 0.5718 - val_precision: 0.7414 - val_r
ecall: 0.1248 - val_f1: 0.2137
Epoch 20/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
250 - acc: 0.5816 - precision: 0.8004 - recall: 0.1377 - f1: 0.2349
- val_loss: 0.9439 - val_acc: 0.5965 - val_precision: 0.7542 - val_r
ecall: 0.1292 - val_f1: 0.2206
Epoch 21/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
168 - acc: 0.6047 - precision: 0.7612 - recall: 0.1451 - f1: 0.2436
- val_loss: 0.9377 - val_acc: 0.5980 - val_precision: 0.7293 - val_r
ecall: 0.1408 - val_f1: 0.2360
Epoch 22/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
102 - acc: 0.5998 - precision: 0.7628 - recall: 0.1589 - f1: 0.2630
- val_loss: 0.9342 - val_acc: 0.5733 - val_precision: 0.7656 - val_r
ecall: 0.1422 - val_f1: 0.2399
Epoch 23/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.9
031 - acc: 0.6001 - precision: 0.7878 - recall: 0.1756 - f1: 0.2865
- val_loss: 0.9256 - val_acc: 0.5922 - val_precision: 0.7451 - val_r
ecall: 0.1655 - val_f1: 0.2708
Epoch 24/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
935 - acc: 0.6229 - precision: 0.7693 - recall: 0.1871 - f1: 0.3010
- val_loss: 0.9181 - val_acc: 0.6067 - val_precision: 0.7244 - val_r
ecall: 0.1640 - val_f1: 0.2675
Epoch 25/100
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3901/3901 [==============================] - 0s 8us/step - loss: 0.8
880 - acc: 0.6127 - precision: 0.7708 - recall: 0.1938 - f1: 0.3097
- val_loss: 0.9174 - val_acc: 0.5965 - val_precision: 0.7333 - val_r
ecall: 0.1916 - val_f1: 0.3038
Epoch 26/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
802 - acc: 0.6216 - precision: 0.7581 - recall: 0.2235 - f1: 0.3452
- val_loss: 0.9036 - val_acc: 0.6241 - val_precision: 0.7297 - val_r
ecall: 0.1959 - val_f1: 0.3089
Epoch 27/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.8
747 - acc: 0.6311 - precision: 0.7728 - recall: 0.2279 - f1: 0.3519
- val_loss: 0.9057 - val_acc: 0.5965 - val_precision: 0.7259 - val_r
ecall: 0.2075 - val_f1: 0.3228
Epoch 28/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
688 - acc: 0.6252 - precision: 0.7748 - recall: 0.2374 - f1: 0.3633
- val_loss: 0.8943 - val_acc: 0.6125 - val_precision: 0.7324 - val_r
ecall: 0.2264 - val_f1: 0.3459
Epoch 29/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
620 - acc: 0.6337 - precision: 0.7626 - recall: 0.2707 - f1: 0.3995
- val_loss: 0.8938 - val_acc: 0.5994 - val_precision: 0.7390 - val_r
ecall: 0.2671 - val_f1: 0.3923
Epoch 30/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
561 - acc: 0.6396 - precision: 0.7802 - recall: 0.2776 - f1: 0.4093
- val_loss: 0.8806 - val_acc: 0.6357 - val_precision: 0.7407 - val_r
ecall: 0.2322 - val_f1: 0.3536
Epoch 31/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.8
479 - acc: 0.6388 - precision: 0.7819 - recall: 0.2922 - f1: 0.4249
- val_loss: 0.8892 - val_acc: 0.5951 - val_precision: 0.7318 - val_r
ecall: 0.3208 - val_f1: 0.4460
Epoch 32/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
458 - acc: 0.6416 - precision: 0.7576 - recall: 0.3174 - f1: 0.4464
- val_loss: 0.8676 - val_acc: 0.6444 - val_precision: 0.7490 - val_r
ecall: 0.2729 - val_f1: 0.4000
Epoch 33/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
374 - acc: 0.6491 - precision: 0.7812 - recall: 0.3325 - f1: 0.4654
- val_loss: 0.8638 - val_acc: 0.6343 - val_precision: 0.7462 - val_r
ecall: 0.2859 - val_f1: 0.4134
Epoch 34/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
308 - acc: 0.6516 - precision: 0.7848 - recall: 0.3312 - f1: 0.4658
- val_loss: 0.8680 - val_acc: 0.6299 - val_precision: 0.7561 - val_r
ecall: 0.3149 - val_f1: 0.4447
Epoch 35/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
261 - acc: 0.6550 - precision: 0.7864 - recall: 0.3576 - f1: 0.4914
- val_loss: 0.8504 - val_acc: 0.6488 - val_precision: 0.7569 - val_r
ecall: 0.3164 - val_f1: 0.4463
Epoch 36/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
193 - acc: 0.6570 - precision: 0.7840 - recall: 0.3779 - f1: 0.5096
- val_loss: 0.8509 - val_acc: 0.6430 - val_precision: 0.7562 - val_r
ecall: 0.3556 - val_f1: 0.4837
Epoch 37/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
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141 - acc: 0.6624 - precision: 0.7877 - recall: 0.3768 - f1: 0.5098
- val_loss: 0.8429 - val_acc: 0.6618 - val_precision: 0.7541 - val_r
ecall: 0.3338 - val_f1: 0.4628
Epoch 38/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.8
088 - acc: 0.6627 - precision: 0.7899 - recall: 0.3950 - f1: 0.5262
- val_loss: 0.8365 - val_acc: 0.6430 - val_precision: 0.7620 - val_r
ecall: 0.3672 - val_f1: 0.4956
Epoch 39/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.8
029 - acc: 0.6665 - precision: 0.7907 - recall: 0.4076 - f1: 0.5375
- val_loss: 0.8336 - val_acc: 0.6546 - val_precision: 0.7737 - val_r
ecall: 0.3672 - val_f1: 0.4980
Epoch 40/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
979 - acc: 0.6688 - precision: 0.7925 - recall: 0.4032 - f1: 0.5342
- val_loss: 0.8295 - val_acc: 0.6531 - val_precision: 0.7722 - val_r
ecall: 0.4035 - val_f1: 0.5300
Epoch 41/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
921 - acc: 0.6709 - precision: 0.7935 - recall: 0.4299 - f1: 0.5576
- val_loss: 0.8247 - val_acc: 0.6546 - val_precision: 0.7757 - val_r
ecall: 0.4267 - val_f1: 0.5506
Epoch 42/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
867 - acc: 0.6742 - precision: 0.7901 - recall: 0.4366 - f1: 0.5623
- val_loss: 0.8171 - val_acc: 0.6691 - val_precision: 0.7830 - val_r
ecall: 0.3875 - val_f1: 0.5184
Epoch 43/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
820 - acc: 0.6801 - precision: 0.7963 - recall: 0.4348 - f1: 0.5623
- val_loss: 0.8159 - val_acc: 0.6633 - val_precision: 0.7789 - val_r
ecall: 0.4499 - val_f1: 0.5704
Epoch 44/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
763 - acc: 0.6791 - precision: 0.7886 - recall: 0.4596 - f1: 0.5807
- val_loss: 0.8057 - val_acc: 0.6807 - val_precision: 0.7867 - val_r
ecall: 0.4282 - val_f1: 0.5545
Epoch 45/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
716 - acc: 0.6855 - precision: 0.7972 - recall: 0.4599 - f1: 0.5831
- val_loss: 0.8101 - val_acc: 0.6633 - val_precision: 0.7873 - val_r
ecall: 0.4673 - val_f1: 0.5865
Epoch 46/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
685 - acc: 0.6855 - precision: 0.7938 - recall: 0.4691 - f1: 0.5896
- val_loss: 0.8000 - val_acc: 0.6778 - val_precision: 0.7893 - val_r
ecall: 0.4731 - val_f1: 0.5917
Epoch 47/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
619 - acc: 0.6855 - precision: 0.7947 - recall: 0.4873 - f1: 0.6040
- val_loss: 0.7936 - val_acc: 0.6865 - val_precision: 0.7928 - val_r
ecall: 0.4499 - val_f1: 0.5741
Epoch 48/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
587 - acc: 0.6908 - precision: 0.8006 - recall: 0.4865 - f1: 0.6051
- val_loss: 0.7885 - val_acc: 0.6894 - val_precision: 0.7864 - val_r
ecall: 0.4543 - val_f1: 0.5759
Epoch 49/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
531 - acc: 0.6893 - precision: 0.7945 - recall: 0.5027 - f1: 0.6156
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- val_loss: 0.7833 - val_acc: 0.6938 - val_precision: 0.7966 - val_r
ecall: 0.4775 - val_f1: 0.5971
Epoch 50/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
478 - acc: 0.6973 - precision: 0.7991 - recall: 0.5012 - f1: 0.6159
- val_loss: 0.7877 - val_acc: 0.6880 - val_precision: 0.7892 - val_r
ecall: 0.5109 - val_f1: 0.6203
Epoch 51/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
436 - acc: 0.6980 - precision: 0.7961 - recall: 0.5199 - f1: 0.6286
- val_loss: 0.7751 - val_acc: 0.6981 - val_precision: 0.7972 - val_r
ecall: 0.4906 - val_f1: 0.6074
Epoch 52/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
396 - acc: 0.6973 - precision: 0.7937 - recall: 0.5273 - f1: 0.6334
- val_loss: 0.7754 - val_acc: 0.6938 - val_precision: 0.7885 - val_r
ecall: 0.5196 - val_f1: 0.6264
Epoch 53/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
361 - acc: 0.7029 - precision: 0.7974 - recall: 0.5252 - f1: 0.6331
- val_loss: 0.7682 - val_acc: 0.6996 - val_precision: 0.7976 - val_r
ecall: 0.4862 - val_f1: 0.6041
Epoch 54/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
328 - acc: 0.7032 - precision: 0.7900 - recall: 0.5340 - f1: 0.6366
- val_loss: 0.7657 - val_acc: 0.6894 - val_precision: 0.7738 - val_r
ecall: 0.5312 - val_f1: 0.6299
Epoch 55/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
278 - acc: 0.7119 - precision: 0.7996 - recall: 0.5437 - f1: 0.6469
- val_loss: 0.7710 - val_acc: 0.6880 - val_precision: 0.7763 - val_r
ecall: 0.5239 - val_f1: 0.6256
Epoch 56/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
234 - acc: 0.7049 - precision: 0.7934 - recall: 0.5565 - f1: 0.6541
- val_loss: 0.7534 - val_acc: 0.7010 - val_precision: 0.8004 - val_r
ecall: 0.5298 - val_f1: 0.6376
Epoch 57/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
205 - acc: 0.7139 - precision: 0.7960 - recall: 0.5476 - f1: 0.6486
- val_loss: 0.7789 - val_acc: 0.6676 - val_precision: 0.7624 - val_r
ecall: 0.5588 - val_f1: 0.6449
Epoch 58/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
202 - acc: 0.7093 - precision: 0.7864 - recall: 0.5583 - f1: 0.6526
- val_loss: 0.7548 - val_acc: 0.6996 - val_precision: 0.7977 - val_r
ecall: 0.5036 - val_f1: 0.6174
Epoch 59/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.7
158 - acc: 0.7108 - precision: 0.7910 - recall: 0.5604 - f1: 0.6554
- val_loss: 0.7540 - val_acc: 0.6909 - val_precision: 0.7714 - val_r
ecall: 0.5631 - val_f1: 0.6510
Epoch 60/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
125 - acc: 0.7162 - precision: 0.7963 - recall: 0.5622 - f1: 0.6589
- val_loss: 0.7547 - val_acc: 0.6880 - val_precision: 0.7760 - val_r
ecall: 0.5530 - val_f1: 0.6458
Epoch 61/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
078 - acc: 0.7132 - precision: 0.7916 - recall: 0.5791 - f1: 0.6688
- val_loss: 0.7411 - val_acc: 0.7010 - val_precision: 0.8008 - val_r
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ecall: 0.5544 - val_f1: 0.6552
Epoch 62/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.7
025 - acc: 0.7226 - precision: 0.7997 - recall: 0.5760 - f1: 0.6696
- val_loss: 0.7404 - val_acc: 0.7010 - val_precision: 0.7764 - val_r
ecall: 0.5646 - val_f1: 0.6538
Epoch 63/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
991 - acc: 0.7201 - precision: 0.7969 - recall: 0.5863 - f1: 0.6755
- val_loss: 0.7332 - val_acc: 0.7054 - val_precision: 0.8021 - val_r
ecall: 0.5588 - val_f1: 0.6587
Epoch 64/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
981 - acc: 0.7221 - precision: 0.7947 - recall: 0.5852 - f1: 0.6740
- val_loss: 0.7385 - val_acc: 0.6865 - val_precision: 0.7782 - val_r
ecall: 0.5806 - val_f1: 0.6650
Epoch 65/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
943 - acc: 0.7208 - precision: 0.7988 - recall: 0.5945 - f1: 0.6816
- val_loss: 0.7279 - val_acc: 0.7054 - val_precision: 0.7822 - val_r
ecall: 0.5733 - val_f1: 0.6616
Epoch 66/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
904 - acc: 0.7252 - precision: 0.8010 - recall: 0.6045 - f1: 0.6890
- val_loss: 0.7276 - val_acc: 0.7068 - val_precision: 0.7996 - val_r
ecall: 0.5675 - val_f1: 0.6638
Epoch 67/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
897 - acc: 0.7262 - precision: 0.8015 - recall: 0.5955 - f1: 0.6832
- val_loss: 0.7281 - val_acc: 0.6923 - val_precision: 0.7757 - val_r
ecall: 0.5922 - val_f1: 0.6716
Epoch 68/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
841 - acc: 0.7306 - precision: 0.7942 - recall: 0.6078 - f1: 0.6883
- val_loss: 0.7268 - val_acc: 0.6996 - val_precision: 0.7992 - val_r
ecall: 0.5602 - val_f1: 0.6587
Epoch 69/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
855 - acc: 0.7311 - precision: 0.7988 - recall: 0.6001 - f1: 0.6852
- val_loss: 0.7225 - val_acc: 0.6996 - val_precision: 0.7829 - val_r
ecall: 0.5965 - val_f1: 0.6771
Epoch 70/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
822 - acc: 0.7290 - precision: 0.8013 - recall: 0.6027 - f1: 0.6879
- val_loss: 0.7194 - val_acc: 0.7010 - val_precision: 0.7854 - val_r
ecall: 0.5951 - val_f1: 0.6771
Epoch 71/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
760 - acc: 0.7275 - precision: 0.7982 - recall: 0.6191 - f1: 0.6973
- val_loss: 0.7186 - val_acc: 0.7068 - val_precision: 0.7929 - val_r
ecall: 0.5835 - val_f1: 0.6722
Epoch 72/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
728 - acc: 0.7331 - precision: 0.8017 - recall: 0.6188 - f1: 0.6985
- val_loss: 0.7135 - val_acc: 0.7083 - val_precision: 0.7882 - val_r
ecall: 0.5994 - val_f1: 0.6810
Epoch 73/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
719 - acc: 0.7329 - precision: 0.7955 - recall: 0.6219 - f1: 0.6981
- val_loss: 0.7067 - val_acc: 0.7097 - val_precision: 0.7912 - val_r
ecall: 0.5994 - val_f1: 0.6821
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Epoch 74/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
679 - acc: 0.7370 - precision: 0.8046 - recall: 0.6247 - f1: 0.7033
- val_loss: 0.7127 - val_acc: 0.7112 - val_precision: 0.7903 - val_r
ecall: 0.5907 - val_f1: 0.6761
Epoch 75/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
660 - acc: 0.7357 - precision: 0.8033 - recall: 0.6278 - f1: 0.7047
- val_loss: 0.7016 - val_acc: 0.7141 - val_precision: 0.7857 - val_r
ecall: 0.6067 - val_f1: 0.6847
Epoch 76/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
636 - acc: 0.7367 - precision: 0.8017 - recall: 0.6301 - f1: 0.7056
- val_loss: 0.7046 - val_acc: 0.7054 - val_precision: 0.7864 - val_r
ecall: 0.6038 - val_f1: 0.6831
Epoch 77/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
617 - acc: 0.7365 - precision: 0.8048 - recall: 0.6334 - f1: 0.7088
- val_loss: 0.6990 - val_acc: 0.7141 - val_precision: 0.7925 - val_r
ecall: 0.6096 - val_f1: 0.6891
Epoch 78/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
583 - acc: 0.7380 - precision: 0.7992 - recall: 0.6386 - f1: 0.7099
- val_loss: 0.7000 - val_acc: 0.7068 - val_precision: 0.7903 - val_r
ecall: 0.6125 - val_f1: 0.6901
Epoch 79/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
571 - acc: 0.7380 - precision: 0.8047 - recall: 0.6360 - f1: 0.7105
- val_loss: 0.7018 - val_acc: 0.7126 - val_precision: 0.7862 - val_r
ecall: 0.6139 - val_f1: 0.6895
Epoch 80/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
545 - acc: 0.7393 - precision: 0.8028 - recall: 0.6357 - f1: 0.7095
- val_loss: 0.6904 - val_acc: 0.7184 - val_precision: 0.7918 - val_r
ecall: 0.6183 - val_f1: 0.6944
Epoch 81/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
572 - acc: 0.7293 - precision: 0.7969 - recall: 0.6421 - f1: 0.7112
- val_loss: 0.6960 - val_acc: 0.7112 - val_precision: 0.7881 - val_r
ecall: 0.5936 - val_f1: 0.6772
Epoch 82/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
557 - acc: 0.7416 - precision: 0.7978 - recall: 0.6345 - f1: 0.7066
- val_loss: 0.7018 - val_acc: 0.7097 - val_precision: 0.7792 - val_r
ecall: 0.6197 - val_f1: 0.6904
Epoch 83/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
513 - acc: 0.7396 - precision: 0.8072 - recall: 0.6429 - f1: 0.7157
- val_loss: 0.6884 - val_acc: 0.7184 - val_precision: 0.7926 - val_r
ecall: 0.6212 - val_f1: 0.6965
Epoch 84/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
459 - acc: 0.7431 - precision: 0.8025 - recall: 0.6491 - f1: 0.7177
- val_loss: 0.6850 - val_acc: 0.7126 - val_precision: 0.7948 - val_r
ecall: 0.6241 - val_f1: 0.6992
Epoch 85/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
435 - acc: 0.7490 - precision: 0.8072 - recall: 0.6503 - f1: 0.7203
- val_loss: 0.6881 - val_acc: 0.7170 - val_precision: 0.7862 - val_r
ecall: 0.6299 - val_f1: 0.6994
Epoch 86/100
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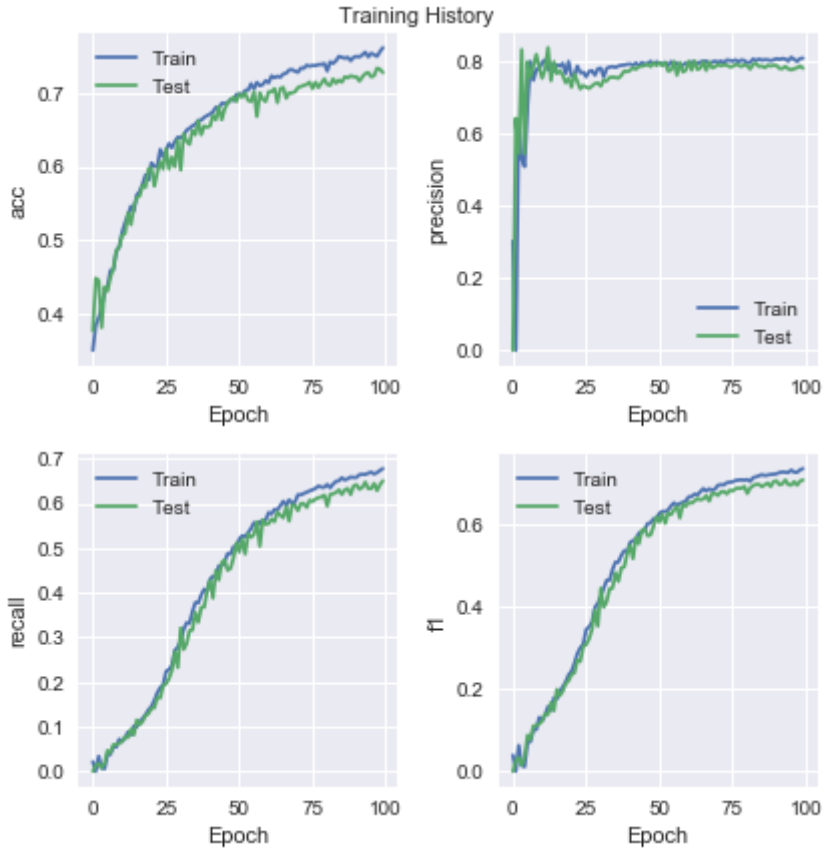
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
404 - acc: 0.7478 - precision: 0.8039 - recall: 0.6570 - f1: 0.7230
- val_loss: 0.6834 - val_acc: 0.7141 - val_precision: 0.7878 - val_r
ecall: 0.6197 - val_f1: 0.6937
Epoch 87/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
406 - acc: 0.7465 - precision: 0.8056 - recall: 0.6521 - f1: 0.7208
- val_loss: 0.6876 - val_acc: 0.7213 - val_precision: 0.7834 - val_r
ecall: 0.6299 - val_f1: 0.6983
Epoch 88/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
382 - acc: 0.7478 - precision: 0.8050 - recall: 0.6547 - f1: 0.7221
- val_loss: 0.6806 - val_acc: 0.7199 - val_precision: 0.7899 - val_r
ecall: 0.6328 - val_f1: 0.7027
Epoch 89/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
364 - acc: 0.7431 - precision: 0.8027 - recall: 0.6588 - f1: 0.7236
- val_loss: 0.6776 - val_acc: 0.7228 - val_precision: 0.7878 - val_r
ecall: 0.6197 - val_f1: 0.6937
Epoch 90/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
354 - acc: 0.7478 - precision: 0.8050 - recall: 0.6578 - f1: 0.7239
- val_loss: 0.6751 - val_acc: 0.7213 - val_precision: 0.7899 - val_r
ecall: 0.6386 - val_f1: 0.7063
Epoch 91/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
333 - acc: 0.7490 - precision: 0.8083 - recall: 0.6578 - f1: 0.7252
- val_loss: 0.6795 - val_acc: 0.7213 - val_precision: 0.7893 - val_r
ecall: 0.6415 - val_f1: 0.7078
Epoch 92/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
304 - acc: 0.7483 - precision: 0.8060 - recall: 0.6642 - f1: 0.7282
- val_loss: 0.6687 - val_acc: 0.7155 - val_precision: 0.7810 - val_r
ecall: 0.6313 - val_f1: 0.6982
Epoch 93/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
285 - acc: 0.7511 - precision: 0.8086 - recall: 0.6647 - f1: 0.7296
- val_loss: 0.6799 - val_acc: 0.7213 - val_precision: 0.7807 - val_r
ecall: 0.6357 - val_f1: 0.7008
Epoch 94/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
280 - acc: 0.7547 - precision: 0.8071 - recall: 0.6644 - f1: 0.7288
- val_loss: 0.6694 - val_acc: 0.7257 - val_precision: 0.7866 - val_r
ecall: 0.6473 - val_f1: 0.7102
Epoch 95/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
259 - acc: 0.7483 - precision: 0.8016 - recall: 0.6673 - f1: 0.7283
- val_loss: 0.6656 - val_acc: 0.7271 - val_precision: 0.7800 - val_r
ecall: 0.6328 - val_f1: 0.6987
Epoch 96/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
235 - acc: 0.7531 - precision: 0.8121 - recall: 0.6698 - f1: 0.7341
- val_loss: 0.6732 - val_acc: 0.7213 - val_precision: 0.7772 - val_r
ecall: 0.6328 - val_f1: 0.6976
Epoch 97/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
229 - acc: 0.7513 - precision: 0.8064 - recall: 0.6655 - f1: 0.7291
- val_loss: 0.6688 - val_acc: 0.7228 - val_precision: 0.7803 - val_r
ecall: 0.6444 - val_f1: 0.7059
Epoch 98/100
3901/3901 [==============================] - 0s 9us/step - loss: 0.6
```

```
234 - acc: 0.7490 - precision: 0.8007 - recall: 0.6685 - f1: 0.7286
- val_loss: 0.6641 - val_acc: 0.7329 - val_precision: 0.7830 - val_r
ecall: 0.6284 - val_f1: 0.6973
Epoch 99/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
187 - acc: 0.7554 - precision: 0.8082 - recall: 0.6734 - f1: 0.7346
- val_loss: 0.6636 - val_acc: 0.7315 - val_precision: 0.7879 - val_r
ecall: 0.6415 - val_f1: 0.7072
Epoch 100/100
3901/3901 [==============================] - 0s 8us/step - loss: 0.6
153 - acc: 0.7608 - precision: 0.8097 - recall: 0.6775 - f1: 0.7377
- val_loss: 0.6605 - val_acc: 0.7271 - val_precision: 0.7818 - val_r
ecall: 0.6502 - val_f1: 0.7100
```

Plot it training history

In [46]:

```
plot_train_history(history)
```

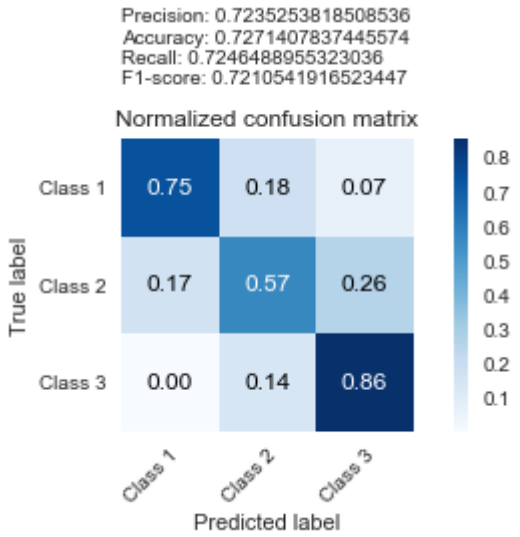


Show the summary of the model performance and confusion matrix

In [47]:

```
model_test_summary(model)
```

```
Normalized confusion matrix
```

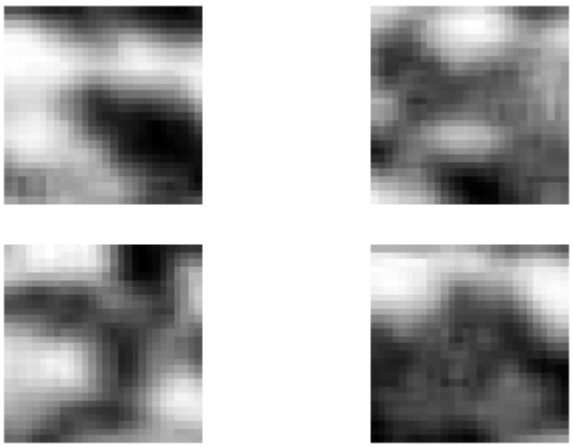


Illustrate the wrong predictions

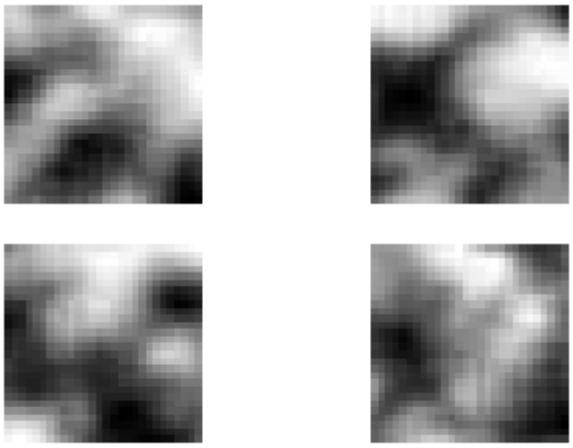
In [48]:

```
model_wrong_predictions(model)
```

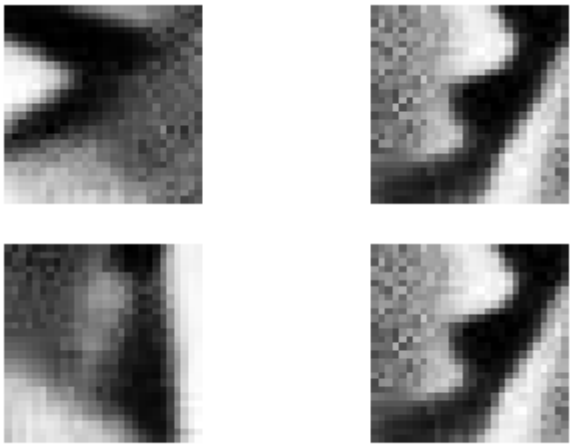
```
True class:  1
Wrongly predicted as Class 2
```



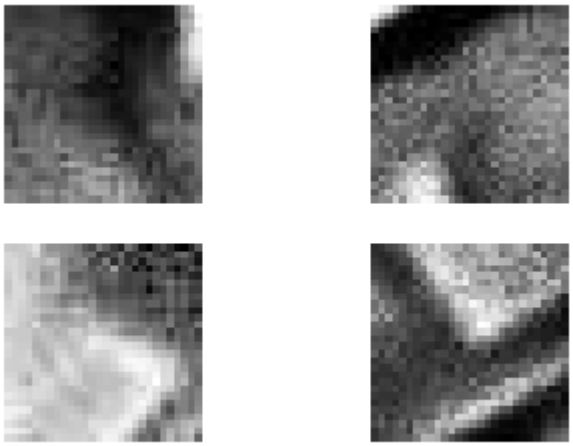
```
Wrongly predicted as Class 3
```



```
True class:  2
Wrongly predicted as Class 1
```

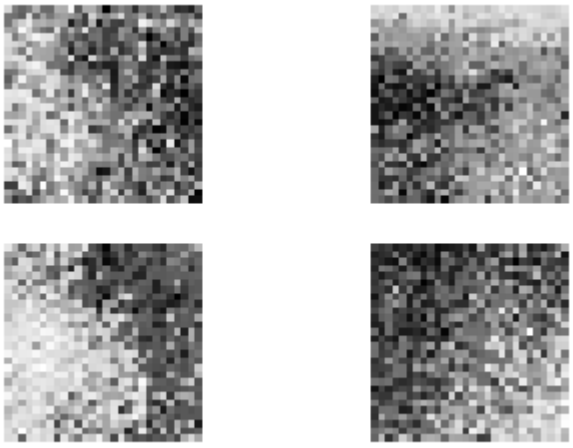


```
Wrongly predicted as Class 3
```



```
True class:  3
Wrongly predicted as Class 1
```

```
Wrongly predicted as Class 2
```



My model(s)

In [49]:

```
from keras.layers import Convolution2D, Conv2D, Dropout, BatchNormalization, Max
Pooling2D
from keras import backend as K
K.set_image_dim_ordering('tf')
```

In [50]:

```
from keras import backend as K
K.set_image_dim_ordering('tf')
```

In [51]:

```
input_shape
```

Out[51]:

```
(28, 28, 1)
```

In [52]:

```
from keras import backend as K
K.set_image_dim_ordering('tf')

model=Sequential()
model.add(InputLayer(input_shape=input_shape))
model.add(Conv2D(20, (4, 4), input_shape=input_shape, activation='relu'))
model.add(Conv2D(10, (3,3), input_shape=input_shape, activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Flatten())
model.add(Dense(3,activation="softmax"))
optimizer="adam"
model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=['ac
curacy', precision,recall,f1])
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 25, 25, 8)         136
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 12, 12, 8)         0
_________________________________________________________________
dense_3 (Dense)              (None, 12, 12, 10)        90
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 8, 8, 10)          2510
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 4, 4, 10)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 160)               0
_________________________________________________________________
dense_4 (Dense)              (None, 3)                 483
=================================================================
Total params: 3,219
Trainable params: 3,219
Non-trainable params: 0
_________________________________________________________________
```

In [53]:

```
history=model.fit(X_train_ch,y_train, validation_data=(X_test_ch,y_test),epochs=
100)
```

```
Train on 3901 samples, validate on 689 samples
Epoch 1/100
3901/3901 [==============================] - 2s 398us/step - loss:
1.0335 - acc: 0.4565 - precision: 0.2495 - recall: 0.0666 - f1: 0.09
64 - val_loss: 0.8150 - val_acc: 0.6255 - val_precision: 0.8165 - va
l_recall: 0.3077 - val_f1: 0.4435
Epoch 2/100
3901/3901 [==============================] - 1s 317us/step - loss:
0.5476 - acc: 0.7924 - precision: 0.8394 - recall: 0.7132 - f1: 0.76
50 - val_loss: 0.3839 - val_acc: 0.8476 - val_precision: 0.8674 - va
l_recall: 0.8331 - val_f1: 0.8496
Epoch 3/100
3901/3901 [==============================] - 1s 334us/step - loss:
0.3650 - acc: 0.8767 - precision: 0.8848 - recall: 0.8611 - f1: 0.87
25 - val_loss: 0.2741 - val_acc: 0.8999 - val_precision: 0.9119 - va
l_recall: 0.8839 - val_f1: 0.8975
Epoch 4/100
3901/3901 [==============================] - 1s 329us/step - loss:
0.2728 - acc: 0.9126 - precision: 0.9160 - recall: 0.9077 - f1: 0.91
17 - val_loss: 0.2038 - val_acc: 0.9492 - val_precision: 0.9492 - va
l_recall: 0.9478 - val_f1: 0.9485
Epoch 5/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.2144 - acc: 0.9308 - precision: 0.9312 - recall: 0.9295 - f1: 0.93
03 - val_loss: 0.1865 - val_acc: 0.9478 - val_precision: 0.9478 - va
l_recall: 0.9478 - val_f1: 0.9478
Epoch 6/100
3901/3901 [==============================] - 1s 317us/step - loss:
0.1905 - acc: 0.9405 - precision: 0.9412 - recall: 0.9395 - f1: 0.94
03 - val_loss: 0.1291 - val_acc: 0.9623 - val_precision: 0.9623 - va
l_recall: 0.9623 - val_f1: 0.9623
Epoch 7/100
3901/3901 [==============================] - 1s 330us/step - loss:
0.1572 - acc: 0.9533 - precision: 0.9536 - recall: 0.9531 - f1: 0.95
33 - val_loss: 0.1308 - val_acc: 0.9637 - val_precision: 0.9651 - va
l_recall: 0.9637 - val_f1: 0.9644
Epoch 8/100
3901/3901 [==============================] - 1s 318us/step - loss:
0.1410 - acc: 0.9557 - precision: 0.9559 - recall: 0.9557 - f1: 0.95
58 - val_loss: 0.1235 - val_acc: 0.9536 - val_precision: 0.9536 - va
l_recall: 0.9536 - val_f1: 0.9536
Epoch 9/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.1633 - acc: 0.9439 - precision: 0.9443 - recall: 0.9439 - f1: 0.94
41 - val_loss: 0.0919 - val_acc: 0.9666 - val_precision: 0.9666 - va
l_recall: 0.9666 - val_f1: 0.9666
Epoch 10/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.1164 - acc: 0.9613 - precision: 0.9613 - recall: 0.9613 - f1: 0.96
13 - val_loss: 0.0987 - val_acc: 0.9739 - val_precision: 0.9739 - va
l_recall: 0.9739 - val_f1: 0.9739
Epoch 11/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.1170 - acc: 0.9603 - precision: 0.9603 - recall: 0.9603 - f1: 0.96
03 - val_loss: 0.0944 - val_acc: 0.9710 - val_precision: 0.9710 - va
l_recall: 0.9710 - val_f1: 0.9710
Epoch 12/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.1098 - acc: 0.9580 - precision: 0.9580 - recall: 0.9580 - f1: 0.95
80 - val_loss: 0.0867 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
```

```
Epoch 13/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.1121 - acc: 0.9613 - precision: 0.9613 - recall: 0.9613 - f1: 0.96
13 - val_loss: 0.0813 - val_acc: 0.9753 - val_precision: 0.9753 - va
l_recall: 0.9753 - val_f1: 0.9753
Epoch 14/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.1139 - acc: 0.9574 - precision: 0.9574 - recall: 0.9574 - f1: 0.95
74 - val_loss: 0.0960 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
Epoch 15/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.1114 - acc: 0.9590 - precision: 0.9590 - recall: 0.9587 - f1: 0.95
89 - val_loss: 0.0671 - val_acc: 0.9768 - val_precision: 0.9768 - va
l_recall: 0.9768 - val_f1: 0.9768
Epoch 16/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.1038 - acc: 0.9639 - precision: 0.9639 - recall: 0.9639 - f1: 0.96
39 - val_loss: 0.0681 - val_acc: 0.9753 - val_precision: 0.9753 - va
l_recall: 0.9753 - val_f1: 0.9753
Epoch 17/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.1184 - acc: 0.9562 - precision: 0.9562 - recall: 0.9562 - f1: 0.95
62 - val_loss: 0.0753 - val_acc: 0.9768 - val_precision: 0.9768 - va
l_recall: 0.9768 - val_f1: 0.9768
Epoch 18/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.1035 - acc: 0.9662 - precision: 0.9662 - recall: 0.9662 - f1: 0.96
62 - val_loss: 0.0634 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 19/100
3901/3901 [==============================] - 1s 320us/step - loss:
0.0997 - acc: 0.9641 - precision: 0.9641 - recall: 0.9641 - f1: 0.96
41 - val_loss: 0.0933 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
Epoch 20/100
3901/3901 [==============================] - 1s 305us/step - loss:
0.1002 - acc: 0.9633 - precision: 0.9636 - recall: 0.9633 - f1: 0.96
35 - val_loss: 0.0590 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 21/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.0971 - acc: 0.9654 - precision: 0.9654 - recall: 0.9654 - f1: 0.96
54 - val_loss: 0.0723 - val_acc: 0.9753 - val_precision: 0.9753 - va
l_recall: 0.9753 - val_f1: 0.9753
Epoch 22/100
3901/3901 [==============================] - 1s 303us/step - loss:
0.0877 - acc: 0.9687 - precision: 0.9687 - recall: 0.9687 - f1: 0.96
87 - val_loss: 0.0588 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
Epoch 23/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.1072 - acc: 0.9587 - precision: 0.9587 - recall: 0.9587 - f1: 0.95
87 - val_loss: 0.0650 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 24/100
3901/3901 [==============================] - 1s 308us/step - loss:
0.0802 - acc: 0.9718 - precision: 0.9718 - recall: 0.9718 - f1: 0.97
18 - val_loss: 0.0723 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 25/100
```

```
3901/3901 [==============================] - 1s 310us/step - loss:
0.0947 - acc: 0.9672 - precision: 0.9672 - recall: 0.9672 - f1: 0.96
72 - val_loss: 0.0564 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
Epoch 26/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0859 - acc: 0.9682 - precision: 0.9682 - recall: 0.9682 - f1: 0.96
82 - val_loss: 0.0557 - val_acc: 0.9840 - val_precision: 0.9840 - va
l_recall: 0.9840 - val_f1: 0.9840
Epoch 27/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.0867 - acc: 0.9687 - precision: 0.9687 - recall: 0.9687 - f1: 0.96
87 - val_loss: 0.0634 - val_acc: 0.9753 - val_precision: 0.9753 - va
l_recall: 0.9753 - val_f1: 0.9753
Epoch 28/100
3901/3901 [==============================] - 1s 333us/step - loss:
0.0929 - acc: 0.9664 - precision: 0.9664 - recall: 0.9664 - f1: 0.96
64 - val_loss: 0.0513 - val_acc: 0.9855 - val_precision: 0.9855 - va
l_recall: 0.9855 - val_f1: 0.9855
Epoch 29/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0784 - acc: 0.9708 - precision: 0.9708 - recall: 0.9708 - f1: 0.97
08 - val_loss: 0.0571 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 30/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0753 - acc: 0.9713 - precision: 0.9713 - recall: 0.9713 - f1: 0.97
13 - val_loss: 0.0573 - val_acc: 0.9855 - val_precision: 0.9855 - va
l_recall: 0.9855 - val_f1: 0.9855
Epoch 31/100
3901/3901 [==============================] - 1s 325us/step - loss:
0.0937 - acc: 0.9687 - precision: 0.9687 - recall: 0.9687 - f1: 0.96
87 - val_loss: 0.0689 - val_acc: 0.9739 - val_precision: 0.9739 - va
l_recall: 0.9739 - val_f1: 0.9739
Epoch 32/100
3901/3901 [==============================] - 1s 323us/step - loss:
0.0806 - acc: 0.9713 - precision: 0.9713 - recall: 0.9713 - f1: 0.97
13 - val_loss: 0.0465 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 33/100
3901/3901 [==============================] - 1s 321us/step - loss:
0.0943 - acc: 0.9631 - precision: 0.9631 - recall: 0.9631 - f1: 0.96
31 - val_loss: 0.1786 - val_acc: 0.9245 - val_precision: 0.9245 - va
l_recall: 0.9231 - val_f1: 0.9238
Epoch 34/100
3901/3901 [==============================] - 1s 303us/step - loss:
0.0949 - acc: 0.9667 - precision: 0.9667 - recall: 0.9667 - f1: 0.96
67 - val_loss: 0.0473 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 35/100
3901/3901 [==============================] - 1s 303us/step - loss:
0.0858 - acc: 0.9685 - precision: 0.9685 - recall: 0.9685 - f1: 0.96
85 - val_loss: 0.0509 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 36/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.0785 - acc: 0.9700 - precision: 0.9700 - recall: 0.9700 - f1: 0.97
00 - val_loss: 0.0494 - val_acc: 0.9840 - val_precision: 0.9840 - va
l_recall: 0.9840 - val_f1: 0.9840
Epoch 37/100
3901/3901 [==============================] - 1s 307us/step - loss:
```

```
0.0720 - acc: 0.9733 - precision: 0.9733 - recall: 0.9733 - f1: 0.97
33 - val_loss: 0.0512 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 38/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0698 - acc: 0.9723 - precision: 0.9723 - recall: 0.9723 - f1: 0.97
23 - val_loss: 0.1095 - val_acc: 0.9521 - val_precision: 0.9521 - va
l_recall: 0.9521 - val_f1: 0.9521
Epoch 39/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0742 - acc: 0.9736 - precision: 0.9736 - recall: 0.9736 - f1: 0.97
36 - val_loss: 0.0549 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 40/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0702 - acc: 0.9733 - precision: 0.9733 - recall: 0.9733 - f1: 0.97
33 - val_loss: 0.0413 - val_acc: 0.9884 - val_precision: 0.9884 - va
l_recall: 0.9884 - val_f1: 0.9884
Epoch 41/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.0687 - acc: 0.9744 - precision: 0.9744 - recall: 0.9744 - f1: 0.97
44 - val_loss: 0.0423 - val_acc: 0.9884 - val_precision: 0.9884 - va
l_recall: 0.9884 - val_f1: 0.9884
Epoch 42/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0650 - acc: 0.9762 - precision: 0.9762 - recall: 0.9762 - f1: 0.97
62 - val_loss: 0.0522 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
Epoch 43/100
3901/3901 [==============================] - 1s 306us/step - loss:
0.0720 - acc: 0.9746 - precision: 0.9746 - recall: 0.9746 - f1: 0.97
46 - val_loss: 0.0613 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 44/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0833 - acc: 0.9662 - precision: 0.9662 - recall: 0.9662 - f1: 0.96
62 - val_loss: 0.0503 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 45/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0656 - acc: 0.9746 - precision: 0.9746 - recall: 0.9746 - f1: 0.97
46 - val_loss: 0.0485 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 46/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.0821 - acc: 0.9672 - precision: 0.9672 - recall: 0.9672 - f1: 0.96
72 - val_loss: 0.1081 - val_acc: 0.9637 - val_precision: 0.9637 - va
l_recall: 0.9637 - val_f1: 0.9637
Epoch 47/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.1013 - acc: 0.9621 - precision: 0.9621 - recall: 0.9621 - f1: 0.96
21 - val_loss: 0.1042 - val_acc: 0.9594 - val_precision: 0.9594 - va
l_recall: 0.9594 - val_f1: 0.9594
Epoch 48/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.0622 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.97
59 - val_loss: 0.0432 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 49/100
3901/3901 [==============================] - 1s 318us/step - loss:
0.0778 - acc: 0.9687 - precision: 0.9687 - recall: 0.9687 - f1: 0.96
```

```
87 - val_loss: 0.0414 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 50/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0729 - acc: 0.9715 - precision: 0.9718 - recall: 0.9715 - f1: 0.97
17 - val_loss: 0.0372 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 51/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0597 - acc: 0.9787 - precision: 0.9787 - recall: 0.9787 - f1: 0.97
87 - val_loss: 0.0404 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 52/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0702 - acc: 0.9741 - precision: 0.9741 - recall: 0.9741 - f1: 0.97
41 - val_loss: 0.0545 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 53/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.0659 - acc: 0.9739 - precision: 0.9739 - recall: 0.9739 - f1: 0.97
39 - val_loss: 0.0382 - val_acc: 0.9884 - val_precision: 0.9884 - va
l_recall: 0.9884 - val_f1: 0.9884
Epoch 54/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0614 - acc: 0.9756 - precision: 0.9756 - recall: 0.9756 - f1: 0.97
56 - val_loss: 0.0378 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 55/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0579 - acc: 0.9767 - precision: 0.9767 - recall: 0.9767 - f1: 0.97
67 - val_loss: 0.0389 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 56/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.0575 - acc: 0.9792 - precision: 0.9792 - recall: 0.9792 - f1: 0.97
92 - val_loss: 0.0494 - val_acc: 0.9840 - val_precision: 0.9840 - va
l_recall: 0.9840 - val_f1: 0.9840
Epoch 57/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0663 - acc: 0.9751 - precision: 0.9751 - recall: 0.9751 - f1: 0.97
51 - val_loss: 0.0471 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 58/100
3901/3901 [==============================] - 1s 318us/step - loss:
0.0619 - acc: 0.9764 - precision: 0.9764 - recall: 0.9764 - f1: 0.97
64 - val_loss: 0.0377 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 59/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0813 - acc: 0.9682 - precision: 0.9682 - recall: 0.9682 - f1: 0.96
82 - val_loss: 0.0421 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 60/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0641 - acc: 0.9767 - precision: 0.9767 - recall: 0.9767 - f1: 0.97
67 - val_loss: 0.0555 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 61/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.0592 - acc: 0.9787 - precision: 0.9787 - recall: 0.9787 - f1: 0.97
87 - val_loss: 0.0358 - val_acc: 0.9898 - val_precision: 0.9898 - va
```

```
l_recall: 0.9898 - val_f1: 0.9898
Epoch 62/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.0709 - acc: 0.9739 - precision: 0.9739 - recall: 0.9739 - f1: 0.97
39 - val_loss: 0.0342 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 63/100
3901/3901 [==============================] - 1s 308us/step - loss:
0.0603 - acc: 0.9767 - precision: 0.9767 - recall: 0.9767 - f1: 0.97
67 - val_loss: 0.0394 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 64/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0789 - acc: 0.9682 - precision: 0.9682 - recall: 0.9682 - f1: 0.96
82 - val_loss: 0.0334 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 65/100
3901/3901 [==============================] - 1s 319us/step - loss:
0.0618 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.97
59 - val_loss: 0.0378 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 66/100
3901/3901 [==============================] - 1s 317us/step - loss:
0.0537 - acc: 0.9790 - precision: 0.9790 - recall: 0.9790 - f1: 0.97
90 - val_loss: 0.0345 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 67/100
3901/3901 [==============================] - 1s 305us/step - loss:
0.0682 - acc: 0.9746 - precision: 0.9746 - recall: 0.9746 - f1: 0.97
46 - val_loss: 0.0407 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 68/100
3901/3901 [==============================] - 1s 309us/step - loss:
0.0740 - acc: 0.9731 - precision: 0.9731 - recall: 0.9731 - f1: 0.97
31 - val_loss: 0.0422 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 69/100
3901/3901 [==============================] - 1s 308us/step - loss:
0.0582 - acc: 0.9780 - precision: 0.9780 - recall: 0.9780 - f1: 0.97
80 - val_loss: 0.0381 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 70/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0600 - acc: 0.9790 - precision: 0.9790 - recall: 0.9790 - f1: 0.97
90 - val_loss: 0.0317 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 71/100
3901/3901 [==============================] - 1s 308us/step - loss:
0.0495 - acc: 0.9808 - precision: 0.9808 - recall: 0.9808 - f1: 0.98
08 - val_loss: 0.0319 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 72/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.0520 - acc: 0.9813 - precision: 0.9813 - recall: 0.9813 - f1: 0.98
13 - val_loss: 0.0407 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 73/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.0597 - acc: 0.9769 - precision: 0.9769 - recall: 0.9769 - f1: 0.97
69 - val_loss: 0.0428 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
```

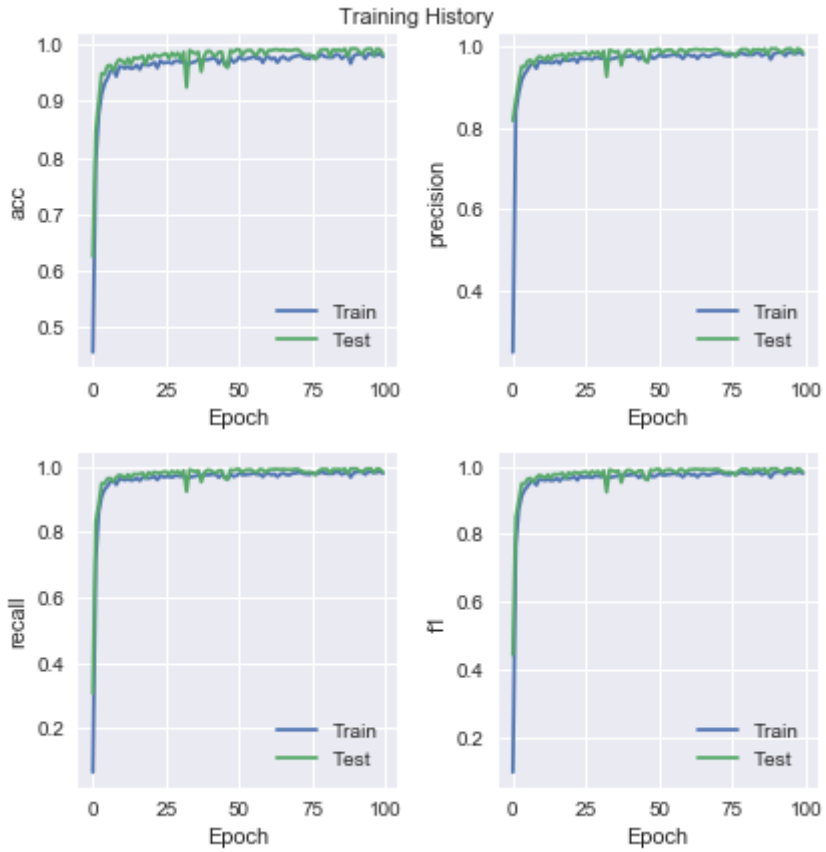
```
Epoch 74/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.0602 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.97
59 - val_loss: 0.0600 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 75/100
3901/3901 [==============================] - 1s 314us/step - loss:
0.0647 - acc: 0.9749 - precision: 0.9749 - recall: 0.9749 - f1: 0.97
49 - val_loss: 0.0521 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
Epoch 76/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0530 - acc: 0.9805 - precision: 0.9805 - recall: 0.9805 - f1: 0.98
05 - val_loss: 0.0665 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 77/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0657 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.97
59 - val_loss: 0.0783 - val_acc: 0.9739 - val_precision: 0.9739 - va
l_recall: 0.9739 - val_f1: 0.9739
Epoch 78/100
3901/3901 [==============================] - 1s 314us/step - loss:
0.0504 - acc: 0.9785 - precision: 0.9785 - recall: 0.9785 - f1: 0.97
85 - val_loss: 0.0415 - val_acc: 0.9855 - val_precision: 0.9855 - va
l_recall: 0.9855 - val_f1: 0.9855
Epoch 79/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0481 - acc: 0.9831 - precision: 0.9831 - recall: 0.9831 - f1: 0.98
31 - val_loss: 0.0349 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 80/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0596 - acc: 0.9792 - precision: 0.9792 - recall: 0.9792 - f1: 0.97
92 - val_loss: 0.0388 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 81/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.0573 - acc: 0.9777 - precision: 0.9777 - recall: 0.9777 - f1: 0.97
77 - val_loss: 0.0315 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 82/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0612 - acc: 0.9774 - precision: 0.9774 - recall: 0.9774 - f1: 0.97
74 - val_loss: 0.0657 - val_acc: 0.9797 - val_precision: 0.9797 - va
l_recall: 0.9797 - val_f1: 0.9797
Epoch 83/100
3901/3901 [==============================] - 1s 317us/step - loss:
0.0607 - acc: 0.9777 - precision: 0.9777 - recall: 0.9777 - f1: 0.97
77 - val_loss: 0.0348 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 84/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0503 - acc: 0.9828 - precision: 0.9828 - recall: 0.9828 - f1: 0.98
28 - val_loss: 0.0397 - val_acc: 0.9898 - val_precision: 0.9898 - va
l_recall: 0.9898 - val_f1: 0.9898
Epoch 85/100
3901/3901 [==============================] - 1s 311us/step - loss:
0.0471 - acc: 0.9818 - precision: 0.9818 - recall: 0.9818 - f1: 0.98
18 - val_loss: 0.0294 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 86/100
```

```
3901/3901 [==============================] - 1s 322us/step - loss:
0.0702 - acc: 0.9751 - precision: 0.9751 - recall: 0.9751 - f1: 0.97
51 - val_loss: 0.0472 - val_acc: 0.9884 - val_precision: 0.9884 - va
l_recall: 0.9884 - val_f1: 0.9884
Epoch 87/100
3901/3901 [==============================] - 1s 312us/step - loss:
0.0522 - acc: 0.9792 - precision: 0.9792 - recall: 0.9792 - f1: 0.97
92 - val_loss: 0.0304 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 88/100
3901/3901 [==============================] - 1s 315us/step - loss:
0.0581 - acc: 0.9808 - precision: 0.9808 - recall: 0.9808 - f1: 0.98
08 - val_loss: 0.0581 - val_acc: 0.9782 - val_precision: 0.9782 - va
l_recall: 0.9782 - val_f1: 0.9782
Epoch 89/100
3901/3901 [==============================] - 1s 313us/step - loss:
0.0862 - acc: 0.9667 - precision: 0.9667 - recall: 0.9667 - f1: 0.96
67 - val_loss: 0.0307 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 90/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0500 - acc: 0.9797 - precision: 0.9797 - recall: 0.9797 - f1: 0.97
97 - val_loss: 0.0336 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 91/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0448 - acc: 0.9826 - precision: 0.9826 - recall: 0.9826 - f1: 0.98
26 - val_loss: 0.0293 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 92/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0442 - acc: 0.9833 - precision: 0.9833 - recall: 0.9833 - f1: 0.98
33 - val_loss: 0.0444 - val_acc: 0.9869 - val_precision: 0.9869 - va
l_recall: 0.9869 - val_f1: 0.9869
Epoch 93/100
3901/3901 [==============================] - 1s 310us/step - loss:
0.0495 - acc: 0.9826 - precision: 0.9826 - recall: 0.9826 - f1: 0.98
26 - val_loss: 0.0580 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
Epoch 94/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0674 - acc: 0.9751 - precision: 0.9751 - recall: 0.9751 - f1: 0.97
51 - val_loss: 0.0356 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 95/100
3901/3901 [==============================] - 1s 316us/step - loss:
0.0435 - acc: 0.9839 - precision: 0.9839 - recall: 0.9839 - f1: 0.98
39 - val_loss: 0.0314 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 96/100
3901/3901 [==============================] - 1s 314us/step - loss:
0.0427 - acc: 0.9831 - precision: 0.9831 - recall: 0.9831 - f1: 0.98
31 - val_loss: 0.0296 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 97/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.0519 - acc: 0.9803 - precision: 0.9803 - recall: 0.9803 - f1: 0.98
03 - val_loss: 0.0673 - val_acc: 0.9811 - val_precision: 0.9811 - va
l_recall: 0.9811 - val_f1: 0.9811
Epoch 98/100
3901/3901 [==============================] - 1s 315us/step - loss:
```

```
0.0499 - acc: 0.9818 - precision: 0.9818 - recall: 0.9818 - f1: 0.98
18 - val_loss: 0.0329 - val_acc: 0.9927 - val_precision: 0.9927 - va
l_recall: 0.9927 - val_f1: 0.9927
Epoch 99/100
3901/3901 [==============================] - 1s 308us/step - loss:
0.0450 - acc: 0.9844 - precision: 0.9844 - recall: 0.9844 - f1: 0.98
44 - val_loss: 0.0307 - val_acc: 0.9913 - val_precision: 0.9913 - va
l_recall: 0.9913 - val_f1: 0.9913
Epoch 100/100
3901/3901 [==============================] - 1s 307us/step - loss:
0.0593 - acc: 0.9785 - precision: 0.9785 - recall: 0.9785 - f1: 0.97
85 - val_loss: 0.0522 - val_acc: 0.9826 - val_precision: 0.9826 - va
l_recall: 0.9826 - val_f1: 0.9826
```

In [54]:

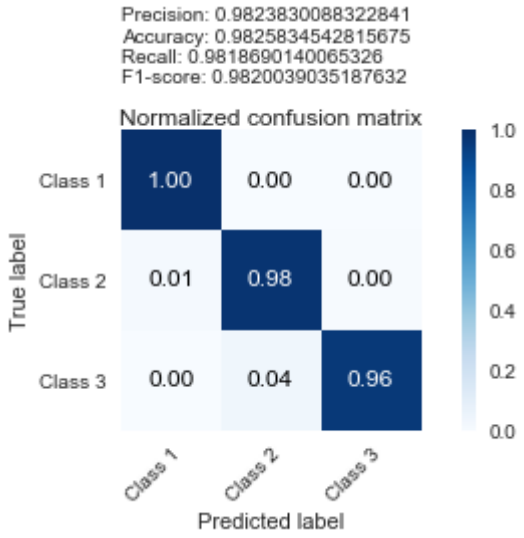
```
plot_train_history(history)
#plt.tight_layout()
#plt.savefig('train_history_model1.png', dpi = 300)
```



In [55]:

```
model_test_summary(model)
#plt.tight_layout()
#plt.savefig('confmat_model_new.png', dpi = 300)
```

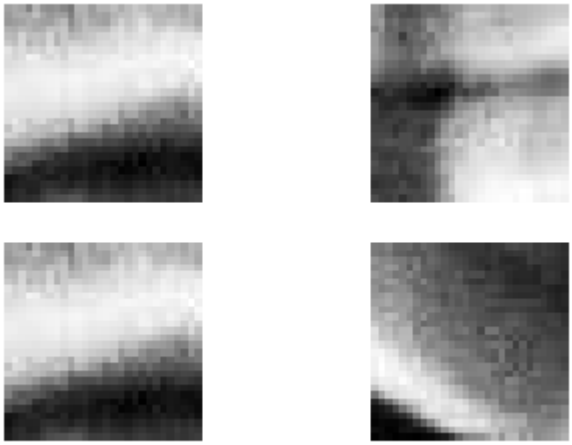
Normalized confusion matrix



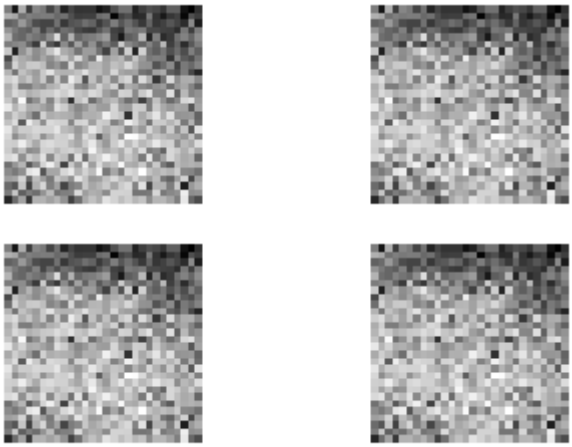
In [56]:

```
model_wrong_predictions(model)
```

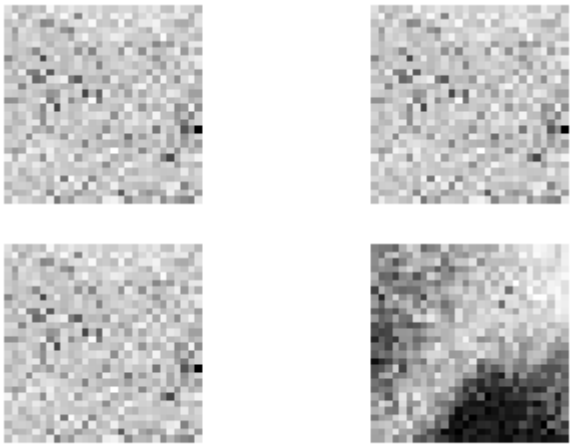
```
True class:  1
True class:  2
Wrongly predicted as Class 1
```



```
Wrongly predicted as Class 3
```



```
True class:  3
Wrongly predicted as Class 2
```



How does the model performance change as a function of input image size?

In [57]:

```
sizes = [8, 12, 16, 28, 32]

for size in sizes:

    sx=size
    sy=size

    MAX_X = img1_gr.shape[0]
    MAX_Y = img1_gr.shape[1]

    class1_data=[]
    class2_data=[]
    class3_data=[]

    for x_coord in np.arange(0,MAX_X-sx,sx):
        for y_coord in np.arange(0,MAX_Y-sy,sy):
            class1_data.append(img1_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
            class2_data.append(img2_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
            class3_data.append(img3_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])


    X = np.vstack([class1_data, class2_data, class3_data])
    labels = np.array([0]*len(class1_data) + [1]*len(class2_data) + [2]*len(clas
s3_data))
    y = OneHotEncoder().fit_transform(labels.reshape(-1,1))

    # Validation

    X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.15, random_
state=42, shuffle=True)
    y_test_class=prob_to_class(y_test)
    X_train_ch=X_train.reshape(-1,sx,sy,1)
    X_test_ch=X_test.reshape(-1,sx,sy,1)
    input_shape = (sx,sy,1)

    model=Sequential()
    model.add(InputLayer(input_shape=input_shape))
    model.add(Conv2D(20, (4, 4), input_shape=input_shape, activation='relu'))
    model.add(Conv2D(10, (3,3), input_shape=input_shape, activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Flatten())
    model.add(Dense(3,activation="softmax"))
    optimizer="adam"
    model.compile(loss='categorical_crossentropy', optimizer=optimizer, metrics=
['accuracy', precision,recall,f1])
    model.summary()

    history=model.fit(X_train_ch,y_train, validation_data=(X_test_ch,y_test),epo
chs=100)


    model_test_summary(model)
    plt.savefig('plot_test_summery'+str(size)+'.png', dpi = 180)


    # Plot it training history
    plot_train_history(history)
    plt.savefig('plot_history_size'+str(size)+'.png', dpi = 180)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         (None, 8, 8, 1)           0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 5, 5, 20)          340
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 3, 3, 10)          1810
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 1, 1, 10)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 10)                0
_________________________________________________________________
dense_5 (Dense)              (None, 3)                 33
=================================================================
Total params: 2,183
Trainable params: 2,183
Non-trainable params: 0
_________________________________________________________________
Train on 48248 samples, validate on 8515 samples
Epoch 1/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.7927 - acc: 0.6241 - precision: 0.6381 - recall: 0.3946 - f1: 0.46
88 - val_loss: 0.5529 - val_acc: 0.7730 - val_precision: 0.8289 - va
l_recall: 0.6672 - val_f1: 0.7382
Epoch 2/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.4746 - acc: 0.8215 - precision: 0.8404 - recall: 0.7820 - f1: 0.80
90 - val_loss: 0.3906 - val_acc: 0.8637 - val_precision: 0.8680 - va
l_recall: 0.8568 - val_f1: 0.8623
Epoch 3/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.3703 - acc: 0.8632 - precision: 0.8669 - recall: 0.8586 - f1: 0.86
27 - val_loss: 0.3861 - val_acc: 0.8506 - val_precision: 0.8509 - va
l_recall: 0.8498 - val_f1: 0.8503
Epoch 4/100
48248/48248 [==============================] - 5s 96us/step - loss:
0.3236 - acc: 0.8789 - precision: 0.8804 - recall: 0.8769 - f1: 0.87
86 - val_loss: 0.2928 - val_acc: 0.8950 - val_precision: 0.8956 - va
l_recall: 0.8934 - val_f1: 0.8944
Epoch 5/100
48248/48248 [==============================] - 5s 95us/step - loss:
0.3023 - acc: 0.8843 - precision: 0.8853 - recall: 0.8828 - f1: 0.88
40 - val_loss: 0.3232 - val_acc: 0.8698 - val_precision: 0.8706 - va
l_recall: 0.8692 - val_f1: 0.8699
Epoch 6/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2919 - acc: 0.8868 - precision: 0.8876 - recall: 0.8857 - f1: 0.88
66 - val_loss: 0.2851 - val_acc: 0.8930 - val_precision: 0.8935 - va
l_recall: 0.8928 - val_f1: 0.8931
Epoch 7/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.2789 - acc: 0.8914 - precision: 0.8919 - recall: 0.8907 - f1: 0.89
13 - val_loss: 0.2679 - val_acc: 0.9008 - val_precision: 0.9013 - va
l_recall: 0.9003 - val_f1: 0.9008
Epoch 8/100
48248/48248 [==============================] - 5s 93us/step - loss:
0.2744 - acc: 0.8924 - precision: 0.8931 - recall: 0.8917 - f1: 0.89
24 - val_loss: 0.2521 - val_acc: 0.9043 - val_precision: 0.9049 - va
l_recall: 0.9037 - val_f1: 0.9043
Epoch 9/100
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48248/48248 [==============================] - 4s 92us/step - loss:
0.2675 - acc: 0.8951 - precision: 0.8956 - recall: 0.8946 - f1: 0.89
51 - val_loss: 0.2550 - val_acc: 0.9044 - val_precision: 0.9047 - va
l_recall: 0.9039 - val_f1: 0.9043
Epoch 10/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.2610 - acc: 0.8983 - precision: 0.8986 - recall: 0.8977 - f1: 0.89
81 - val_loss: 0.2677 - val_acc: 0.8967 - val_precision: 0.8968 - va
l_recall: 0.8961 - val_f1: 0.8964
Epoch 11/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.2581 - acc: 0.8992 - precision: 0.8996 - recall: 0.8987 - f1: 0.89
92 - val_loss: 0.2450 - val_acc: 0.9090 - val_precision: 0.9094 - va
l_recall: 0.9087 - val_f1: 0.9091
Epoch 12/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.2537 - acc: 0.9011 - precision: 0.9016 - recall: 0.9006 - f1: 0.90
11 - val_loss: 0.2641 - val_acc: 0.8978 - val_precision: 0.8986 - va
l_recall: 0.8971 - val_f1: 0.8979
Epoch 13/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.2486 - acc: 0.9041 - precision: 0.9044 - recall: 0.9037 - f1: 0.90
41 - val_loss: 0.2293 - val_acc: 0.9118 - val_precision: 0.9121 - va
l_recall: 0.9117 - val_f1: 0.9119
Epoch 14/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.2475 - acc: 0.9028 - precision: 0.9030 - recall: 0.9024 - f1: 0.90
27 - val_loss: 0.2647 - val_acc: 0.8969 - val_precision: 0.8976 - va
l_recall: 0.8963 - val_f1: 0.8970
Epoch 15/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2465 - acc: 0.9040 - precision: 0.9046 - recall: 0.9036 - f1: 0.90
41 - val_loss: 0.2385 - val_acc: 0.9082 - val_precision: 0.9087 - va
l_recall: 0.9075 - val_f1: 0.9080
Epoch 16/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2433 - acc: 0.9048 - precision: 0.9051 - recall: 0.9044 - f1: 0.90
48 - val_loss: 0.2410 - val_acc: 0.9072 - val_precision: 0.9076 - va
l_recall: 0.9071 - val_f1: 0.9074
Epoch 17/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.2420 - acc: 0.9045 - precision: 0.9049 - recall: 0.9041 - f1: 0.90
45 - val_loss: 0.2826 - val_acc: 0.8888 - val_precision: 0.8888 - va
l_recall: 0.8881 - val_f1: 0.8884
Epoch 18/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2401 - acc: 0.9049 - precision: 0.9053 - recall: 0.9045 - f1: 0.90
49 - val_loss: 0.2218 - val_acc: 0.9134 - val_precision: 0.9144 - va
l_recall: 0.9131 - val_f1: 0.9137
Epoch 19/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2356 - acc: 0.9084 - precision: 0.9089 - recall: 0.9079 - f1: 0.90
83 - val_loss: 0.2567 - val_acc: 0.8996 - val_precision: 0.9001 - va
l_recall: 0.8994 - val_f1: 0.8997
Epoch 20/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.2347 - acc: 0.9083 - precision: 0.9085 - recall: 0.9079 - f1: 0.90
82 - val_loss: 0.2268 - val_acc: 0.9163 - val_precision: 0.9165 - va
l_recall: 0.9159 - val_f1: 0.9162
Epoch 21/100
48248/48248 [==============================] - 4s 93us/step - loss:
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0.2326 - acc: 0.9096 - precision: 0.9100 - recall: 0.9092 - f1: 0.90
95 - val_loss: 0.2286 - val_acc: 0.9112 - val_precision: 0.9113 - va
l_recall: 0.9104 - val_f1: 0.9109
Epoch 22/100
48248/48248 [==============================] - 4s 87us/step - loss:
0.2285 - acc: 0.9110 - precision: 0.9113 - recall: 0.9106 - f1: 0.91
10 - val_loss: 0.2230 - val_acc: 0.9115 - val_precision: 0.9120 - va
l_recall: 0.9110 - val_f1: 0.9115
Epoch 23/100
48248/48248 [==============================] - 4s 87us/step - loss:
0.2276 - acc: 0.9110 - precision: 0.9114 - recall: 0.9106 - f1: 0.91
10 - val_loss: 0.2122 - val_acc: 0.9181 - val_precision: 0.9184 - va
l_recall: 0.9176 - val_f1: 0.9180
Epoch 24/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.2220 - acc: 0.9133 - precision: 0.9136 - recall: 0.9131 - f1: 0.91
33 - val_loss: 0.2195 - val_acc: 0.9157 - val_precision: 0.9159 - va
l_recall: 0.9154 - val_f1: 0.9157
Epoch 25/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.2234 - acc: 0.9127 - precision: 0.9130 - recall: 0.9124 - f1: 0.91
27 - val_loss: 0.2088 - val_acc: 0.9201 - val_precision: 0.9203 - va
l_recall: 0.9201 - val_f1: 0.9202
Epoch 26/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.2211 - acc: 0.9137 - precision: 0.9141 - recall: 0.9134 - f1: 0.91
37 - val_loss: 0.2078 - val_acc: 0.9199 - val_precision: 0.9203 - va
l_recall: 0.9197 - val_f1: 0.9200
Epoch 27/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.2186 - acc: 0.9146 - precision: 0.9149 - recall: 0.9143 - f1: 0.91
46 - val_loss: 0.2624 - val_acc: 0.8962 - val_precision: 0.8964 - va
l_recall: 0.8961 - val_f1: 0.8962
Epoch 28/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.2184 - acc: 0.9154 - precision: 0.9158 - recall: 0.9151 - f1: 0.91
55 - val_loss: 0.2040 - val_acc: 0.9201 - val_precision: 0.9202 - va
l_recall: 0.9199 - val_f1: 0.9201
Epoch 29/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.2149 - acc: 0.9164 - precision: 0.9167 - recall: 0.9160 - f1: 0.91
63 - val_loss: 0.2078 - val_acc: 0.9188 - val_precision: 0.9188 - va
l_recall: 0.9186 - val_f1: 0.9187
Epoch 30/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.2156 - acc: 0.9151 - precision: 0.9155 - recall: 0.9148 - f1: 0.91
51 - val_loss: 0.2404 - val_acc: 0.9063 - val_precision: 0.9064 - va
l_recall: 0.9060 - val_f1: 0.9062
Epoch 31/100
48248/48248 [==============================] - 4s 86us/step - loss:
0.2129 - acc: 0.9162 - precision: 0.9166 - recall: 0.9159 - f1: 0.91
62 - val_loss: 0.2149 - val_acc: 0.9145 - val_precision: 0.9149 - va
l_recall: 0.9144 - val_f1: 0.9147
Epoch 32/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.2112 - acc: 0.9166 - precision: 0.9171 - recall: 0.9162 - f1: 0.91
67 - val_loss: 0.2012 - val_acc: 0.9196 - val_precision: 0.9195 - va
l_recall: 0.9194 - val_f1: 0.9195
Epoch 33/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.2123 - acc: 0.9169 - precision: 0.9170 - recall: 0.9165 - f1: 0.91
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67 - val_loss: 0.1971 - val_acc: 0.9221 - val_precision: 0.9223 - va
l_recall: 0.9218 - val_f1: 0.9221
Epoch 34/100
48248/48248 [==============================] - 4s 84us/step - loss:
0.2069 - acc: 0.9194 - precision: 0.9198 - recall: 0.9191 - f1: 0.91
95 - val_loss: 0.1971 - val_acc: 0.9240 - val_precision: 0.9243 - va
l_recall: 0.9233 - val_f1: 0.9238
Epoch 35/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.2049 - acc: 0.9191 - precision: 0.9196 - recall: 0.9189 - f1: 0.91
93 - val_loss: 0.1969 - val_acc: 0.9243 - val_precision: 0.9247 - va
l_recall: 0.9240 - val_f1: 0.9243
Epoch 36/100
48248/48248 [==============================] - 4s 87us/step - loss:
0.2040 - acc: 0.9205 - precision: 0.9209 - recall: 0.9200 - f1: 0.92
05 - val_loss: 0.1992 - val_acc: 0.9228 - val_precision: 0.9231 - va
l_recall: 0.9220 - val_f1: 0.9225
Epoch 37/100
48248/48248 [==============================] - 4s 86us/step - loss:
0.2037 - acc: 0.9204 - precision: 0.9208 - recall: 0.9200 - f1: 0.92
04 - val_loss: 0.2259 - val_acc: 0.9143 - val_precision: 0.9153 - va
l_recall: 0.9139 - val_f1: 0.9146
Epoch 38/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.2064 - acc: 0.9197 - precision: 0.9199 - recall: 0.9194 - f1: 0.91
96 - val_loss: 0.1966 - val_acc: 0.9268 - val_precision: 0.9271 - va
l_recall: 0.9261 - val_f1: 0.9266
Epoch 39/100
48248/48248 [==============================] - 4s 86us/step - loss:
0.2051 - acc: 0.9210 - precision: 0.9212 - recall: 0.9206 - f1: 0.92
09 - val_loss: 0.1968 - val_acc: 0.9246 - val_precision: 0.9250 - va
l_recall: 0.9244 - val_f1: 0.9247
Epoch 40/100
48248/48248 [==============================] - 4s 87us/step - loss:
0.2042 - acc: 0.9196 - precision: 0.9200 - recall: 0.9191 - f1: 0.91
95 - val_loss: 0.2293 - val_acc: 0.9103 - val_precision: 0.9113 - va
l_recall: 0.9098 - val_f1: 0.9106
Epoch 41/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.2043 - acc: 0.9205 - precision: 0.9209 - recall: 0.9201 - f1: 0.92
05 - val_loss: 0.1879 - val_acc: 0.9272 - val_precision: 0.9275 - va
l_recall: 0.9265 - val_f1: 0.9270
Epoch 42/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.1974 - acc: 0.9236 - precision: 0.9239 - recall: 0.9233 - f1: 0.92
36 - val_loss: 0.2107 - val_acc: 0.9198 - val_precision: 0.9201 - va
l_recall: 0.9197 - val_f1: 0.9199
Epoch 43/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.1979 - acc: 0.9220 - precision: 0.9224 - recall: 0.9215 - f1: 0.92
20 - val_loss: 0.2161 - val_acc: 0.9177 - val_precision: 0.9208 - va
l_recall: 0.9152 - val_f1: 0.9179
Epoch 44/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1992 - acc: 0.9218 - precision: 0.9221 - recall: 0.9214 - f1: 0.92
18 - val_loss: 0.1916 - val_acc: 0.9265 - val_precision: 0.9270 - va
l_recall: 0.9261 - val_f1: 0.9266
Epoch 45/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1982 - acc: 0.9229 - precision: 0.9231 - recall: 0.9225 - f1: 0.92
28 - val_loss: 0.1975 - val_acc: 0.9235 - val_precision: 0.9239 - va
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l_recall: 0.9232 - val_f1: 0.9236
Epoch 46/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1947 - acc: 0.9242 - precision: 0.9246 - recall: 0.9239 - f1: 0.92
42 - val_loss: 0.2179 - val_acc: 0.9151 - val_precision: 0.9155 - va
l_recall: 0.9145 - val_f1: 0.9150
Epoch 47/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1940 - acc: 0.9234 - precision: 0.9236 - recall: 0.9230 - f1: 0.92
33 - val_loss: 0.1934 - val_acc: 0.9251 - val_precision: 0.9254 - va
l_recall: 0.9250 - val_f1: 0.9252
Epoch 48/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1934 - acc: 0.9232 - precision: 0.9236 - recall: 0.9229 - f1: 0.92
33 - val_loss: 0.2041 - val_acc: 0.9241 - val_precision: 0.9254 - va
l_recall: 0.9234 - val_f1: 0.9244
Epoch 49/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1908 - acc: 0.9258 - precision: 0.9261 - recall: 0.9254 - f1: 0.92
57 - val_loss: 0.1961 - val_acc: 0.9234 - val_precision: 0.9236 - va
l_recall: 0.9231 - val_f1: 0.9233
Epoch 50/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1986 - acc: 0.9214 - precision: 0.9216 - recall: 0.9208 - f1: 0.92
12 - val_loss: 0.1839 - val_acc: 0.9291 - val_precision: 0.9296 - va
l_recall: 0.9288 - val_f1: 0.9292
Epoch 51/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1890 - acc: 0.9258 - precision: 0.9261 - recall: 0.9255 - f1: 0.92
58 - val_loss: 0.2185 - val_acc: 0.9129 - val_precision: 0.9130 - va
l_recall: 0.9125 - val_f1: 0.9128
Epoch 52/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1897 - acc: 0.9254 - precision: 0.9258 - recall: 0.9250 - f1: 0.92
54 - val_loss: 0.1875 - val_acc: 0.9272 - val_precision: 0.9274 - va
l_recall: 0.9270 - val_f1: 0.9272
Epoch 53/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1878 - acc: 0.9260 - precision: 0.9264 - recall: 0.9256 - f1: 0.92
60 - val_loss: 0.1925 - val_acc: 0.9273 - val_precision: 0.9274 - va
l_recall: 0.9267 - val_f1: 0.9270
Epoch 54/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1889 - acc: 0.9250 - precision: 0.9254 - recall: 0.9246 - f1: 0.92
50 - val_loss: 0.1858 - val_acc: 0.9311 - val_precision: 0.9312 - va
l_recall: 0.9308 - val_f1: 0.9310
Epoch 55/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1915 - acc: 0.9237 - precision: 0.9240 - recall: 0.9233 - f1: 0.92
37 - val_loss: 0.2006 - val_acc: 0.9232 - val_precision: 0.9233 - va
l_recall: 0.9226 - val_f1: 0.9229
Epoch 56/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1839 - acc: 0.9271 - precision: 0.9274 - recall: 0.9268 - f1: 0.92
71 - val_loss: 0.1867 - val_acc: 0.9318 - val_precision: 0.9319 - va
l_recall: 0.9317 - val_f1: 0.9318
Epoch 57/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1851 - acc: 0.9273 - precision: 0.9276 - recall: 0.9268 - f1: 0.92
72 - val_loss: 0.1841 - val_acc: 0.9304 - val_precision: 0.9306 - va
l_recall: 0.9302 - val_f1: 0.9304
```

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Epoch 58/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1834 - acc: 0.9278 - precision: 0.9284 - recall: 0.9273 - f1: 0.92
78 - val_loss: 0.1805 - val_acc: 0.9334 - val_precision: 0.9337 - va
l_recall: 0.9333 - val_f1: 0.9335
Epoch 59/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1832 - acc: 0.9278 - precision: 0.9282 - recall: 0.9275 - f1: 0.92
79 - val_loss: 0.1882 - val_acc: 0.9287 - val_precision: 0.9289 - va
l_recall: 0.9284 - val_f1: 0.9286
Epoch 60/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1852 - acc: 0.9283 - precision: 0.9286 - recall: 0.9280 - f1: 0.92
83 - val_loss: 0.1877 - val_acc: 0.9272 - val_precision: 0.9276 - va
l_recall: 0.9270 - val_f1: 0.9273
Epoch 61/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1855 - acc: 0.9273 - precision: 0.9278 - recall: 0.9269 - f1: 0.92
73 - val_loss: 0.2030 - val_acc: 0.9224 - val_precision: 0.9228 - va
l_recall: 0.9221 - val_f1: 0.9225
Epoch 62/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1835 - acc: 0.9283 - precision: 0.9286 - recall: 0.9280 - f1: 0.92
83 - val_loss: 0.1875 - val_acc: 0.9307 - val_precision: 0.9310 - va
l_recall: 0.9302 - val_f1: 0.9306
Epoch 63/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1853 - acc: 0.9265 - precision: 0.9269 - recall: 0.9262 - f1: 0.92
65 - val_loss: 0.1724 - val_acc: 0.9353 - val_precision: 0.9354 - va
l_recall: 0.9352 - val_f1: 0.9353
Epoch 64/100
48248/48248 [==============================] - 4s 88us/step - loss:
0.1843 - acc: 0.9269 - precision: 0.9273 - recall: 0.9265 - f1: 0.92
69 - val_loss: 0.1860 - val_acc: 0.9279 - val_precision: 0.9285 - va
l_recall: 0.9277 - val_f1: 0.9281
Epoch 65/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1818 - acc: 0.9290 - precision: 0.9294 - recall: 0.9284 - f1: 0.92
89 - val_loss: 0.1813 - val_acc: 0.9312 - val_precision: 0.9314 - va
l_recall: 0.9312 - val_f1: 0.9313
Epoch 66/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1814 - acc: 0.9292 - precision: 0.9296 - recall: 0.9287 - f1: 0.92
92 - val_loss: 0.1853 - val_acc: 0.9294 - val_precision: 0.9297 - va
l_recall: 0.9293 - val_f1: 0.9295
Epoch 67/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1812 - acc: 0.9289 - precision: 0.9294 - recall: 0.9284 - f1: 0.92
89 - val_loss: 0.1789 - val_acc: 0.9321 - val_precision: 0.9323 - va
l_recall: 0.9318 - val_f1: 0.9320
Epoch 68/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1816 - acc: 0.9285 - precision: 0.9287 - recall: 0.9280 - f1: 0.92
83 - val_loss: 0.1954 - val_acc: 0.9272 - val_precision: 0.9275 - va
l_recall: 0.9270 - val_f1: 0.9272
Epoch 69/100
48248/48248 [==============================] - 5s 94us/step - loss:
0.1808 - acc: 0.9296 - precision: 0.9299 - recall: 0.9290 - f1: 0.92
95 - val_loss: 0.1894 - val_acc: 0.9280 - val_precision: 0.9289 - va
l_recall: 0.9253 - val_f1: 0.9271
Epoch 70/100
```

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48248/48248 [==============================] - 5s 95us/step - loss:
0.1804 - acc: 0.9297 - precision: 0.9300 - recall: 0.9292 - f1: 0.92
96 - val_loss: 0.2051 - val_acc: 0.9203 - val_precision: 0.9208 - va
l_recall: 0.9196 - val_f1: 0.9202
Epoch 71/100
48248/48248 [==============================] - 5s 93us/step - loss:
0.1793 - acc: 0.9302 - precision: 0.9306 - recall: 0.9297 - f1: 0.93
01 - val_loss: 0.1938 - val_acc: 0.9252 - val_precision: 0.9256 - va
l_recall: 0.9243 - val_f1: 0.9249
Epoch 72/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1783 - acc: 0.9305 - precision: 0.9308 - recall: 0.9299 - f1: 0.93
03 - val_loss: 0.1928 - val_acc: 0.9251 - val_precision: 0.9255 - va
l_recall: 0.9251 - val_f1: 0.9253
Epoch 73/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1828 - acc: 0.9285 - precision: 0.9291 - recall: 0.9279 - f1: 0.92
85 - val_loss: 0.1966 - val_acc: 0.9226 - val_precision: 0.9231 - va
l_recall: 0.9223 - val_f1: 0.9227
Epoch 74/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1784 - acc: 0.9301 - precision: 0.9306 - recall: 0.9297 - f1: 0.93
01 - val_loss: 0.1870 - val_acc: 0.9305 - val_precision: 0.9314 - va
l_recall: 0.9294 - val_f1: 0.9304
Epoch 75/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1788 - acc: 0.9302 - precision: 0.9307 - recall: 0.9296 - f1: 0.93
01 - val_loss: 0.2024 - val_acc: 0.9210 - val_precision: 0.9214 - va
l_recall: 0.9210 - val_f1: 0.9212
Epoch 76/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1805 - acc: 0.9301 - precision: 0.9306 - recall: 0.9297 - f1: 0.93
02 - val_loss: 0.1793 - val_acc: 0.9309 - val_precision: 0.9312 - va
l_recall: 0.9305 - val_f1: 0.9308
Epoch 77/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1769 - acc: 0.9319 - precision: 0.9323 - recall: 0.9314 - f1: 0.93
19 - val_loss: 0.1822 - val_acc: 0.9315 - val_precision: 0.9326 - va
l_recall: 0.9306 - val_f1: 0.9316
Epoch 78/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1770 - acc: 0.9306 - precision: 0.9312 - recall: 0.9301 - f1: 0.93
06 - val_loss: 0.2015 - val_acc: 0.9212 - val_precision: 0.9215 - va
l_recall: 0.9208 - val_f1: 0.9212
Epoch 79/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1744 - acc: 0.9316 - precision: 0.9320 - recall: 0.9309 - f1: 0.93
15 - val_loss: 0.1837 - val_acc: 0.9312 - val_precision: 0.9322 - va
l_recall: 0.9308 - val_f1: 0.9315
Epoch 80/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1743 - acc: 0.9307 - precision: 0.9313 - recall: 0.9301 - f1: 0.93
07 - val_loss: 0.1856 - val_acc: 0.9288 - val_precision: 0.9289 - va
l_recall: 0.9286 - val_f1: 0.9288
Epoch 81/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1750 - acc: 0.9307 - precision: 0.9312 - recall: 0.9303 - f1: 0.93
08 - val_loss: 0.2007 - val_acc: 0.9234 - val_precision: 0.9247 - va
l_recall: 0.9226 - val_f1: 0.9236
Epoch 82/100
48248/48248 [==============================] - 4s 91us/step - loss:
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0.1754 - acc: 0.9321 - precision: 0.9324 - recall: 0.9316 - f1: 0.93
20 - val_loss: 0.1999 - val_acc: 0.9237 - val_precision: 0.9239 - va
l_recall: 0.9234 - val_f1: 0.9236
Epoch 83/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1812 - acc: 0.9285 - precision: 0.9290 - recall: 0.9280 - f1: 0.92
85 - val_loss: 0.1750 - val_acc: 0.9322 - val_precision: 0.9324 - va
l_recall: 0.9317 - val_f1: 0.9320
Epoch 84/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1745 - acc: 0.9321 - precision: 0.9325 - recall: 0.9315 - f1: 0.93
20 - val_loss: 0.1937 - val_acc: 0.9262 - val_precision: 0.9272 - va
l_recall: 0.9258 - val_f1: 0.9265
Epoch 85/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1751 - acc: 0.9314 - precision: 0.9317 - recall: 0.9307 - f1: 0.93
12 - val_loss: 0.1906 - val_acc: 0.9288 - val_precision: 0.9298 - va
l_recall: 0.9286 - val_f1: 0.9292
Epoch 86/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1744 - acc: 0.9323 - precision: 0.9330 - recall: 0.9317 - f1: 0.93
23 - val_loss: 0.2056 - val_acc: 0.9230 - val_precision: 0.9245 - va
l_recall: 0.9203 - val_f1: 0.9223
Epoch 87/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1752 - acc: 0.9327 - precision: 0.9331 - recall: 0.9321 - f1: 0.93
26 - val_loss: 0.1931 - val_acc: 0.9289 - val_precision: 0.9304 - va
l_recall: 0.9275 - val_f1: 0.9289
Epoch 88/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1752 - acc: 0.9308 - precision: 0.9314 - recall: 0.9302 - f1: 0.93
08 - val_loss: 0.1966 - val_acc: 0.9230 - val_precision: 0.9230 - va
l_recall: 0.9226 - val_f1: 0.9228
Epoch 89/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1723 - acc: 0.9332 - precision: 0.9338 - recall: 0.9326 - f1: 0.93
32 - val_loss: 0.1830 - val_acc: 0.9315 - val_precision: 0.9316 - va
l_recall: 0.9311 - val_f1: 0.9313
Epoch 90/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1775 - acc: 0.9305 - precision: 0.9310 - recall: 0.9299 - f1: 0.93
04 - val_loss: 0.1815 - val_acc: 0.9320 - val_precision: 0.9322 - va
l_recall: 0.9317 - val_f1: 0.9319
Epoch 91/100
48248/48248 [==============================] - 4s 92us/step - loss:
0.1718 - acc: 0.9316 - precision: 0.9322 - recall: 0.9310 - f1: 0.93
16 - val_loss: 0.2125 - val_acc: 0.9170 - val_precision: 0.9176 - va
l_recall: 0.9157 - val_f1: 0.9166
Epoch 92/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1743 - acc: 0.9320 - precision: 0.9326 - recall: 0.9314 - f1: 0.93
20 - val_loss: 0.1801 - val_acc: 0.9308 - val_precision: 0.9315 - va
l_recall: 0.9307 - val_f1: 0.9311
Epoch 93/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1730 - acc: 0.9324 - precision: 0.9327 - recall: 0.9320 - f1: 0.93
23 - val_loss: 0.1935 - val_acc: 0.9272 - val_precision: 0.9274 - va
l_recall: 0.9265 - val_f1: 0.9270
Epoch 94/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1726 - acc: 0.9328 - precision: 0.9332 - recall: 0.9320 - f1: 0.93
```

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26 - val_loss: 0.1832 - val_acc: 0.9291 - val_precision: 0.9299 - va
l_recall: 0.9291 - val_f1: 0.9295
Epoch 95/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1706 - acc: 0.9319 - precision: 0.9324 - recall: 0.9315 - f1: 0.93
19 - val_loss: 0.1794 - val_acc: 0.9321 - val_precision: 0.9329 - va
l_recall: 0.9318 - val_f1: 0.9323
Epoch 96/100
48248/48248 [==============================] - 4s 93us/step - loss:
0.1708 - acc: 0.9333 - precision: 0.9338 - recall: 0.9328 - f1: 0.93
33 - val_loss: 0.1774 - val_acc: 0.9325 - val_precision: 0.9337 - va
l_recall: 0.9315 - val_f1: 0.9326
Epoch 97/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1705 - acc: 0.9338 - precision: 0.9345 - recall: 0.9333 - f1: 0.93
39 - val_loss: 0.1774 - val_acc: 0.9338 - val_precision: 0.9346 - va
l_recall: 0.9335 - val_f1: 0.9341
Epoch 98/100
48248/48248 [==============================] - 4s 90us/step - loss:
0.1728 - acc: 0.9319 - precision: 0.9325 - recall: 0.9315 - f1: 0.93
20 - val_loss: 0.1763 - val_acc: 0.9320 - val_precision: 0.9323 - va
l_recall: 0.9314 - val_f1: 0.9318
Epoch 99/100
48248/48248 [==============================] - 4s 91us/step - loss:
0.1701 - acc: 0.9334 - precision: 0.9340 - recall: 0.9330 - f1: 0.93
35 - val_loss: 0.1835 - val_acc: 0.9297 - val_precision: 0.9298 - va
l_recall: 0.9293 - val_f1: 0.9296
Epoch 100/100
48248/48248 [==============================] - 4s 89us/step - loss:
0.1721 - acc: 0.9326 - precision: 0.9331 - recall: 0.9320 - f1: 0.93
25 - val_loss: 0.1760 - val_acc: 0.9338 - val_precision: 0.9348 - va
l_recall: 0.9335 - val_f1: 0.9342
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_4 (InputLayer)         (None, 12, 12, 1)         0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 9, 9, 20)          340
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 7, 7, 10)          1810
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 3, 3, 10)          0
_________________________________________________________________
flatten_4 (Flatten)          (None, 90)                0
_________________________________________________________________
dense_6 (Dense)              (None, 3)                 273
=================================================================
Total params: 2,423
Trainable params: 2,423
Non-trainable params: 0
_________________________________________________________________
Train on 21353 samples, validate on 3769 samples
Epoch 1/100
21353/21353 [==============================] - 4s 170us/step - loss:
0.6927 - acc: 0.7066 - precision: 0.7040 - recall: 0.4971 - f1: 0.56
15 - val_loss: 0.4165 - val_acc: 0.8708 - val_precision: 0.8820 - va
l_recall: 0.8421 - val_f1: 0.8613
Epoch 2/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.3467 - acc: 0.8857 - precision: 0.8918 - recall: 0.8783 - f1: 0.88
```

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48 - val_loss: 0.2958 - val_acc: 0.9021 - val_precision: 0.9042 - va
l_recall: 0.9013 - val_f1: 0.9027
Epoch 3/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.2748 - acc: 0.9078 - precision: 0.9092 - recall: 0.9066 - f1: 0.90
79 - val_loss: 0.2452 - val_acc: 0.9233 - val_precision: 0.9243 - va
l_recall: 0.9225 - val_f1: 0.9234
Epoch 4/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.2390 - acc: 0.9168 - precision: 0.9176 - recall: 0.9163 - f1: 0.91
69 - val_loss: 0.2365 - val_acc: 0.9172 - val_precision: 0.9188 - va
l_recall: 0.9162 - val_f1: 0.9175
Epoch 5/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.2272 - acc: 0.9209 - precision: 0.9216 - recall: 0.9204 - f1: 0.92
10 - val_loss: 0.2136 - val_acc: 0.9313 - val_precision: 0.9317 - va
l_recall: 0.9308 - val_f1: 0.9312
Epoch 6/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.2006 - acc: 0.9311 - precision: 0.9315 - recall: 0.9308 - f1: 0.93
11 - val_loss: 0.1881 - val_acc: 0.9334 - val_precision: 0.9341 - va
l_recall: 0.9331 - val_f1: 0.9336
Epoch 7/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1919 - acc: 0.9318 - precision: 0.9324 - recall: 0.9313 - f1: 0.93
18 - val_loss: 0.1863 - val_acc: 0.9334 - val_precision: 0.9342 - va
l_recall: 0.9334 - val_f1: 0.9338
Epoch 8/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1816 - acc: 0.9356 - precision: 0.9363 - recall: 0.9352 - f1: 0.93
57 - val_loss: 0.1792 - val_acc: 0.9347 - val_precision: 0.9347 - va
l_recall: 0.9345 - val_f1: 0.9346
Epoch 9/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1723 - acc: 0.9394 - precision: 0.9398 - recall: 0.9393 - f1: 0.93
95 - val_loss: 0.1819 - val_acc: 0.9350 - val_precision: 0.9352 - va
l_recall: 0.9347 - val_f1: 0.9350
Epoch 10/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1667 - acc: 0.9405 - precision: 0.9410 - recall: 0.9404 - f1: 0.94
07 - val_loss: 0.1786 - val_acc: 0.9315 - val_precision: 0.9318 - va
l_recall: 0.9313 - val_f1: 0.9315
Epoch 11/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1570 - acc: 0.9438 - precision: 0.9441 - recall: 0.9436 - f1: 0.94
38 - val_loss: 0.1598 - val_acc: 0.9408 - val_precision: 0.9414 - va
l_recall: 0.9408 - val_f1: 0.9411
Epoch 12/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1544 - acc: 0.9446 - precision: 0.9451 - recall: 0.9446 - f1: 0.94
48 - val_loss: 0.1581 - val_acc: 0.9416 - val_precision: 0.9416 - va
l_recall: 0.9414 - val_f1: 0.9415
Epoch 13/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1549 - acc: 0.9438 - precision: 0.9441 - recall: 0.9435 - f1: 0.94
38 - val_loss: 0.1524 - val_acc: 0.9469 - val_precision: 0.9473 - va
l_recall: 0.9464 - val_f1: 0.9469
Epoch 14/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.1469 - acc: 0.9479 - precision: 0.9481 - recall: 0.9477 - f1: 0.94
79 - val_loss: 0.1443 - val_acc: 0.9483 - val_precision: 0.9485 - va
```

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l_recall: 0.9477 - val_f1: 0.9481
Epoch 15/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1446 - acc: 0.9480 - precision: 0.9483 - recall: 0.9478 - f1: 0.94
80 - val_loss: 0.1316 - val_acc: 0.9514 - val_precision: 0.9514 - va
l_recall: 0.9514 - val_f1: 0.9514
Epoch 16/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1425 - acc: 0.9468 - precision: 0.9469 - recall: 0.9467 - f1: 0.94
68 - val_loss: 0.1744 - val_acc: 0.9289 - val_precision: 0.9292 - va
l_recall: 0.9289 - val_f1: 0.9290
Epoch 17/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.1448 - acc: 0.9464 - precision: 0.9469 - recall: 0.9460 - f1: 0.94
65 - val_loss: 0.1439 - val_acc: 0.9456 - val_precision: 0.9456 - va
l_recall: 0.9456 - val_f1: 0.9456
Epoch 18/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.1361 - acc: 0.9494 - precision: 0.9495 - recall: 0.9493 - f1: 0.94
94 - val_loss: 0.1861 - val_acc: 0.9262 - val_precision: 0.9269 - va
l_recall: 0.9257 - val_f1: 0.9263
Epoch 19/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1305 - acc: 0.9519 - precision: 0.9521 - recall: 0.9517 - f1: 0.95
19 - val_loss: 0.1238 - val_acc: 0.9525 - val_precision: 0.9525 - va
l_recall: 0.9525 - val_f1: 0.9525
Epoch 20/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.1320 - acc: 0.9518 - precision: 0.9522 - recall: 0.9517 - f1: 0.95
19 - val_loss: 0.1237 - val_acc: 0.9554 - val_precision: 0.9554 - va
l_recall: 0.9549 - val_f1: 0.9551
Epoch 21/100
21353/21353 [==============================] - 3s 160us/step - loss:
0.1307 - acc: 0.9509 - precision: 0.9512 - recall: 0.9504 - f1: 0.95
08 - val_loss: 0.1258 - val_acc: 0.9517 - val_precision: 0.9520 - va
l_recall: 0.9517 - val_f1: 0.9518
Epoch 22/100
21353/21353 [==============================] - 3s 160us/step - loss:
0.1313 - acc: 0.9505 - precision: 0.9507 - recall: 0.9501 - f1: 0.95
04 - val_loss: 0.1613 - val_acc: 0.9361 - val_precision: 0.9363 - va
l_recall: 0.9361 - val_f1: 0.9362
Epoch 23/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1219 - acc: 0.9541 - precision: 0.9544 - recall: 0.9538 - f1: 0.95
41 - val_loss: 0.1231 - val_acc: 0.9533 - val_precision: 0.9533 - va
l_recall: 0.9533 - val_f1: 0.9533
Epoch 24/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1197 - acc: 0.9550 - precision: 0.9554 - recall: 0.9547 - f1: 0.95
50 - val_loss: 0.1253 - val_acc: 0.9530 - val_precision: 0.9533 - va
l_recall: 0.9530 - val_f1: 0.9532
Epoch 25/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1233 - acc: 0.9533 - precision: 0.9535 - recall: 0.9531 - f1: 0.95
33 - val_loss: 0.1340 - val_acc: 0.9469 - val_precision: 0.9474 - va
l_recall: 0.9469 - val_f1: 0.9472
Epoch 26/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1182 - acc: 0.9549 - precision: 0.9552 - recall: 0.9549 - f1: 0.95
50 - val_loss: 0.1169 - val_acc: 0.9530 - val_precision: 0.9530 - va
l_recall: 0.9530 - val_f1: 0.9530
```

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Epoch 27/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1149 - acc: 0.9571 - precision: 0.9573 - recall: 0.9569 - f1: 0.95
71 - val_loss: 0.1186 - val_acc: 0.9552 - val_precision: 0.9554 - va
l_recall: 0.9546 - val_f1: 0.9550
Epoch 28/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1152 - acc: 0.9581 - precision: 0.9583 - recall: 0.9579 - f1: 0.95
81 - val_loss: 0.1258 - val_acc: 0.9499 - val_precision: 0.9499 - va
l_recall: 0.9496 - val_f1: 0.9497
Epoch 29/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1151 - acc: 0.9574 - precision: 0.9578 - recall: 0.9573 - f1: 0.95
75 - val_loss: 0.1276 - val_acc: 0.9496 - val_precision: 0.9498 - va
l_recall: 0.9496 - val_f1: 0.9497
Epoch 30/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1151 - acc: 0.9566 - precision: 0.9568 - recall: 0.9564 - f1: 0.95
66 - val_loss: 0.1129 - val_acc: 0.9552 - val_precision: 0.9552 - va
l_recall: 0.9552 - val_f1: 0.9552
Epoch 31/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1126 - acc: 0.9577 - precision: 0.9580 - recall: 0.9577 - f1: 0.95
78 - val_loss: 0.1104 - val_acc: 0.9544 - val_precision: 0.9546 - va
l_recall: 0.9544 - val_f1: 0.9545
Epoch 32/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1135 - acc: 0.9572 - precision: 0.9573 - recall: 0.9569 - f1: 0.95
71 - val_loss: 0.1371 - val_acc: 0.9491 - val_precision: 0.9491 - va
l_recall: 0.9491 - val_f1: 0.9491
Epoch 33/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1103 - acc: 0.9574 - precision: 0.9576 - recall: 0.9572 - f1: 0.95
74 - val_loss: 0.1098 - val_acc: 0.9568 - val_precision: 0.9567 - va
l_recall: 0.9565 - val_f1: 0.9566
Epoch 34/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.1081 - acc: 0.9590 - precision: 0.9591 - recall: 0.9588 - f1: 0.95
90 - val_loss: 0.1232 - val_acc: 0.9520 - val_precision: 0.9520 - va
l_recall: 0.9520 - val_f1: 0.9520
Epoch 35/100
21353/21353 [==============================] - 3s 156us/step - loss:
0.1107 - acc: 0.9576 - precision: 0.9577 - recall: 0.9575 - f1: 0.95
76 - val_loss: 0.1163 - val_acc: 0.9562 - val_precision: 0.9562 - va
l_recall: 0.9562 - val_f1: 0.9562
Epoch 36/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.1088 - acc: 0.9582 - precision: 0.9584 - recall: 0.9581 - f1: 0.95
83 - val_loss: 0.1080 - val_acc: 0.9560 - val_precision: 0.9565 - va
l_recall: 0.9560 - val_f1: 0.9562
Epoch 37/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.1043 - acc: 0.9604 - precision: 0.9607 - recall: 0.9602 - f1: 0.96
05 - val_loss: 0.1333 - val_acc: 0.9491 - val_precision: 0.9505 - va
l_recall: 0.9483 - val_f1: 0.9494
Epoch 38/100
21353/21353 [==============================] - 4s 171us/step - loss:
0.1043 - acc: 0.9613 - precision: 0.9614 - recall: 0.9612 - f1: 0.96
13 - val_loss: 0.1050 - val_acc: 0.9575 - val_precision: 0.9578 - va
l_recall: 0.9575 - val_f1: 0.9577
Epoch 39/100
```

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21353/21353 [==============================] - 4s 175us/step - loss:
0.0990 - acc: 0.9616 - precision: 0.9618 - recall: 0.9614 - f1: 0.96
16 - val_loss: 0.1172 - val_acc: 0.9549 - val_precision: 0.9549 - va
l_recall: 0.9549 - val_f1: 0.9549
Epoch 40/100
21353/21353 [==============================] - 4s 168us/step - loss:
0.1025 - acc: 0.9609 - precision: 0.9614 - recall: 0.9608 - f1: 0.96
11 - val_loss: 0.1215 - val_acc: 0.9522 - val_precision: 0.9530 - va
l_recall: 0.9520 - val_f1: 0.9525
Epoch 41/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0971 - acc: 0.9624 - precision: 0.9627 - recall: 0.9622 - f1: 0.96
24 - val_loss: 0.1167 - val_acc: 0.9538 - val_precision: 0.9541 - va
l_recall: 0.9536 - val_f1: 0.9538
Epoch 42/100
21353/21353 [==============================] - 4s 165us/step - loss:
0.1004 - acc: 0.9616 - precision: 0.9619 - recall: 0.9614 - f1: 0.96
16 - val_loss: 0.1111 - val_acc: 0.9554 - val_precision: 0.9557 - va
l_recall: 0.9552 - val_f1: 0.9554
Epoch 43/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0982 - acc: 0.9616 - precision: 0.9618 - recall: 0.9615 - f1: 0.96
16 - val_loss: 0.1108 - val_acc: 0.9583 - val_precision: 0.9583 - va
l_recall: 0.9583 - val_f1: 0.9583
Epoch 44/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0931 - acc: 0.9643 - precision: 0.9646 - recall: 0.9642 - f1: 0.96
44 - val_loss: 0.1077 - val_acc: 0.9568 - val_precision: 0.9568 - va
l_recall: 0.9568 - val_f1: 0.9568
Epoch 45/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0976 - acc: 0.9629 - precision: 0.9631 - recall: 0.9626 - f1: 0.96
29 - val_loss: 0.1095 - val_acc: 0.9568 - val_precision: 0.9570 - va
l_recall: 0.9565 - val_f1: 0.9567
Epoch 46/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0948 - acc: 0.9643 - precision: 0.9646 - recall: 0.9640 - f1: 0.96
43 - val_loss: 0.1111 - val_acc: 0.9541 - val_precision: 0.9541 - va
l_recall: 0.9541 - val_f1: 0.9541
Epoch 47/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0929 - acc: 0.9649 - precision: 0.9653 - recall: 0.9647 - f1: 0.96
50 - val_loss: 0.1172 - val_acc: 0.9533 - val_precision: 0.9533 - va
l_recall: 0.9533 - val_f1: 0.9533
Epoch 48/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0927 - acc: 0.9635 - precision: 0.9640 - recall: 0.9633 - f1: 0.96
36 - val_loss: 0.1002 - val_acc: 0.9621 - val_precision: 0.9621 - va
l_recall: 0.9621 - val_f1: 0.9621
Epoch 49/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0869 - acc: 0.9669 - precision: 0.9671 - recall: 0.9664 - f1: 0.96
68 - val_loss: 0.1104 - val_acc: 0.9562 - val_precision: 0.9572 - va
l_recall: 0.9557 - val_f1: 0.9564
Epoch 50/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0890 - acc: 0.9658 - precision: 0.9661 - recall: 0.9655 - f1: 0.96
58 - val_loss: 0.1092 - val_acc: 0.9581 - val_precision: 0.9581 - va
l_recall: 0.9581 - val_f1: 0.9581
Epoch 51/100
21353/21353 [==============================] - 3s 163us/step - loss:
```

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0.0921 - acc: 0.9652 - precision: 0.9657 - recall: 0.9650 - f1: 0.96
53 - val_loss: 0.1094 - val_acc: 0.9568 - val_precision: 0.9567 - va
l_recall: 0.9565 - val_f1: 0.9566
Epoch 52/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0882 - acc: 0.9668 - precision: 0.9673 - recall: 0.9666 - f1: 0.96
69 - val_loss: 0.1093 - val_acc: 0.9589 - val_precision: 0.9591 - va
l_recall: 0.9586 - val_f1: 0.9589
Epoch 53/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0886 - acc: 0.9653 - precision: 0.9655 - recall: 0.9645 - f1: 0.96
50 - val_loss: 0.1058 - val_acc: 0.9583 - val_precision: 0.9583 - va
l_recall: 0.9581 - val_f1: 0.9582
Epoch 54/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0863 - acc: 0.9675 - precision: 0.9680 - recall: 0.9674 - f1: 0.96
77 - val_loss: 0.0987 - val_acc: 0.9591 - val_precision: 0.9606 - va
l_recall: 0.9589 - val_f1: 0.9597
Epoch 55/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.0833 - acc: 0.9678 - precision: 0.9679 - recall: 0.9676 - f1: 0.96
78 - val_loss: 0.1067 - val_acc: 0.9546 - val_precision: 0.9549 - va
l_recall: 0.9546 - val_f1: 0.9548
Epoch 56/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.0828 - acc: 0.9683 - precision: 0.9686 - recall: 0.9681 - f1: 0.96
84 - val_loss: 0.1049 - val_acc: 0.9594 - val_precision: 0.9597 - va
l_recall: 0.9594 - val_f1: 0.9595
Epoch 57/100
21353/21353 [==============================] - 3s 157us/step - loss:
0.0846 - acc: 0.9680 - precision: 0.9685 - recall: 0.9676 - f1: 0.96
80 - val_loss: 0.1035 - val_acc: 0.9562 - val_precision: 0.9572 - va
l_recall: 0.9552 - val_f1: 0.9562
Epoch 58/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.0837 - acc: 0.9682 - precision: 0.9687 - recall: 0.9679 - f1: 0.96
83 - val_loss: 0.1071 - val_acc: 0.9578 - val_precision: 0.9595 - va
l_recall: 0.9570 - val_f1: 0.9583
Epoch 59/100
21353/21353 [==============================] - 3s 158us/step - loss:
0.0840 - acc: 0.9679 - precision: 0.9686 - recall: 0.9675 - f1: 0.96
80 - val_loss: 0.0988 - val_acc: 0.9605 - val_precision: 0.9614 - va
l_recall: 0.9591 - val_f1: 0.9603
Epoch 60/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.0814 - acc: 0.9695 - precision: 0.9697 - recall: 0.9691 - f1: 0.96
94 - val_loss: 0.0984 - val_acc: 0.9639 - val_precision: 0.9639 - va
l_recall: 0.9639 - val_f1: 0.9639
Epoch 61/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.0781 - acc: 0.9702 - precision: 0.9704 - recall: 0.9698 - f1: 0.97
01 - val_loss: 0.1050 - val_acc: 0.9621 - val_precision: 0.9623 - va
l_recall: 0.9621 - val_f1: 0.9622
Epoch 62/100
21353/21353 [==============================] - 3s 159us/step - loss:
0.0813 - acc: 0.9690 - precision: 0.9692 - recall: 0.9684 - f1: 0.96
88 - val_loss: 0.0954 - val_acc: 0.9637 - val_precision: 0.9644 - va
l_recall: 0.9631 - val_f1: 0.9638
Epoch 63/100
21353/21353 [==============================] - 3s 164us/step - loss:
0.0790 - acc: 0.9698 - precision: 0.9703 - recall: 0.9695 - f1: 0.96
```

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99 - val_loss: 0.0984 - val_acc: 0.9642 - val_precision: 0.9644 - va
l_recall: 0.9639 - val_f1: 0.9642
Epoch 64/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0809 - acc: 0.9695 - precision: 0.9698 - recall: 0.9692 - f1: 0.96
95 - val_loss: 0.1017 - val_acc: 0.9610 - val_precision: 0.9612 - va
l_recall: 0.9602 - val_f1: 0.9607
Epoch 65/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0773 - acc: 0.9698 - precision: 0.9701 - recall: 0.9695 - f1: 0.96
98 - val_loss: 0.0886 - val_acc: 0.9658 - val_precision: 0.9662 - va
l_recall: 0.9652 - val_f1: 0.9657
Epoch 66/100
21353/21353 [==============================] - 4s 166us/step - loss:
0.0778 - acc: 0.9702 - precision: 0.9706 - recall: 0.9701 - f1: 0.97
04 - val_loss: 0.1085 - val_acc: 0.9549 - val_precision: 0.9549 - va
l_recall: 0.9546 - val_f1: 0.9548
Epoch 67/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0756 - acc: 0.9707 - precision: 0.9710 - recall: 0.9702 - f1: 0.97
06 - val_loss: 0.0932 - val_acc: 0.9655 - val_precision: 0.9655 - va
l_recall: 0.9650 - val_f1: 0.9652
Epoch 68/100
21353/21353 [==============================] - 4s 165us/step - loss:
0.0775 - acc: 0.9704 - precision: 0.9707 - recall: 0.9701 - f1: 0.97
04 - val_loss: 0.0963 - val_acc: 0.9605 - val_precision: 0.9607 - va
l_recall: 0.9605 - val_f1: 0.9606
Epoch 69/100
21353/21353 [==============================] - 4s 165us/step - loss:
0.0769 - acc: 0.9712 - precision: 0.9714 - recall: 0.9706 - f1: 0.97
10 - val_loss: 0.0932 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
Epoch 70/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0748 - acc: 0.9715 - precision: 0.9720 - recall: 0.9710 - f1: 0.97
15 - val_loss: 0.1035 - val_acc: 0.9597 - val_precision: 0.9597 - va
l_recall: 0.9597 - val_f1: 0.9597
Epoch 71/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0716 - acc: 0.9725 - precision: 0.9728 - recall: 0.9721 - f1: 0.97
25 - val_loss: 0.0954 - val_acc: 0.9660 - val_precision: 0.9660 - va
l_recall: 0.9660 - val_f1: 0.9660
Epoch 72/100
21353/21353 [==============================] - 4s 169us/step - loss:
0.0757 - acc: 0.9707 - precision: 0.9710 - recall: 0.9704 - f1: 0.97
07 - val_loss: 0.0927 - val_acc: 0.9647 - val_precision: 0.9647 - va
l_recall: 0.9644 - val_f1: 0.9646
Epoch 73/100
21353/21353 [==============================] - 4s 169us/step - loss:
0.0717 - acc: 0.9721 - precision: 0.9726 - recall: 0.9718 - f1: 0.97
22 - val_loss: 0.0972 - val_acc: 0.9650 - val_precision: 0.9650 - va
l_recall: 0.9650 - val_f1: 0.9650
Epoch 74/100
21353/21353 [==============================] - 3s 164us/step - loss:
0.0732 - acc: 0.9722 - precision: 0.9724 - recall: 0.9719 - f1: 0.97
21 - val_loss: 0.1061 - val_acc: 0.9610 - val_precision: 0.9613 - va
l_recall: 0.9610 - val_f1: 0.9611
Epoch 75/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0721 - acc: 0.9734 - precision: 0.9738 - recall: 0.9731 - f1: 0.97
34 - val_loss: 0.0940 - val_acc: 0.9631 - val_precision: 0.9631 - va
```

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l_recall: 0.9631 - val_f1: 0.9631
Epoch 76/100
21353/21353 [==============================] - 3s 164us/step - loss:
0.0718 - acc: 0.9716 - precision: 0.9718 - recall: 0.9711 - f1: 0.97
14 - val_loss: 0.0949 - val_acc: 0.9644 - val_precision: 0.9655 - va
l_recall: 0.9644 - val_f1: 0.9650
Epoch 77/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0718 - acc: 0.9721 - precision: 0.9725 - recall: 0.9717 - f1: 0.97
21 - val_loss: 0.0930 - val_acc: 0.9631 - val_precision: 0.9634 - va
l_recall: 0.9631 - val_f1: 0.9632
Epoch 78/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0698 - acc: 0.9743 - precision: 0.9746 - recall: 0.9741 - f1: 0.97
44 - val_loss: 0.0956 - val_acc: 0.9650 - val_precision: 0.9650 - va
l_recall: 0.9650 - val_f1: 0.9650
Epoch 79/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0684 - acc: 0.9738 - precision: 0.9740 - recall: 0.9736 - f1: 0.97
38 - val_loss: 0.1270 - val_acc: 0.9536 - val_precision: 0.9543 - va
l_recall: 0.9533 - val_f1: 0.9538
Epoch 80/100
21353/21353 [==============================] - 4s 165us/step - loss:
0.0679 - acc: 0.9742 - precision: 0.9745 - recall: 0.9741 - f1: 0.97
43 - val_loss: 0.1034 - val_acc: 0.9623 - val_precision: 0.9623 - va
l_recall: 0.9623 - val_f1: 0.9623
Epoch 81/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0690 - acc: 0.9744 - precision: 0.9747 - recall: 0.9741 - f1: 0.97
44 - val_loss: 0.0911 - val_acc: 0.9668 - val_precision: 0.9671 - va
l_recall: 0.9666 - val_f1: 0.9668
Epoch 82/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0703 - acc: 0.9727 - precision: 0.9729 - recall: 0.9726 - f1: 0.97
28 - val_loss: 0.0898 - val_acc: 0.9652 - val_precision: 0.9658 - va
l_recall: 0.9652 - val_f1: 0.9655
Epoch 83/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0698 - acc: 0.9730 - precision: 0.9732 - recall: 0.9727 - f1: 0.97
29 - val_loss: 0.1031 - val_acc: 0.9634 - val_precision: 0.9636 - va
l_recall: 0.9631 - val_f1: 0.9634
Epoch 84/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0670 - acc: 0.9733 - precision: 0.9736 - recall: 0.9729 - f1: 0.97
32 - val_loss: 0.0963 - val_acc: 0.9644 - val_precision: 0.9644 - va
l_recall: 0.9642 - val_f1: 0.9643
Epoch 85/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0659 - acc: 0.9753 - precision: 0.9755 - recall: 0.9752 - f1: 0.97
53 - val_loss: 0.1047 - val_acc: 0.9618 - val_precision: 0.9618 - va
l_recall: 0.9613 - val_f1: 0.9615
Epoch 86/100
21353/21353 [==============================] - 4s 164us/step - loss:
0.0667 - acc: 0.9743 - precision: 0.9746 - recall: 0.9741 - f1: 0.97
44 - val_loss: 0.0945 - val_acc: 0.9647 - val_precision: 0.9647 - va
l_recall: 0.9647 - val_f1: 0.9647
Epoch 87/100
21353/21353 [==============================] - 3s 160us/step - loss:
0.0648 - acc: 0.9756 - precision: 0.9762 - recall: 0.9753 - f1: 0.97
57 - val_loss: 0.0925 - val_acc: 0.9692 - val_precision: 0.9692 - va
l_recall: 0.9687 - val_f1: 0.9689
```

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Epoch 88/100
21353/21353 [==============================] - 3s 160us/step - loss:
0.0670 - acc: 0.9749 - precision: 0.9753 - recall: 0.9746 - f1: 0.97
50 - val_loss: 0.0883 - val_acc: 0.9666 - val_precision: 0.9668 - va
l_recall: 0.9666 - val_f1: 0.9667
Epoch 89/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0671 - acc: 0.9742 - precision: 0.9747 - recall: 0.9739 - f1: 0.97
43 - val_loss: 0.0880 - val_acc: 0.9674 - val_precision: 0.9674 - va
l_recall: 0.9674 - val_f1: 0.9674
Epoch 90/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0649 - acc: 0.9752 - precision: 0.9754 - recall: 0.9749 - f1: 0.97
51 - val_loss: 0.0976 - val_acc: 0.9642 - val_precision: 0.9642 - va
l_recall: 0.9642 - val_f1: 0.9642
Epoch 91/100
21353/21353 [==============================] - 3s 164us/step - loss:
0.0657 - acc: 0.9755 - precision: 0.9756 - recall: 0.9750 - f1: 0.97
53 - val_loss: 0.1262 - val_acc: 0.9552 - val_precision: 0.9552 - va
l_recall: 0.9552 - val_f1: 0.9552
Epoch 92/100
21353/21353 [==============================] - 4s 166us/step - loss:
0.0648 - acc: 0.9754 - precision: 0.9758 - recall: 0.9752 - f1: 0.97
55 - val_loss: 0.0950 - val_acc: 0.9644 - val_precision: 0.9665 - va
l_recall: 0.9637 - val_f1: 0.9651
Epoch 93/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0645 - acc: 0.9755 - precision: 0.9756 - recall: 0.9751 - f1: 0.97
54 - val_loss: 0.0940 - val_acc: 0.9660 - val_precision: 0.9663 - va
l_recall: 0.9658 - val_f1: 0.9660
Epoch 94/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0637 - acc: 0.9757 - precision: 0.9760 - recall: 0.9755 - f1: 0.97
57 - val_loss: 0.0943 - val_acc: 0.9658 - val_precision: 0.9660 - va
l_recall: 0.9658 - val_f1: 0.9659
Epoch 95/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0646 - acc: 0.9757 - precision: 0.9758 - recall: 0.9756 - f1: 0.97
57 - val_loss: 0.0936 - val_acc: 0.9663 - val_precision: 0.9666 - va
l_recall: 0.9660 - val_f1: 0.9663
Epoch 96/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0621 - acc: 0.9763 - precision: 0.9765 - recall: 0.9759 - f1: 0.97
62 - val_loss: 0.0867 - val_acc: 0.9682 - val_precision: 0.9682 - va
l_recall: 0.9682 - val_f1: 0.9682
Epoch 97/100
21353/21353 [==============================] - 3s 161us/step - loss:
0.0619 - acc: 0.9770 - precision: 0.9771 - recall: 0.9768 - f1: 0.97
70 - val_loss: 0.1463 - val_acc: 0.9493 - val_precision: 0.9493 - va
l_recall: 0.9493 - val_f1: 0.9493
Epoch 98/100
21353/21353 [==============================] - 3s 163us/step - loss:
0.0625 - acc: 0.9772 - precision: 0.9773 - recall: 0.9771 - f1: 0.97
72 - val_loss: 0.1183 - val_acc: 0.9589 - val_precision: 0.9589 - va
l_recall: 0.9589 - val_f1: 0.9589
Epoch 99/100
21353/21353 [==============================] - 3s 162us/step - loss:
0.0628 - acc: 0.9771 - precision: 0.9773 - recall: 0.9770 - f1: 0.97
71 - val_loss: 0.1027 - val_acc: 0.9605 - val_precision: 0.9607 - va
l_recall: 0.9602 - val_f1: 0.9604
Epoch 100/100
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21353/21353 [==============================] - 3s 163us/step - loss:
0.0606 - acc: 0.9769 - precision: 0.9769 - recall: 0.9767 - f1: 0.97
68 - val_loss: 0.0924 - val_acc: 0.9658 - val_precision: 0.9660 - va
l_recall: 0.9652 - val_f1: 0.9656
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_5 (InputLayer)         (None, 16, 16, 1)         0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 13, 13, 20)        340
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 11, 11, 10)        1810
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 5, 5, 10)          0
_________________________________________________________________
flatten_5 (Flatten)          (None, 250)               0
_________________________________________________________________
dense_7 (Dense)              (None, 3)                 753
=================================================================
Total params: 2,903
Trainable params: 2,903
Non-trainable params: 0
_________________________________________________________________
Train on 11885 samples, validate on 2098 samples
Epoch 1/100
11885/11885 [==============================] - 4s 302us/step - loss:
0.7134 - acc: 0.7042 - precision: 0.6829 - recall: 0.4698 - f1: 0.52
50 - val_loss: 0.3581 - val_acc: 0.9166 - val_precision: 0.9207 - va
l_recall: 0.9018 - val_f1: 0.9110
Epoch 2/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.2984 - acc: 0.9039 - precision: 0.9070 - recall: 0.8989 - f1: 0.90
29 - val_loss: 0.2346 - val_acc: 0.9271 - val_precision: 0.9283 - va
l_recall: 0.9261 - val_f1: 0.9272
Epoch 3/100
11885/11885 [==============================] - 3s 272us/step - loss:
0.2212 - acc: 0.9275 - precision: 0.9276 - recall: 0.9272 - f1: 0.92
74 - val_loss: 0.1845 - val_acc: 0.9399 - val_precision: 0.9399 - va
l_recall: 0.9395 - val_f1: 0.9397
Epoch 4/100
11885/11885 [==============================] - 3s 273us/step - loss:
0.1815 - acc: 0.9418 - precision: 0.9420 - recall: 0.9415 - f1: 0.94
18 - val_loss: 0.1542 - val_acc: 0.9480 - val_precision: 0.9485 - va
l_recall: 0.9480 - val_f1: 0.9483
Epoch 5/100
11885/11885 [==============================] - 3s 276us/step - loss:
0.1611 - acc: 0.9480 - precision: 0.9481 - recall: 0.9477 - f1: 0.94
79 - val_loss: 0.1334 - val_acc: 0.9542 - val_precision: 0.9547 - va
l_recall: 0.9538 - val_f1: 0.9542
Epoch 6/100
11885/11885 [==============================] - 3s 272us/step - loss:
0.1551 - acc: 0.9475 - precision: 0.9476 - recall: 0.9473 - f1: 0.94
74 - val_loss: 0.1295 - val_acc: 0.9585 - val_precision: 0.9585 - va
l_recall: 0.9581 - val_f1: 0.9583
Epoch 7/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.1412 - acc: 0.9527 - precision: 0.9528 - recall: 0.9525 - f1: 0.95
27 - val_loss: 0.1344 - val_acc: 0.9519 - val_precision: 0.9519 - va
l_recall: 0.9519 - val_f1: 0.9519
Epoch 8/100
```

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11885/11885 [==============================] - 3s 274us/step - loss:
0.1382 - acc: 0.9520 - precision: 0.9520 - recall: 0.9520 - f1: 0.95
20 - val_loss: 0.1273 - val_acc: 0.9523 - val_precision: 0.9523 - va
l_recall: 0.9523 - val_f1: 0.9523
Epoch 9/100
11885/11885 [==============================] - 3s 272us/step - loss:
0.1319 - acc: 0.9549 - precision: 0.9550 - recall: 0.9548 - f1: 0.95
49 - val_loss: 0.1481 - val_acc: 0.9471 - val_precision: 0.9471 - va
l_recall: 0.9471 - val_f1: 0.9471
Epoch 10/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.1250 - acc: 0.9568 - precision: 0.9572 - recall: 0.9568 - f1: 0.95
70 - val_loss: 0.0993 - val_acc: 0.9676 - val_precision: 0.9676 - va
l_recall: 0.9676 - val_f1: 0.9676
Epoch 11/100
11885/11885 [==============================] - 3s 275us/step - loss:
0.1265 - acc: 0.9570 - precision: 0.9570 - recall: 0.9568 - f1: 0.95
69 - val_loss: 0.1346 - val_acc: 0.9504 - val_precision: 0.9504 - va
l_recall: 0.9504 - val_f1: 0.9504
Epoch 12/100
11885/11885 [==============================] - 3s 275us/step - loss:
0.1231 - acc: 0.9573 - precision: 0.9573 - recall: 0.9572 - f1: 0.95
72 - val_loss: 0.1016 - val_acc: 0.9690 - val_precision: 0.9690 - va
l_recall: 0.9685 - val_f1: 0.9688
Epoch 13/100
11885/11885 [==============================] - 3s 282us/step - loss:
0.1108 - acc: 0.9596 - precision: 0.9596 - recall: 0.9595 - f1: 0.95
96 - val_loss: 0.1062 - val_acc: 0.9628 - val_precision: 0.9628 - va
l_recall: 0.9628 - val_f1: 0.9628
Epoch 14/100
11885/11885 [==============================] - 3s 284us/step - loss:
0.1125 - acc: 0.9602 - precision: 0.9603 - recall: 0.9601 - f1: 0.96
02 - val_loss: 0.1345 - val_acc: 0.9466 - val_precision: 0.9466 - va
l_recall: 0.9457 - val_f1: 0.9461
Epoch 15/100
11885/11885 [==============================] - 3s 273us/step - loss:
0.1161 - acc: 0.9593 - precision: 0.9593 - recall: 0.9591 - f1: 0.95
92 - val_loss: 0.0927 - val_acc: 0.9666 - val_precision: 0.9666 - va
l_recall: 0.9666 - val_f1: 0.9666
Epoch 16/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.1098 - acc: 0.9610 - precision: 0.9610 - recall: 0.9610 - f1: 0.96
10 - val_loss: 0.1072 - val_acc: 0.9628 - val_precision: 0.9628 - va
l_recall: 0.9628 - val_f1: 0.9628
Epoch 17/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.1037 - acc: 0.9626 - precision: 0.9626 - recall: 0.9626 - f1: 0.96
26 - val_loss: 0.0927 - val_acc: 0.9690 - val_precision: 0.9690 - va
l_recall: 0.9690 - val_f1: 0.9690
Epoch 18/100
11885/11885 [==============================] - 3s 271us/step - loss:
0.0994 - acc: 0.9662 - precision: 0.9662 - recall: 0.9661 - f1: 0.96
61 - val_loss: 0.0903 - val_acc: 0.9666 - val_precision: 0.9666 - va
l_recall: 0.9666 - val_f1: 0.9666
Epoch 19/100
11885/11885 [==============================] - 3s 271us/step - loss:
0.1112 - acc: 0.9604 - precision: 0.9605 - recall: 0.9603 - f1: 0.96
04 - val_loss: 0.0911 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9719 - val_f1: 0.9719
Epoch 20/100
11885/11885 [==============================] - 3s 269us/step - loss:
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0.0971 - acc: 0.9658 - precision: 0.9658 - recall: 0.9657 - f1: 0.96
58 - val_loss: 0.1046 - val_acc: 0.9657 - val_precision: 0.9657 - va
l_recall: 0.9657 - val_f1: 0.9657
Epoch 21/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0932 - acc: 0.9666 - precision: 0.9666 - recall: 0.9666 - f1: 0.96
66 - val_loss: 0.1246 - val_acc: 0.9552 - val_precision: 0.9552 - va
l_recall: 0.9552 - val_f1: 0.9552
Epoch 22/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0977 - acc: 0.9667 - precision: 0.9668 - recall: 0.9667 - f1: 0.96
67 - val_loss: 0.1061 - val_acc: 0.9566 - val_precision: 0.9566 - va
l_recall: 0.9566 - val_f1: 0.9566
Epoch 23/100
11885/11885 [==============================] - 3s 272us/step - loss:
0.0975 - acc: 0.9658 - precision: 0.9660 - recall: 0.9658 - f1: 0.96
59 - val_loss: 0.0821 - val_acc: 0.9709 - val_precision: 0.9709 - va
l_recall: 0.9709 - val_f1: 0.9709
Epoch 24/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0966 - acc: 0.9648 - precision: 0.9651 - recall: 0.9648 - f1: 0.96
49 - val_loss: 0.0745 - val_acc: 0.9728 - val_precision: 0.9728 - va
l_recall: 0.9728 - val_f1: 0.9728
Epoch 25/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0954 - acc: 0.9663 - precision: 0.9663 - recall: 0.9663 - f1: 0.96
63 - val_loss: 0.0848 - val_acc: 0.9709 - val_precision: 0.9709 - va
l_recall: 0.9709 - val_f1: 0.9709
Epoch 26/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0906 - acc: 0.9672 - precision: 0.9673 - recall: 0.9672 - f1: 0.96
72 - val_loss: 0.0778 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9719 - val_f1: 0.9719
Epoch 27/100
11885/11885 [==============================] - 3s 271us/step - loss:
0.0938 - acc: 0.9648 - precision: 0.9648 - recall: 0.9648 - f1: 0.96
48 - val_loss: 0.0860 - val_acc: 0.9700 - val_precision: 0.9704 - va
l_recall: 0.9690 - val_f1: 0.9697
Epoch 28/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0881 - acc: 0.9697 - precision: 0.9697 - recall: 0.9697 - f1: 0.96
97 - val_loss: 0.0850 - val_acc: 0.9728 - val_precision: 0.9733 - va
l_recall: 0.9724 - val_f1: 0.9728
Epoch 29/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0831 - acc: 0.9698 - precision: 0.9698 - recall: 0.9695 - f1: 0.96
97 - val_loss: 0.0904 - val_acc: 0.9643 - val_precision: 0.9643 - va
l_recall: 0.9643 - val_f1: 0.9643
Epoch 30/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0860 - acc: 0.9676 - precision: 0.9676 - recall: 0.9676 - f1: 0.96
76 - val_loss: 0.0892 - val_acc: 0.9614 - val_precision: 0.9614 - va
l_recall: 0.9614 - val_f1: 0.9614
Epoch 31/100
11885/11885 [==============================] - 3s 272us/step - loss:
0.0816 - acc: 0.9696 - precision: 0.9697 - recall: 0.9696 - f1: 0.96
97 - val_loss: 0.0846 - val_acc: 0.9700 - val_precision: 0.9714 - va
l_recall: 0.9700 - val_f1: 0.9707
Epoch 32/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.0868 - acc: 0.9681 - precision: 0.9683 - recall: 0.9681 - f1: 0.96
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82 - val_loss: 0.0865 - val_acc: 0.9681 - val_precision: 0.9681 - va
l_recall: 0.9681 - val_f1: 0.9681
Epoch 33/100
11885/11885 [==============================] - 3s 271us/step - loss:
0.0860 - acc: 0.9679 - precision: 0.9681 - recall: 0.9679 - f1: 0.96
80 - val_loss: 0.0930 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
Epoch 34/100
11885/11885 [==============================] - 3s 282us/step - loss:
0.0847 - acc: 0.9693 - precision: 0.9693 - recall: 0.9693 - f1: 0.96
93 - val_loss: 0.0753 - val_acc: 0.9714 - val_precision: 0.9714 - va
l_recall: 0.9709 - val_f1: 0.9712
Epoch 35/100
11885/11885 [==============================] - 3s 275us/step - loss:
0.0762 - acc: 0.9713 - precision: 0.9713 - recall: 0.9713 - f1: 0.97
13 - val_loss: 0.0969 - val_acc: 0.9671 - val_precision: 0.9681 - va
l_recall: 0.9671 - val_f1: 0.9676
Epoch 36/100
11885/11885 [==============================] - 3s 279us/step - loss:
0.0811 - acc: 0.9700 - precision: 0.9700 - recall: 0.9700 - f1: 0.97
00 - val_loss: 0.0730 - val_acc: 0.9704 - val_precision: 0.9704 - va
l_recall: 0.9704 - val_f1: 0.9704
Epoch 37/100
11885/11885 [==============================] - 3s 277us/step - loss:
0.0812 - acc: 0.9709 - precision: 0.9709 - recall: 0.9709 - f1: 0.97
09 - val_loss: 0.0834 - val_acc: 0.9695 - val_precision: 0.9695 - va
l_recall: 0.9695 - val_f1: 0.9695
Epoch 38/100
11885/11885 [==============================] - 3s 286us/step - loss:
0.0793 - acc: 0.9706 - precision: 0.9706 - recall: 0.9706 - f1: 0.97
06 - val_loss: 0.1081 - val_acc: 0.9609 - val_precision: 0.9609 - va
l_recall: 0.9604 - val_f1: 0.9607
Epoch 39/100
11885/11885 [==============================] - 3s 279us/step - loss:
0.0790 - acc: 0.9711 - precision: 0.9711 - recall: 0.9711 - f1: 0.97
11 - val_loss: 0.0765 - val_acc: 0.9724 - val_precision: 0.9724 - va
l_recall: 0.9724 - val_f1: 0.9724
Epoch 40/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.0759 - acc: 0.9720 - precision: 0.9720 - recall: 0.9720 - f1: 0.97
20 - val_loss: 0.0693 - val_acc: 0.9762 - val_precision: 0.9762 - va
l_recall: 0.9757 - val_f1: 0.9759
Epoch 41/100
11885/11885 [==============================] - 3s 280us/step - loss:
0.0720 - acc: 0.9734 - precision: 0.9734 - recall: 0.9734 - f1: 0.97
34 - val_loss: 0.0652 - val_acc: 0.9781 - val_precision: 0.9781 - va
l_recall: 0.9776 - val_f1: 0.9778
Epoch 42/100
11885/11885 [==============================] - 3s 276us/step - loss:
0.0732 - acc: 0.9729 - precision: 0.9732 - recall: 0.9729 - f1: 0.97
30 - val_loss: 0.1088 - val_acc: 0.9571 - val_precision: 0.9571 - va
l_recall: 0.9571 - val_f1: 0.9571
Epoch 43/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.0742 - acc: 0.9720 - precision: 0.9721 - recall: 0.9720 - f1: 0.97
20 - val_loss: 0.0704 - val_acc: 0.9733 - val_precision: 0.9733 - va
l_recall: 0.9733 - val_f1: 0.9733
Epoch 44/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.0784 - acc: 0.9715 - precision: 0.9715 - recall: 0.9715 - f1: 0.97
15 - val_loss: 0.1100 - val_acc: 0.9581 - val_precision: 0.9580 - va
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l_recall: 0.9571 - val_f1: 0.9575
Epoch 45/100
11885/11885 [==============================] - 3s 277us/step - loss:
0.0753 - acc: 0.9725 - precision: 0.9726 - recall: 0.9725 - f1: 0.97
25 - val_loss: 0.1004 - val_acc: 0.9590 - val_precision: 0.9590 - va
l_recall: 0.9585 - val_f1: 0.9588
Epoch 46/100
11885/11885 [==============================] - 3s 274us/step - loss:
0.0736 - acc: 0.9730 - precision: 0.9731 - recall: 0.9730 - f1: 0.97
30 - val_loss: 0.0652 - val_acc: 0.9757 - val_precision: 0.9762 - va
l_recall: 0.9757 - val_f1: 0.9759
Epoch 47/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0687 - acc: 0.9752 - precision: 0.9752 - recall: 0.9752 - f1: 0.97
52 - val_loss: 0.0625 - val_acc: 0.9762 - val_precision: 0.9762 - va
l_recall: 0.9762 - val_f1: 0.9762
Epoch 48/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0692 - acc: 0.9756 - precision: 0.9756 - recall: 0.9755 - f1: 0.97
56 - val_loss: 0.0856 - val_acc: 0.9671 - val_precision: 0.9671 - va
l_recall: 0.9671 - val_f1: 0.9671
Epoch 49/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0693 - acc: 0.9748 - precision: 0.9749 - recall: 0.9748 - f1: 0.97
49 - val_loss: 0.0714 - val_acc: 0.9728 - val_precision: 0.9728 - va
l_recall: 0.9728 - val_f1: 0.9728
Epoch 50/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0675 - acc: 0.9756 - precision: 0.9756 - recall: 0.9755 - f1: 0.97
56 - val_loss: 0.0833 - val_acc: 0.9681 - val_precision: 0.9681 - va
l_recall: 0.9681 - val_f1: 0.9681
Epoch 51/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0711 - acc: 0.9748 - precision: 0.9748 - recall: 0.9747 - f1: 0.97
48 - val_loss: 0.0673 - val_acc: 0.9757 - val_precision: 0.9757 - va
l_recall: 0.9757 - val_f1: 0.9757
Epoch 52/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0661 - acc: 0.9749 - precision: 0.9749 - recall: 0.9749 - f1: 0.97
49 - val_loss: 0.0742 - val_acc: 0.9724 - val_precision: 0.9728 - va
l_recall: 0.9724 - val_f1: 0.9726
Epoch 53/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0651 - acc: 0.9745 - precision: 0.9746 - recall: 0.9745 - f1: 0.97
45 - val_loss: 0.0696 - val_acc: 0.9728 - val_precision: 0.9738 - va
l_recall: 0.9728 - val_f1: 0.9733
Epoch 54/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0658 - acc: 0.9757 - precision: 0.9758 - recall: 0.9756 - f1: 0.97
57 - val_loss: 0.0912 - val_acc: 0.9643 - val_precision: 0.9643 - va
l_recall: 0.9643 - val_f1: 0.9643
Epoch 55/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0617 - acc: 0.9765 - precision: 0.9766 - recall: 0.9765 - f1: 0.97
66 - val_loss: 0.0846 - val_acc: 0.9652 - val_precision: 0.9652 - va
l_recall: 0.9652 - val_f1: 0.9652
Epoch 56/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0651 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.97
59 - val_loss: 0.0902 - val_acc: 0.9662 - val_precision: 0.9666 - va
l_recall: 0.9662 - val_f1: 0.9664
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Epoch 57/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0662 - acc: 0.9748 - precision: 0.9748 - recall: 0.9747 - f1: 0.97
47 - val_loss: 0.0679 - val_acc: 0.9752 - val_precision: 0.9752 - va
l_recall: 0.9747 - val_f1: 0.9750
Epoch 58/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0664 - acc: 0.9755 - precision: 0.9755 - recall: 0.9755 - f1: 0.97
55 - val_loss: 0.0687 - val_acc: 0.9743 - val_precision: 0.9743 - va
l_recall: 0.9743 - val_f1: 0.9743
Epoch 59/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0596 - acc: 0.9778 - precision: 0.9780 - recall: 0.9778 - f1: 0.97
79 - val_loss: 0.0645 - val_acc: 0.9738 - val_precision: 0.9738 - va
l_recall: 0.9738 - val_f1: 0.9738
Epoch 60/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0591 - acc: 0.9770 - precision: 0.9770 - recall: 0.9769 - f1: 0.97
69 - val_loss: 0.0593 - val_acc: 0.9776 - val_precision: 0.9776 - va
l_recall: 0.9776 - val_f1: 0.9776
Epoch 61/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0621 - acc: 0.9764 - precision: 0.9765 - recall: 0.9764 - f1: 0.97
64 - val_loss: 0.0610 - val_acc: 0.9766 - val_precision: 0.9766 - va
l_recall: 0.9766 - val_f1: 0.9766
Epoch 62/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0569 - acc: 0.9789 - precision: 0.9790 - recall: 0.9788 - f1: 0.97
89 - val_loss: 0.0702 - val_acc: 0.9738 - val_precision: 0.9738 - va
l_recall: 0.9728 - val_f1: 0.9733
Epoch 63/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0591 - acc: 0.9785 - precision: 0.9785 - recall: 0.9785 - f1: 0.97
85 - val_loss: 0.0791 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9719 - val_f1: 0.9719
Epoch 64/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0573 - acc: 0.9786 - precision: 0.9787 - recall: 0.9786 - f1: 0.97
87 - val_loss: 0.0616 - val_acc: 0.9762 - val_precision: 0.9762 - va
l_recall: 0.9762 - val_f1: 0.9762
Epoch 65/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0551 - acc: 0.9790 - precision: 0.9791 - recall: 0.9787 - f1: 0.97
89 - val_loss: 0.0647 - val_acc: 0.9733 - val_precision: 0.9737 - va
l_recall: 0.9724 - val_f1: 0.9730
Epoch 66/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0599 - acc: 0.9785 - precision: 0.9785 - recall: 0.9785 - f1: 0.97
85 - val_loss: 0.0730 - val_acc: 0.9714 - val_precision: 0.9714 - va
l_recall: 0.9714 - val_f1: 0.9714
Epoch 67/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0593 - acc: 0.9777 - precision: 0.9778 - recall: 0.9776 - f1: 0.97
77 - val_loss: 0.0761 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9719 - val_f1: 0.9719
Epoch 68/100
11885/11885 [==============================] - 3s 271us/step - loss:
0.0570 - acc: 0.9780 - precision: 0.9781 - recall: 0.9780 - f1: 0.97
81 - val_loss: 0.0755 - val_acc: 0.9743 - val_precision: 0.9742 - va
l_recall: 0.9738 - val_f1: 0.9740
Epoch 69/100
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11885/11885 [==============================] - 3s 271us/step - loss:
0.0582 - acc: 0.9773 - precision: 0.9774 - recall: 0.9772 - f1: 0.97
73 - val_loss: 0.0745 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9714 - val_f1: 0.9716
Epoch 70/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0567 - acc: 0.9777 - precision: 0.9781 - recall: 0.9774 - f1: 0.97
77 - val_loss: 0.0607 - val_acc: 0.9752 - val_precision: 0.9752 - va
l_recall: 0.9752 - val_f1: 0.9752
Epoch 71/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0536 - acc: 0.9796 - precision: 0.9797 - recall: 0.9794 - f1: 0.97
96 - val_loss: 0.0691 - val_acc: 0.9738 - val_precision: 0.9738 - va
l_recall: 0.9738 - val_f1: 0.9738
Epoch 72/100
11885/11885 [==============================] - 3s 270us/step - loss:
0.0513 - acc: 0.9791 - precision: 0.9792 - recall: 0.9790 - f1: 0.97
91 - val_loss: 0.0683 - val_acc: 0.9747 - val_precision: 0.9747 - va
l_recall: 0.9747 - val_f1: 0.9747
Epoch 73/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0533 - acc: 0.9796 - precision: 0.9796 - recall: 0.9796 - f1: 0.97
96 - val_loss: 0.0683 - val_acc: 0.9743 - val_precision: 0.9743 - va
l_recall: 0.9743 - val_f1: 0.9743
Epoch 74/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0531 - acc: 0.9797 - precision: 0.9798 - recall: 0.9797 - f1: 0.97
98 - val_loss: 0.0656 - val_acc: 0.9752 - val_precision: 0.9752 - va
l_recall: 0.9752 - val_f1: 0.9752
Epoch 75/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0544 - acc: 0.9785 - precision: 0.9786 - recall: 0.9782 - f1: 0.97
84 - val_loss: 0.0603 - val_acc: 0.9752 - val_precision: 0.9757 - va
l_recall: 0.9752 - val_f1: 0.9754
Epoch 76/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0515 - acc: 0.9804 - precision: 0.9804 - recall: 0.9803 - f1: 0.98
04 - val_loss: 0.1287 - val_acc: 0.9552 - val_precision: 0.9551 - va
l_recall: 0.9547 - val_f1: 0.9549
Epoch 77/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0524 - acc: 0.9800 - precision: 0.9801 - recall: 0.9800 - f1: 0.98
01 - val_loss: 0.0835 - val_acc: 0.9709 - val_precision: 0.9709 - va
l_recall: 0.9709 - val_f1: 0.9709
Epoch 78/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0470 - acc: 0.9821 - precision: 0.9821 - recall: 0.9819 - f1: 0.98
20 - val_loss: 0.0640 - val_acc: 0.9738 - val_precision: 0.9742 - va
l_recall: 0.9733 - val_f1: 0.9738
Epoch 79/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0522 - acc: 0.9794 - precision: 0.9796 - recall: 0.9794 - f1: 0.97
95 - val_loss: 0.0625 - val_acc: 0.9752 - val_precision: 0.9756 - va
l_recall: 0.9747 - val_f1: 0.9752
Epoch 80/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0496 - acc: 0.9806 - precision: 0.9809 - recall: 0.9806 - f1: 0.98
08 - val_loss: 0.0885 - val_acc: 0.9647 - val_precision: 0.9647 - va
l_recall: 0.9643 - val_f1: 0.9645
Epoch 81/100
11885/11885 [==============================] - 3s 268us/step - loss:
```

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0.0519 - acc: 0.9796 - precision: 0.9797 - recall: 0.9796 - f1: 0.97
97 - val_loss: 0.0709 - val_acc: 0.9733 - val_precision: 0.9738 - va
l_recall: 0.9728 - val_f1: 0.9733
Epoch 82/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0477 - acc: 0.9825 - precision: 0.9826 - recall: 0.9825 - f1: 0.98
25 - val_loss: 0.0684 - val_acc: 0.9771 - val_precision: 0.9776 - va
l_recall: 0.9771 - val_f1: 0.9774
Epoch 83/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0490 - acc: 0.9813 - precision: 0.9813 - recall: 0.9813 - f1: 0.98
13 - val_loss: 0.0714 - val_acc: 0.9747 - val_precision: 0.9747 - va
l_recall: 0.9747 - val_f1: 0.9747
Epoch 84/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0443 - acc: 0.9828 - precision: 0.9829 - recall: 0.9828 - f1: 0.98
29 - val_loss: 0.0621 - val_acc: 0.9762 - val_precision: 0.9762 - va
l_recall: 0.9762 - val_f1: 0.9762
Epoch 85/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0461 - acc: 0.9823 - precision: 0.9826 - recall: 0.9822 - f1: 0.98
24 - val_loss: 0.0632 - val_acc: 0.9766 - val_precision: 0.9771 - va
l_recall: 0.9766 - val_f1: 0.9769
Epoch 86/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0469 - acc: 0.9819 - precision: 0.9820 - recall: 0.9817 - f1: 0.98
19 - val_loss: 0.0640 - val_acc: 0.9738 - val_precision: 0.9747 - va
l_recall: 0.9738 - val_f1: 0.9742
Epoch 87/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0469 - acc: 0.9810 - precision: 0.9811 - recall: 0.9809 - f1: 0.98
10 - val_loss: 0.0782 - val_acc: 0.9747 - val_precision: 0.9776 - va
l_recall: 0.9738 - val_f1: 0.9756
Epoch 88/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0449 - acc: 0.9824 - precision: 0.9829 - recall: 0.9821 - f1: 0.98
25 - val_loss: 0.0660 - val_acc: 0.9757 - val_precision: 0.9766 - va
l_recall: 0.9743 - val_f1: 0.9754
Epoch 89/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0447 - acc: 0.9829 - precision: 0.9832 - recall: 0.9827 - f1: 0.98
29 - val_loss: 0.0753 - val_acc: 0.9733 - val_precision: 0.9733 - va
l_recall: 0.9733 - val_f1: 0.9733
Epoch 90/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0431 - acc: 0.9838 - precision: 0.9842 - recall: 0.9835 - f1: 0.98
38 - val_loss: 0.0611 - val_acc: 0.9771 - val_precision: 0.9776 - va
l_recall: 0.9771 - val_f1: 0.9773
Epoch 91/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0430 - acc: 0.9834 - precision: 0.9836 - recall: 0.9832 - f1: 0.98
34 - val_loss: 0.0580 - val_acc: 0.9805 - val_precision: 0.9828 - va
l_recall: 0.9795 - val_f1: 0.9811
Epoch 92/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0409 - acc: 0.9840 - precision: 0.9843 - recall: 0.9838 - f1: 0.98
40 - val_loss: 0.0690 - val_acc: 0.9752 - val_precision: 0.9757 - va
l_recall: 0.9747 - val_f1: 0.9752
Epoch 93/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0452 - acc: 0.9813 - precision: 0.9818 - recall: 0.9811 - f1: 0.98
```

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14 - val_loss: 0.0849 - val_acc: 0.9719 - val_precision: 0.9719 - va
l_recall: 0.9719 - val_f1: 0.9719
Epoch 94/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0406 - acc: 0.9845 - precision: 0.9846 - recall: 0.9840 - f1: 0.98
43 - val_loss: 0.0732 - val_acc: 0.9714 - val_precision: 0.9714 - va
l_recall: 0.9709 - val_f1: 0.9712
Epoch 95/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0448 - acc: 0.9822 - precision: 0.9825 - recall: 0.9821 - f1: 0.98
23 - val_loss: 0.0680 - val_acc: 0.9747 - val_precision: 0.9747 - va
l_recall: 0.9747 - val_f1: 0.9747
Epoch 96/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0419 - acc: 0.9841 - precision: 0.9845 - recall: 0.9837 - f1: 0.98
41 - val_loss: 0.0771 - val_acc: 0.9700 - val_precision: 0.9700 - va
l_recall: 0.9700 - val_f1: 0.9700
Epoch 97/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0406 - acc: 0.9839 - precision: 0.9843 - recall: 0.9838 - f1: 0.98
40 - val_loss: 0.0647 - val_acc: 0.9757 - val_precision: 0.9766 - va
l_recall: 0.9747 - val_f1: 0.9757
Epoch 98/100
11885/11885 [==============================] - 3s 268us/step - loss:
0.0387 - acc: 0.9853 - precision: 0.9854 - recall: 0.9851 - f1: 0.98
53 - val_loss: 0.0726 - val_acc: 0.9709 - val_precision: 0.9709 - va
l_recall: 0.9709 - val_f1: 0.9709
Epoch 99/100
11885/11885 [==============================] - 3s 267us/step - loss:
0.0397 - acc: 0.9853 - precision: 0.9855 - recall: 0.9851 - f1: 0.98
53 - val_loss: 0.0654 - val_acc: 0.9766 - val_precision: 0.9766 - va
l_recall: 0.9762 - val_f1: 0.9764
Epoch 100/100
11885/11885 [==============================] - 3s 269us/step - loss:
0.0418 - acc: 0.9838 - precision: 0.9841 - recall: 0.9838 - f1: 0.98
39 - val_loss: 0.0603 - val_acc: 0.9762 - val_precision: 0.9762 - va
l_recall: 0.9762 - val_f1: 0.9762
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_6 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 11, 11, 10)        0
_________________________________________________________________
flatten_6 (Flatten)          (None, 1210)              0
_________________________________________________________________
dense_8 (Dense)              (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/100
3901/3901 [==============================] - 3s 855us/step - loss:
 0.8098 - acc: 0.6298 - precision: 0.6395 - recall: 0.3432 - f1: 0.4
```

```
173 - val_loss: 0.4366 - val_acc: 0.8737 - val_precision: 0.9076 - v
al_recall: 0.8316 - val_f1: 0.8674
Epoch 2/100
3901/3901 [==============================] - 3s 731us/step - loss:
 0.3494 - acc: 0.9003 - precision: 0.9138 - recall: 0.8746 - f1: 0.8
930 - val_loss: 0.2153 - val_acc: 0.9594 - val_precision: 0.9594 - v
al_recall: 0.9594 - val_f1: 0.9594
Epoch 3/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.2215 - acc: 0.9421 - precision: 0.9436 - recall: 0.9408 - f1: 0.9
422 - val_loss: 0.1413 - val_acc: 0.9637 - val_precision: 0.9665 - v
al_recall: 0.9623 - val_f1: 0.9644
Epoch 4/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.2040 - acc: 0.9395 - precision: 0.9410 - recall: 0.9377 - f1: 0.9
393 - val_loss: 0.1763 - val_acc: 0.9376 - val_precision: 0.9376 - v
al_recall: 0.9376 - val_f1: 0.9376
Epoch 5/100
3901/3901 [==============================] - 3s 723us/step - loss:
 0.1402 - acc: 0.9598 - precision: 0.9598 - recall: 0.9595 - f1: 0.9
596 - val_loss: 0.1056 - val_acc: 0.9710 - val_precision: 0.9710 - v
al_recall: 0.9710 - val_f1: 0.9710
Epoch 6/100
3901/3901 [==============================] - 3s 727us/step - loss:
 0.1243 - acc: 0.9646 - precision: 0.9646 - recall: 0.9646 - f1: 0.9
646 - val_loss: 0.1006 - val_acc: 0.9739 - val_precision: 0.9739 - v
al_recall: 0.9724 - val_f1: 0.9731
Epoch 7/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.1116 - acc: 0.9669 - precision: 0.9669 - recall: 0.9664 - f1: 0.9
667 - val_loss: 0.0892 - val_acc: 0.9768 - val_precision: 0.9768 - v
al_recall: 0.9768 - val_f1: 0.9768
Epoch 8/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.1212 - acc: 0.9641 - precision: 0.9641 - recall: 0.9641 - f1: 0.9
641 - val_loss: 0.0803 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 9/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.1163 - acc: 0.9633 - precision: 0.9633 - recall: 0.9633 - f1: 0.9
633 - val_loss: 0.1051 - val_acc: 0.9637 - val_precision: 0.9637 - v
al_recall: 0.9637 - val_f1: 0.9637
Epoch 10/100
3901/3901 [==============================] - 3s 730us/step - loss:
 0.0965 - acc: 0.9705 - precision: 0.9705 - recall: 0.9705 - f1: 0.9
705 - val_loss: 0.0738 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 11/100
3901/3901 [==============================] - 3s 741us/step - loss:
 0.1021 - acc: 0.9656 - precision: 0.9656 - recall: 0.9656 - f1: 0.9
656 - val_loss: 0.0734 - val_acc: 0.9753 - val_precision: 0.9753 - v
al_recall: 0.9753 - val_f1: 0.9753
Epoch 12/100
3901/3901 [==============================] - 3s 730us/step - loss:
 0.0815 - acc: 0.9754 - precision: 0.9754 - recall: 0.9754 - f1: 0.9
754 - val_loss: 0.0769 - val_acc: 0.9739 - val_precision: 0.9739 - v
al_recall: 0.9739 - val_f1: 0.9739
Epoch 13/100
3901/3901 [==============================] - 3s 742us/step - loss:
 0.0822 - acc: 0.9710 - precision: 0.9710 - recall: 0.9710 - f1: 0.9
710 - val_loss: 0.0698 - val_acc: 0.9768 - val_precision: 0.9768 - v
```

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al_recall: 0.9768 - val_f1: 0.9768
Epoch 14/100
3901/3901 [==============================] - 3s 754us/step - loss:
 0.0753 - acc: 0.9733 - precision: 0.9733 - recall: 0.9733 - f1: 0.9
733 - val_loss: 0.0637 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 15/100
3901/3901 [==============================] - 3s 744us/step - loss:
 0.0842 - acc: 0.9726 - precision: 0.9726 - recall: 0.9726 - f1: 0.9
726 - val_loss: 0.0586 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 16/100
3901/3901 [==============================] - 3s 747us/step - loss:
 0.0825 - acc: 0.9698 - precision: 0.9698 - recall: 0.9698 - f1: 0.9
698 - val_loss: 0.1322 - val_acc: 0.9521 - val_precision: 0.9521 - v
al_recall: 0.9521 - val_f1: 0.9521
Epoch 17/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.0737 - acc: 0.9754 - precision: 0.9754 - recall: 0.9754 - f1: 0.9
754 - val_loss: 0.0611 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 18/100
3901/3901 [==============================] - 3s 737us/step - loss:
 0.0735 - acc: 0.9759 - precision: 0.9759 - recall: 0.9759 - f1: 0.9
759 - val_loss: 0.0711 - val_acc: 0.9739 - val_precision: 0.9739 - v
al_recall: 0.9739 - val_f1: 0.9739
Epoch 19/100
3901/3901 [==============================] - 3s 747us/step - loss:
 0.0652 - acc: 0.9772 - precision: 0.9772 - recall: 0.9772 - f1: 0.9
772 - val_loss: 0.0475 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 20/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.0657 - acc: 0.9774 - precision: 0.9774 - recall: 0.9774 - f1: 0.9
774 - val_loss: 0.0502 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 21/100
3901/3901 [==============================] - 3s 739us/step - loss:
 0.0733 - acc: 0.9741 - precision: 0.9741 - recall: 0.9741 - f1: 0.9
741 - val_loss: 0.0794 - val_acc: 0.9710 - val_precision: 0.9710 - v
al_recall: 0.9710 - val_f1: 0.9710
Epoch 22/100
3901/3901 [==============================] - 3s 754us/step - loss:
 0.0629 - acc: 0.9795 - precision: 0.9795 - recall: 0.9795 - f1: 0.9
795 - val_loss: 0.1003 - val_acc: 0.9652 - val_precision: 0.9652 - v
al_recall: 0.9652 - val_f1: 0.9652
Epoch 23/100
3901/3901 [==============================] - 3s 752us/step - loss:
 0.0565 - acc: 0.9808 - precision: 0.9808 - recall: 0.9808 - f1: 0.9
808 - val_loss: 0.0469 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 24/100
3901/3901 [==============================] - 3s 758us/step - loss:
 0.0739 - acc: 0.9741 - precision: 0.9741 - recall: 0.9741 - f1: 0.9
741 - val_loss: 0.0571 - val_acc: 0.9797 - val_precision: 0.9797 - v
al_recall: 0.9797 - val_f1: 0.9797
Epoch 25/100
3901/3901 [==============================] - 3s 758us/step - loss:
 0.0597 - acc: 0.9795 - precision: 0.9795 - recall: 0.9795 - f1: 0.9
795 - val_loss: 0.0523 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
```

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Epoch 26/100
3901/3901 [==============================] - 3s 749us/step - loss:
 0.0567 - acc: 0.9815 - precision: 0.9815 - recall: 0.9815 - f1: 0.9
815 - val_loss: 0.0623 - val_acc: 0.9739 - val_precision: 0.9739 - v
al_recall: 0.9739 - val_f1: 0.9739
Epoch 27/100
3901/3901 [==============================] - 3s 747us/step - loss:
 0.0485 - acc: 0.9836 - precision: 0.9836 - recall: 0.9836 - f1: 0.9
836 - val_loss: 0.0545 - val_acc: 0.9782 - val_precision: 0.9782 - v
al_recall: 0.9782 - val_f1: 0.9782
Epoch 28/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0475 - acc: 0.9841 - precision: 0.9841 - recall: 0.9841 - f1: 0.9
841 - val_loss: 0.0961 - val_acc: 0.9579 - val_precision: 0.9579 - v
al_recall: 0.9579 - val_f1: 0.9579
Epoch 29/100
3901/3901 [==============================] - 3s 737us/step - loss:
 0.0566 - acc: 0.9800 - precision: 0.9800 - recall: 0.9800 - f1: 0.9
800 - val_loss: 0.0617 - val_acc: 0.9782 - val_precision: 0.9782 - v
al_recall: 0.9782 - val_f1: 0.9782
Epoch 30/100
3901/3901 [==============================] - 3s 741us/step - loss:
 0.0467 - acc: 0.9828 - precision: 0.9828 - recall: 0.9828 - f1: 0.9
828 - val_loss: 0.0614 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 31/100
3901/3901 [==============================] - 3s 742us/step - loss:
 0.0562 - acc: 0.9818 - precision: 0.9818 - recall: 0.9818 - f1: 0.9
818 - val_loss: 0.0582 - val_acc: 0.9782 - val_precision: 0.9782 - v
al_recall: 0.9782 - val_f1: 0.9782
Epoch 32/100
3901/3901 [==============================] - 3s 748us/step - loss:
 0.0569 - acc: 0.9780 - precision: 0.9780 - recall: 0.9780 - f1: 0.9
780 - val_loss: 0.0522 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 33/100
3901/3901 [==============================] - 3s 748us/step - loss:
 0.0436 - acc: 0.9854 - precision: 0.9854 - recall: 0.9854 - f1: 0.9
854 - val_loss: 0.0564 - val_acc: 0.9753 - val_precision: 0.9753 - v
al_recall: 0.9753 - val_f1: 0.9753
Epoch 34/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0512 - acc: 0.9821 - precision: 0.9821 - recall: 0.9821 - f1: 0.9
821 - val_loss: 0.0617 - val_acc: 0.9797 - val_precision: 0.9797 - v
al_recall: 0.9797 - val_f1: 0.9797
Epoch 35/100
3901/3901 [==============================] - 3s 746us/step - loss:
 0.0443 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0393 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 36/100
3901/3901 [==============================] - 3s 746us/step - loss:
 0.0435 - acc: 0.9851 - precision: 0.9851 - recall: 0.9851 - f1: 0.9
851 - val_loss: 0.0362 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 37/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0373 - acc: 0.9869 - precision: 0.9869 - recall: 0.9869 - f1: 0.9
869 - val_loss: 0.0519 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 38/100
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3901/3901 [==============================] - 3s 741us/step - loss:
 0.0462 - acc: 0.9833 - precision: 0.9833 - recall: 0.9833 - f1: 0.9
833 - val_loss: 0.0522 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 39/100
3901/3901 [==============================] - 3s 741us/step - loss:
 0.0411 - acc: 0.9859 - precision: 0.9859 - recall: 0.9856 - f1: 0.9
858 - val_loss: 0.0450 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 40/100
3901/3901 [==============================] - 3s 737us/step - loss:
 0.0403 - acc: 0.9864 - precision: 0.9864 - recall: 0.9864 - f1: 0.9
864 - val_loss: 0.0574 - val_acc: 0.9739 - val_precision: 0.9739 - v
al_recall: 0.9739 - val_f1: 0.9739
Epoch 41/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.0430 - acc: 0.9854 - precision: 0.9854 - recall: 0.9854 - f1: 0.9
854 - val_loss: 0.0586 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 42/100
3901/3901 [==============================] - 3s 736us/step - loss:
 0.0460 - acc: 0.9854 - precision: 0.9854 - recall: 0.9854 - f1: 0.9
854 - val_loss: 0.0557 - val_acc: 0.9768 - val_precision: 0.9768 - v
al_recall: 0.9768 - val_f1: 0.9768
Epoch 43/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.0448 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0412 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 44/100
3901/3901 [==============================] - 3s 737us/step - loss:
 0.0368 - acc: 0.9882 - precision: 0.9882 - recall: 0.9882 - f1: 0.9
882 - val_loss: 0.0375 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 45/100
3901/3901 [==============================] - 3s 737us/step - loss:
 0.0341 - acc: 0.9877 - precision: 0.9877 - recall: 0.9877 - f1: 0.9
877 - val_loss: 0.0386 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 46/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.0325 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0358 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 47/100
3901/3901 [==============================] - 3s 735us/step - loss:
 0.0459 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0396 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 48/100
3901/3901 [==============================] - 3s 791us/step - loss:
 0.0334 - acc: 0.9859 - precision: 0.9859 - recall: 0.9859 - f1: 0.9
859 - val_loss: 0.0437 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 49/100
3901/3901 [==============================] - 3s 758us/step - loss:
 0.0328 - acc: 0.9880 - precision: 0.9880 - recall: 0.9880 - f1: 0.9
880 - val_loss: 0.0510 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 50/100
3901/3901 [==============================] - 3s 740us/step - loss:
```

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 0.0386 - acc: 0.9859 - precision: 0.9859 - recall: 0.9859 - f1: 0.9
859 - val_loss: 0.0444 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 51/100
3901/3901 [==============================] - 3s 742us/step - loss:
 0.0438 - acc: 0.9836 - precision: 0.9836 - recall: 0.9836 - f1: 0.9
836 - val_loss: 0.0319 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 52/100
3901/3901 [==============================] - 3s 738us/step - loss:
 0.0302 - acc: 0.9900 - precision: 0.9900 - recall: 0.9900 - f1: 0.9
900 - val_loss: 0.0401 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 53/100
3901/3901 [==============================] - 3s 733us/step - loss:
 0.0422 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0376 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 54/100
3901/3901 [==============================] - 3s 748us/step - loss:
 0.0333 - acc: 0.9890 - precision: 0.9890 - recall: 0.9890 - f1: 0.9
890 - val_loss: 0.0355 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 55/100
3901/3901 [==============================] - 3s 738us/step - loss:
 0.0262 - acc: 0.9908 - precision: 0.9908 - recall: 0.9908 - f1: 0.9
908 - val_loss: 0.0461 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 56/100
3901/3901 [==============================] - 3s 734us/step - loss:
 0.0337 - acc: 0.9869 - precision: 0.9869 - recall: 0.9869 - f1: 0.9
869 - val_loss: 0.0405 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 57/100
3901/3901 [==============================] - 3s 738us/step - loss:
 0.0433 - acc: 0.9862 - precision: 0.9862 - recall: 0.9862 - f1: 0.9
862 - val_loss: 0.0347 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 58/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0328 - acc: 0.9885 - precision: 0.9885 - recall: 0.9885 - f1: 0.9
885 - val_loss: 0.0385 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 59/100
3901/3901 [==============================] - 3s 740us/step - loss:
 0.0363 - acc: 0.9862 - precision: 0.9862 - recall: 0.9862 - f1: 0.9
862 - val_loss: 0.0334 - val_acc: 0.9898 - val_precision: 0.9898 - v
al_recall: 0.9898 - val_f1: 0.9898
Epoch 60/100
3901/3901 [==============================] - 3s 734us/step - loss:
 0.0254 - acc: 0.9915 - precision: 0.9915 - recall: 0.9915 - f1: 0.9
915 - val_loss: 0.0376 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 61/100
3901/3901 [==============================] - 3s 740us/step - loss:
 0.0273 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0381 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 62/100
3901/3901 [==============================] - 3s 761us/step - loss:
 0.0324 - acc: 0.9874 - precision: 0.9874 - recall: 0.9874 - f1: 0.9
```

```
874 - val_loss: 0.0526 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 63/100
3901/3901 [==============================] - 3s 766us/step - loss:
 0.0571 - acc: 0.9805 - precision: 0.9805 - recall: 0.9805 - f1: 0.9
805 - val_loss: 0.0541 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 64/100
3901/3901 [==============================] - 3s 758us/step - loss:
 0.0347 - acc: 0.9869 - precision: 0.9869 - recall: 0.9869 - f1: 0.9
869 - val_loss: 0.0446 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 65/100
3901/3901 [==============================] - 3s 748us/step - loss:
 0.0260 - acc: 0.9910 - precision: 0.9910 - recall: 0.9910 - f1: 0.9
910 - val_loss: 0.0337 - val_acc: 0.9898 - val_precision: 0.9898 - v
al_recall: 0.9898 - val_f1: 0.9898
Epoch 66/100
3901/3901 [==============================] - 3s 759us/step - loss:
 0.0268 - acc: 0.9900 - precision: 0.9900 - recall: 0.9900 - f1: 0.9
900 - val_loss: 0.0375 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 67/100
3901/3901 [==============================] - 3s 750us/step - loss:
 0.0272 - acc: 0.9892 - precision: 0.9892 - recall: 0.9892 - f1: 0.9
892 - val_loss: 0.0514 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 68/100
3901/3901 [==============================] - 3s 738us/step - loss:
 0.0243 - acc: 0.9908 - precision: 0.9908 - recall: 0.9908 - f1: 0.9
908 - val_loss: 0.0388 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 69/100
3901/3901 [==============================] - 3s 755us/step - loss:
 0.0203 - acc: 0.9931 - precision: 0.9931 - recall: 0.9931 - f1: 0.9
931 - val_loss: 0.0316 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 70/100
3901/3901 [==============================] - 3s 754us/step - loss:
 0.0247 - acc: 0.9915 - precision: 0.9915 - recall: 0.9915 - f1: 0.9
915 - val_loss: 0.0601 - val_acc: 0.9811 - val_precision: 0.9811 - v
al_recall: 0.9811 - val_f1: 0.9811
Epoch 71/100
3901/3901 [==============================] - 3s 745us/step - loss:
 0.0213 - acc: 0.9923 - precision: 0.9923 - recall: 0.9923 - f1: 0.9
923 - val_loss: 0.0355 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 72/100
3901/3901 [==============================] - 3s 754us/step - loss:
 0.0285 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0415 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 73/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0212 - acc: 0.9921 - precision: 0.9921 - recall: 0.9921 - f1: 0.9
921 - val_loss: 0.0468 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 74/100
3901/3901 [==============================] - 3s 788us/step - loss:
 0.0263 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0481 - val_acc: 0.9826 - val_precision: 0.9826 - v
```

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al_recall: 0.9826 - val_f1: 0.9826
Epoch 75/100
3901/3901 [==============================] - 3s 754us/step - loss:
 0.0302 - acc: 0.9890 - precision: 0.9890 - recall: 0.9890 - f1: 0.9
890 - val_loss: 0.0383 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 76/100
3901/3901 [==============================] - 3s 742us/step - loss:
 0.0743 - acc: 0.9728 - precision: 0.9728 - recall: 0.9728 - f1: 0.9
728 - val_loss: 0.0547 - val_acc: 0.9782 - val_precision: 0.9782 - v
al_recall: 0.9782 - val_f1: 0.9782
Epoch 77/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0308 - acc: 0.9900 - precision: 0.9900 - recall: 0.9900 - f1: 0.9
900 - val_loss: 0.0349 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 78/100
3901/3901 [==============================] - 3s 739us/step - loss:
 0.0228 - acc: 0.9918 - precision: 0.9918 - recall: 0.9918 - f1: 0.9
918 - val_loss: 0.0391 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 79/100
3901/3901 [==============================] - 3s 740us/step - loss:
 0.0287 - acc: 0.9874 - precision: 0.9874 - recall: 0.9874 - f1: 0.9
874 - val_loss: 0.0666 - val_acc: 0.9782 - val_precision: 0.9782 - v
al_recall: 0.9782 - val_f1: 0.9782
Epoch 80/100
3901/3901 [==============================] - 3s 740us/step - loss:
 0.0239 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0350 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 81/100
3901/3901 [==============================] - 3s 732us/step - loss:
 0.0209 - acc: 0.9921 - precision: 0.9921 - recall: 0.9921 - f1: 0.9
921 - val_loss: 0.0520 - val_acc: 0.9768 - val_precision: 0.9768 - v
al_recall: 0.9768 - val_f1: 0.9768
Epoch 82/100
3901/3901 [==============================] - 3s 741us/step - loss:
 0.0193 - acc: 0.9923 - precision: 0.9923 - recall: 0.9923 - f1: 0.9
923 - val_loss: 0.0357 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 83/100
3901/3901 [==============================] - 3s 733us/step - loss:
 0.0198 - acc: 0.9936 - precision: 0.9936 - recall: 0.9936 - f1: 0.9
936 - val_loss: 0.0438 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 84/100
3901/3901 [==============================] - 3s 778us/step - loss:
 0.0412 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0355 - val_acc: 0.9898 - val_precision: 0.9898 - v
al_recall: 0.9898 - val_f1: 0.9898
Epoch 85/100
3901/3901 [==============================] - 3s 764us/step - loss:
 0.0222 - acc: 0.9915 - precision: 0.9915 - recall: 0.9915 - f1: 0.9
915 - val_loss: 0.0371 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 86/100
3901/3901 [==============================] - 3s 751us/step - loss:
 0.0234 - acc: 0.9910 - precision: 0.9910 - recall: 0.9910 - f1: 0.9
910 - val_loss: 0.0448 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
```

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Epoch 87/100
3901/3901 [==============================] - 3s 750us/step - loss:
 0.0220 - acc: 0.9923 - precision: 0.9923 - recall: 0.9923 - f1: 0.9
923 - val_loss: 0.0869 - val_acc: 0.9724 - val_precision: 0.9724 - v
al_recall: 0.9724 - val_f1: 0.9724
Epoch 88/100
3901/3901 [==============================] - 3s 745us/step - loss:
 0.0189 - acc: 0.9931 - precision: 0.9931 - recall: 0.9931 - f1: 0.9
931 - val_loss: 0.0379 - val_acc: 0.9855 - val_precision: 0.9855 - v
al_recall: 0.9855 - val_f1: 0.9855
Epoch 89/100
3901/3901 [==============================] - 3s 747us/step - loss:
 0.0290 - acc: 0.9880 - precision: 0.9880 - recall: 0.9880 - f1: 0.9
880 - val_loss: 0.0414 - val_acc: 0.9826 - val_precision: 0.9826 - v
al_recall: 0.9826 - val_f1: 0.9826
Epoch 90/100
3901/3901 [==============================] - 3s 749us/step - loss:
 0.0177 - acc: 0.9928 - precision: 0.9928 - recall: 0.9928 - f1: 0.9
928 - val_loss: 0.0392 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 91/100
3901/3901 [==============================] - 3s 750us/step - loss:
 0.0221 - acc: 0.9921 - precision: 0.9921 - recall: 0.9921 - f1: 0.9
921 - val_loss: 0.0394 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 92/100
3901/3901 [==============================] - 3s 740us/step - loss:
 0.0185 - acc: 0.9923 - precision: 0.9923 - recall: 0.9923 - f1: 0.9
923 - val_loss: 0.0406 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 93/100
3901/3901 [==============================] - 3s 743us/step - loss:
 0.0204 - acc: 0.9941 - precision: 0.9941 - recall: 0.9941 - f1: 0.9
941 - val_loss: 0.0364 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 94/100
3901/3901 [==============================] - 3s 745us/step - loss:
 0.0373 - acc: 0.9846 - precision: 0.9846 - recall: 0.9846 - f1: 0.9
846 - val_loss: 0.0509 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 95/100
3901/3901 [==============================] - 3s 755us/step - loss:
 0.0181 - acc: 0.9931 - precision: 0.9931 - recall: 0.9931 - f1: 0.9
931 - val_loss: 0.0386 - val_acc: 0.9898 - val_precision: 0.9898 - v
al_recall: 0.9898 - val_f1: 0.9898
Epoch 96/100
3901/3901 [==============================] - 3s 763us/step - loss:
 0.0180 - acc: 0.9926 - precision: 0.9926 - recall: 0.9926 - f1: 0.9
926 - val_loss: 0.0445 - val_acc: 0.9884 - val_precision: 0.9884 - v
al_recall: 0.9884 - val_f1: 0.9884
Epoch 97/100
3901/3901 [==============================] - 3s 752us/step - loss:
 0.0389 - acc: 0.9854 - precision: 0.9854 - recall: 0.9854 - f1: 0.9
854 - val_loss: 0.0440 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Epoch 98/100
3901/3901 [==============================] - 3s 749us/step - loss:
 0.0164 - acc: 0.9944 - precision: 0.9944 - recall: 0.9944 - f1: 0.9
944 - val_loss: 0.0551 - val_acc: 0.9840 - val_precision: 0.9840 - v
al_recall: 0.9840 - val_f1: 0.9840
Epoch 99/100
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3901/3901 [==============================] - 3s 759us/step - loss:
 0.0186 - acc: 0.9923 - precision: 0.9923 - recall: 0.9923 - f1: 0.9
923 - val_loss: 0.0469 - val_acc: 0.9913 - val_precision: 0.9913 - v
al_recall: 0.9913 - val_f1: 0.9913
Epoch 100/100
3901/3901 [==============================] - 3s 742us/step - loss:
 0.0178 - acc: 0.9926 - precision: 0.9926 - recall: 0.9926 - f1: 0.9
926 - val_loss: 0.0418 - val_acc: 0.9869 - val_precision: 0.9869 - v
al_recall: 0.9869 - val_f1: 0.9869
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_7 (InputLayer)         (None, 32, 32, 1)         0
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 29, 29, 20)        340
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 27, 27, 10)        1810
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 13, 13, 10)        0
_________________________________________________________________
flatten_7 (Flatten)          (None, 1690)              0
_________________________________________________________________
dense_9 (Dense)              (None, 3)                 5073
=================================================================
Total params: 7,223
Trainable params: 7,223
Non-trainable params: 0
_________________________________________________________________
Train on 2884 samples, validate on 509 samples
Epoch 1/100
2884/2884 [==============================] - 3s 1ms/step - loss: 0.8
510 - acc: 0.4546 - precision: 0.6630 - recall: 0.3006 - f1: 0.4033
 - val_loss: 0.6480 - val_acc: 0.5187 - val_precision: 0.7795 - val_
recall: 0.4519 - val_f1: 0.5705
Epoch 2/100
2884/2884 [==============================] - 3s 981us/step - loss:
 0.3931 - acc: 0.8356 - precision: 0.8779 - recall: 0.7881 - f1: 0.8
279 - val_loss: 0.2399 - val_acc: 0.9293 - val_precision: 0.9496 - v
al_recall: 0.8900 - val_f1: 0.9183
Epoch 3/100
2884/2884 [==============================] - 3s 979us/step - loss:
 0.1994 - acc: 0.9504 - precision: 0.9545 - recall: 0.9438 - f1: 0.9
489 - val_loss: 0.1547 - val_acc: 0.9666 - val_precision: 0.9665 - v
al_recall: 0.9646 - val_f1: 0.9655
Epoch 4/100
2884/2884 [==============================] - 3s 970us/step - loss:
 0.1410 - acc: 0.9629 - precision: 0.9629 - recall: 0.9626 - f1: 0.9
627 - val_loss: 0.2938 - val_acc: 0.8861 - val_precision: 0.8861 - v
al_recall: 0.8861 - val_f1: 0.8861
Epoch 5/100
2884/2884 [==============================] - 3s 960us/step - loss:
 0.1497 - acc: 0.9549 - precision: 0.9563 - recall: 0.9518 - f1: 0.9
540 - val_loss: 0.1342 - val_acc: 0.9568 - val_precision: 0.9568 - v
al_recall: 0.9568 - val_f1: 0.9568
Epoch 6/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.1130 - acc: 0.9702 - precision: 0.9705 - recall: 0.9684 - f1: 0.9
694 - val_loss: 0.0836 - val_acc: 0.9745 - val_precision: 0.9745 - v
al_recall: 0.9745 - val_f1: 0.9745
Epoch 7/100
```

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2884/2884 [==============================] - 3s 978us/step - loss:
 0.0898 - acc: 0.9740 - precision: 0.9740 - recall: 0.9740 - f1: 0.9
740 - val_loss: 0.0841 - val_acc: 0.9745 - val_precision: 0.9783 - v
al_recall: 0.9745 - val_f1: 0.9764
Epoch 8/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.0967 - acc: 0.9705 - precision: 0.9705 - recall: 0.9705 - f1: 0.9
705 - val_loss: 0.1078 - val_acc: 0.9666 - val_precision: 0.9666 - v
al_recall: 0.9666 - val_f1: 0.9666
Epoch 9/100
2884/2884 [==============================] - 3s 961us/step - loss:
 0.0791 - acc: 0.9785 - precision: 0.9785 - recall: 0.9778 - f1: 0.9
781 - val_loss: 0.0862 - val_acc: 0.9725 - val_precision: 0.9725 - v
al_recall: 0.9725 - val_f1: 0.9725
Epoch 10/100
2884/2884 [==============================] - 3s 970us/step - loss:
 0.0711 - acc: 0.9782 - precision: 0.9782 - recall: 0.9782 - f1: 0.9
782 - val_loss: 0.0690 - val_acc: 0.9764 - val_precision: 0.9764 - v
al_recall: 0.9764 - val_f1: 0.9764
Epoch 11/100
2884/2884 [==============================] - 3s 966us/step - loss:
 0.0590 - acc: 0.9785 - precision: 0.9785 - recall: 0.9785 - f1: 0.9
785 - val_loss: 0.1800 - val_acc: 0.9509 - val_precision: 0.9509 - v
al_recall: 0.9509 - val_f1: 0.9509
Epoch 12/100
2884/2884 [==============================] - 3s 965us/step - loss:
 0.0889 - acc: 0.9712 - precision: 0.9715 - recall: 0.9712 - f1: 0.9
714 - val_loss: 0.0570 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9784 - val_f1: 0.9794
Epoch 13/100
2884/2884 [==============================] - 3s 970us/step - loss:
 0.0582 - acc: 0.9816 - precision: 0.9820 - recall: 0.9816 - f1: 0.9
818 - val_loss: 0.0496 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 14/100
2884/2884 [==============================] - 3s 968us/step - loss:
 0.0545 - acc: 0.9820 - precision: 0.9820 - recall: 0.9820 - f1: 0.9
820 - val_loss: 0.0525 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 15/100
2884/2884 [==============================] - 3s 967us/step - loss:
 0.0577 - acc: 0.9802 - precision: 0.9802 - recall: 0.9802 - f1: 0.9
802 - val_loss: 0.0548 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9804 - val_f1: 0.9804
Epoch 16/100
2884/2884 [==============================] - 3s 963us/step - loss:
 0.0515 - acc: 0.9823 - precision: 0.9823 - recall: 0.9823 - f1: 0.9
823 - val_loss: 0.0731 - val_acc: 0.9764 - val_precision: 0.9764 - v
al_recall: 0.9764 - val_f1: 0.9764
Epoch 17/100
2884/2884 [==============================] - 3s 969us/step - loss:
 0.0559 - acc: 0.9813 - precision: 0.9813 - recall: 0.9809 - f1: 0.9
811 - val_loss: 0.0860 - val_acc: 0.9764 - val_precision: 0.9764 - v
al_recall: 0.9764 - val_f1: 0.9764
Epoch 18/100
2884/2884 [==============================] - 3s 963us/step - loss:
 0.0530 - acc: 0.9809 - precision: 0.9809 - recall: 0.9809 - f1: 0.9
809 - val_loss: 0.0463 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 19/100
2884/2884 [==============================] - 3s 963us/step - loss:
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 0.0459 - acc: 0.9830 - precision: 0.9834 - recall: 0.9830 - f1: 0.9
832 - val_loss: 0.0746 - val_acc: 0.9745 - val_precision: 0.9745 - v
al_recall: 0.9745 - val_f1: 0.9745
Epoch 20/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0437 - acc: 0.9854 - precision: 0.9854 - recall: 0.9854 - f1: 0.9
854 - val_loss: 0.0409 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 21/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0371 - acc: 0.9844 - precision: 0.9847 - recall: 0.9837 - f1: 0.9
842 - val_loss: 0.0419 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 22/100
2884/2884 [==============================] - 3s 965us/step - loss:
 0.0370 - acc: 0.9879 - precision: 0.9879 - recall: 0.9879 - f1: 0.9
879 - val_loss: 0.0420 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 23/100
2884/2884 [==============================] - 3s 968us/step - loss:
 0.0432 - acc: 0.9844 - precision: 0.9847 - recall: 0.9837 - f1: 0.9
842 - val_loss: 0.0432 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 24/100
2884/2884 [==============================] - 3s 969us/step - loss:
 0.0477 - acc: 0.9844 - precision: 0.9847 - recall: 0.9840 - f1: 0.9
844 - val_loss: 0.0559 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 25/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0324 - acc: 0.9910 - precision: 0.9910 - recall: 0.9910 - f1: 0.9
910 - val_loss: 0.0392 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 26/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0314 - acc: 0.9899 - precision: 0.9899 - recall: 0.9899 - f1: 0.9
899 - val_loss: 0.0434 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 27/100
2884/2884 [==============================] - 3s 966us/step - loss:
 0.0352 - acc: 0.9893 - precision: 0.9893 - recall: 0.9893 - f1: 0.9
893 - val_loss: 0.0440 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 28/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.0304 - acc: 0.9886 - precision: 0.9886 - recall: 0.9886 - f1: 0.9
886 - val_loss: 0.0433 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 29/100
2884/2884 [==============================] - 3s 966us/step - loss:
 0.0437 - acc: 0.9844 - precision: 0.9844 - recall: 0.9844 - f1: 0.9
844 - val_loss: 0.0768 - val_acc: 0.9764 - val_precision: 0.9764 - v
al_recall: 0.9745 - val_f1: 0.9754
Epoch 30/100
2884/2884 [==============================] - 3s 965us/step - loss:
 0.0484 - acc: 0.9837 - precision: 0.9837 - recall: 0.9837 - f1: 0.9
837 - val_loss: 0.0333 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 31/100
2884/2884 [==============================] - 3s 965us/step - loss:
 0.0284 - acc: 0.9906 - precision: 0.9906 - recall: 0.9906 - f1: 0.9
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906 - val_loss: 0.0424 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 32/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0263 - acc: 0.9899 - precision: 0.9899 - recall: 0.9899 - f1: 0.9
899 - val_loss: 0.0373 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 33/100
2884/2884 [==============================] - 3s 961us/step - loss:
 0.0244 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0434 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 34/100
2884/2884 [==============================] - 3s 963us/step - loss:
 0.0201 - acc: 0.9924 - precision: 0.9924 - recall: 0.9924 - f1: 0.9
924 - val_loss: 0.0293 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 35/100
2884/2884 [==============================] - 3s 964us/step - loss:
 0.0273 - acc: 0.9906 - precision: 0.9906 - recall: 0.9906 - f1: 0.9
906 - val_loss: 0.0426 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 36/100
2884/2884 [==============================] - 3s 968us/step - loss:
 0.0227 - acc: 0.9917 - precision: 0.9917 - recall: 0.9917 - f1: 0.9
917 - val_loss: 0.0446 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 37/100
2884/2884 [==============================] - 3s 993us/step - loss:
 0.0205 - acc: 0.9938 - precision: 0.9938 - recall: 0.9938 - f1: 0.9
938 - val_loss: 0.0642 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 38/100
2884/2884 [==============================] - 3s 987us/step - loss:
 0.0231 - acc: 0.9910 - precision: 0.9910 - recall: 0.9910 - f1: 0.9
910 - val_loss: 0.0433 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 39/100
2884/2884 [==============================] - 3s 977us/step - loss:
 0.0207 - acc: 0.9924 - precision: 0.9924 - recall: 0.9924 - f1: 0.9
924 - val_loss: 0.0546 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 40/100
2884/2884 [==============================] - 3s 992us/step - loss:
 0.0172 - acc: 0.9934 - precision: 0.9934 - recall: 0.9934 - f1: 0.9
934 - val_loss: 0.0333 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 41/100
2884/2884 [==============================] - 3s 998us/step - loss:
 0.0291 - acc: 0.9889 - precision: 0.9889 - recall: 0.9889 - f1: 0.9
889 - val_loss: 0.0929 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9804 - val_f1: 0.9804
Epoch 42/100
2884/2884 [==============================] - 3s 1ms/step - loss: 0.0
288 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9903
 - val_loss: 0.0778 - val_acc: 0.9764 - val_precision: 0.9764 - val_
recall: 0.9764 - val_f1: 0.9764
Epoch 43/100
2884/2884 [==============================] - 3s 980us/step - loss:
 0.0198 - acc: 0.9934 - precision: 0.9934 - recall: 0.9934 - f1: 0.9
934 - val_loss: 0.0415 - val_acc: 0.9843 - val_precision: 0.9843 - v
```

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al_recall: 0.9843 - val_f1: 0.9843
Epoch 44/100
2884/2884 [==============================] - 3s 978us/step - loss:
 0.0173 - acc: 0.9941 - precision: 0.9941 - recall: 0.9941 - f1: 0.9
941 - val_loss: 0.0501 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 45/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.0174 - acc: 0.9931 - precision: 0.9931 - recall: 0.9931 - f1: 0.9
931 - val_loss: 0.0644 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 46/100
2884/2884 [==============================] - 3s 982us/step - loss:
 0.0368 - acc: 0.9868 - precision: 0.9875 - recall: 0.9865 - f1: 0.9
870 - val_loss: 0.0602 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 47/100
2884/2884 [==============================] - 3s 968us/step - loss:
 0.0192 - acc: 0.9934 - precision: 0.9934 - recall: 0.9934 - f1: 0.9
934 - val_loss: 0.0543 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 48/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.0159 - acc: 0.9938 - precision: 0.9938 - recall: 0.9938 - f1: 0.9
938 - val_loss: 0.0459 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 49/100
2884/2884 [==============================] - 3s 975us/step - loss:
 0.0198 - acc: 0.9924 - precision: 0.9924 - recall: 0.9924 - f1: 0.9
924 - val_loss: 0.0387 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 50/100
2884/2884 [==============================] - 3s 1ms/step - loss: 0.0
235 - acc: 0.9927 - precision: 0.9927 - recall: 0.9927 - f1: 0.9927
 - val_loss: 0.0462 - val_acc: 0.9823 - val_precision: 0.9823 - val_
recall: 0.9823 - val_f1: 0.9823
Epoch 51/100
2884/2884 [==============================] - 3s 973us/step - loss:
 0.0237 - acc: 0.9917 - precision: 0.9917 - recall: 0.9917 - f1: 0.9
917 - val_loss: 0.0364 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 52/100
2884/2884 [==============================] - 3s 975us/step - loss:
 0.0193 - acc: 0.9927 - precision: 0.9927 - recall: 0.9927 - f1: 0.9
927 - val_loss: 0.0672 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 53/100
2884/2884 [==============================] - 3s 985us/step - loss:
 0.0146 - acc: 0.9941 - precision: 0.9941 - recall: 0.9941 - f1: 0.9
941 - val_loss: 0.0357 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 54/100
2884/2884 [==============================] - 3s 970us/step - loss:
 0.0239 - acc: 0.9917 - precision: 0.9920 - recall: 0.9917 - f1: 0.9
918 - val_loss: 0.0561 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9804 - val_f1: 0.9804
Epoch 55/100
2884/2884 [==============================] - 3s 984us/step - loss:
 0.0191 - acc: 0.9938 - precision: 0.9938 - recall: 0.9938 - f1: 0.9
938 - val_loss: 0.0886 - val_acc: 0.9764 - val_precision: 0.9764 - v
al_recall: 0.9764 - val_f1: 0.9764
```

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Epoch 56/100
2884/2884 [==============================] - 3s 984us/step - loss:
 0.0268 - acc: 0.9906 - precision: 0.9906 - recall: 0.9906 - f1: 0.9
906 - val_loss: 0.0392 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 57/100
2884/2884 [==============================] - 3s 984us/step - loss:
 0.0155 - acc: 0.9948 - precision: 0.9948 - recall: 0.9948 - f1: 0.9
948 - val_loss: 0.0503 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 58/100
2884/2884 [==============================] - 3s 986us/step - loss:
 0.0131 - acc: 0.9951 - precision: 0.9951 - recall: 0.9951 - f1: 0.9
951 - val_loss: 0.0453 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 59/100
2884/2884 [==============================] - 3s 980us/step - loss:
 0.0247 - acc: 0.9917 - precision: 0.9917 - recall: 0.9917 - f1: 0.9
917 - val_loss: 0.0577 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 60/100
2884/2884 [==============================] - 3s 978us/step - loss:
 0.0164 - acc: 0.9941 - precision: 0.9941 - recall: 0.9941 - f1: 0.9
941 - val_loss: 0.0923 - val_acc: 0.9607 - val_precision: 0.9607 - v
al_recall: 0.9607 - val_f1: 0.9607
Epoch 61/100
2884/2884 [==============================] - 3s 987us/step - loss:
 0.0182 - acc: 0.9941 - precision: 0.9941 - recall: 0.9941 - f1: 0.9
941 - val_loss: 0.0405 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 62/100
2884/2884 [==============================] - 3s 980us/step - loss:
 0.0141 - acc: 0.9948 - precision: 0.9948 - recall: 0.9948 - f1: 0.9
948 - val_loss: 0.0753 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 63/100
2884/2884 [==============================] - 3s 980us/step - loss:
 0.0280 - acc: 0.9879 - precision: 0.9879 - recall: 0.9879 - f1: 0.9
879 - val_loss: 0.0440 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 64/100
2884/2884 [==============================] - 3s 981us/step - loss:
 0.0137 - acc: 0.9951 - precision: 0.9951 - recall: 0.9951 - f1: 0.9
951 - val_loss: 0.0627 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 65/100
2884/2884 [==============================] - 3s 979us/step - loss:
 0.0143 - acc: 0.9945 - precision: 0.9945 - recall: 0.9945 - f1: 0.9
945 - val_loss: 0.1042 - val_acc: 0.9745 - val_precision: 0.9745 - v
al_recall: 0.9745 - val_f1: 0.9745
Epoch 66/100
2884/2884 [==============================] - 3s 978us/step - loss:
 0.0259 - acc: 0.9903 - precision: 0.9903 - recall: 0.9903 - f1: 0.9
903 - val_loss: 0.0674 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9804 - val_f1: 0.9804
Epoch 67/100
2884/2884 [==============================] - 3s 956us/step - loss:
 0.0209 - acc: 0.9924 - precision: 0.9924 - recall: 0.9924 - f1: 0.9
924 - val_loss: 0.0470 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 68/100
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2884/2884 [==============================] - 3s 969us/step - loss:
 0.0107 - acc: 0.9958 - precision: 0.9958 - recall: 0.9958 - f1: 0.9
958 - val_loss: 0.0511 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 69/100
2884/2884 [==============================] - 3s 970us/step - loss:
 0.0103 - acc: 0.9955 - precision: 0.9955 - recall: 0.9955 - f1: 0.9
955 - val_loss: 0.0577 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 70/100
2884/2884 [==============================] - 3s 975us/step - loss:
 0.0141 - acc: 0.9958 - precision: 0.9958 - recall: 0.9958 - f1: 0.9
958 - val_loss: 0.0454 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 71/100
2884/2884 [==============================] - 3s 996us/step - loss:
 0.0266 - acc: 0.9899 - precision: 0.9899 - recall: 0.9899 - f1: 0.9
899 - val_loss: 0.0577 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 72/100
2884/2884 [==============================] - 3s 941us/step - loss:
 0.0111 - acc: 0.9962 - precision: 0.9962 - recall: 0.9962 - f1: 0.9
962 - val_loss: 0.0579 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 73/100
2884/2884 [==============================] - 3s 944us/step - loss:
 0.0121 - acc: 0.9945 - precision: 0.9945 - recall: 0.9945 - f1: 0.9
945 - val_loss: 0.0798 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 74/100
2884/2884 [==============================] - 3s 972us/step - loss:
 0.0136 - acc: 0.9951 - precision: 0.9951 - recall: 0.9951 - f1: 0.9
951 - val_loss: 0.0695 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 75/100
2884/2884 [==============================] - 3s 958us/step - loss:
 0.0123 - acc: 0.9955 - precision: 0.9955 - recall: 0.9955 - f1: 0.9
955 - val_loss: 0.0536 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 76/100
2884/2884 [==============================] - 3s 957us/step - loss:
 0.0105 - acc: 0.9962 - precision: 0.9962 - recall: 0.9962 - f1: 0.9
962 - val_loss: 0.0652 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 77/100
2884/2884 [==============================] - 3s 952us/step - loss:
 0.0160 - acc: 0.9924 - precision: 0.9924 - recall: 0.9924 - f1: 0.9
924 - val_loss: 0.0528 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 78/100
2884/2884 [==============================] - 3s 963us/step - loss:
 0.0315 - acc: 0.9889 - precision: 0.9892 - recall: 0.9889 - f1: 0.9
891 - val_loss: 0.1090 - val_acc: 0.9666 - val_precision: 0.9685 - v
al_recall: 0.9666 - val_f1: 0.9675
Epoch 79/100
2884/2884 [==============================] - 3s 983us/step - loss:
 0.0149 - acc: 0.9948 - precision: 0.9948 - recall: 0.9948 - f1: 0.9
948 - val_loss: 0.0620 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 80/100
2884/2884 [==============================] - 3s 942us/step - loss:
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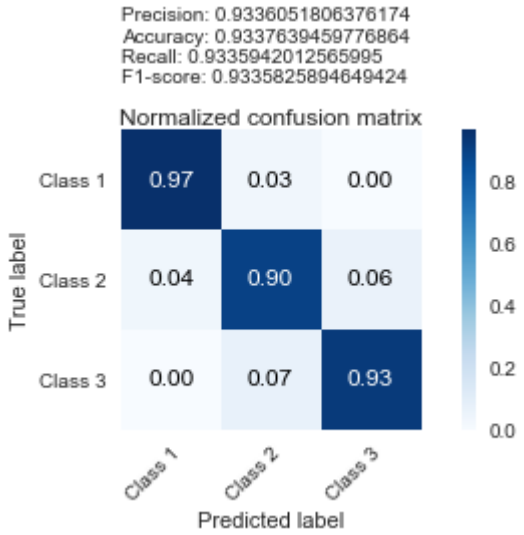
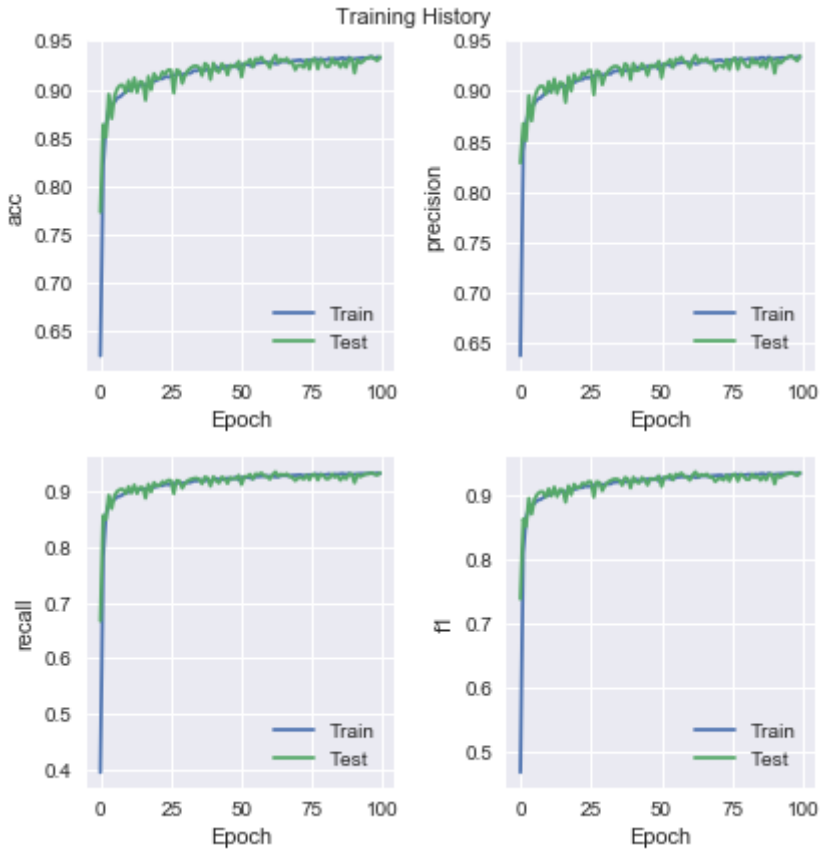
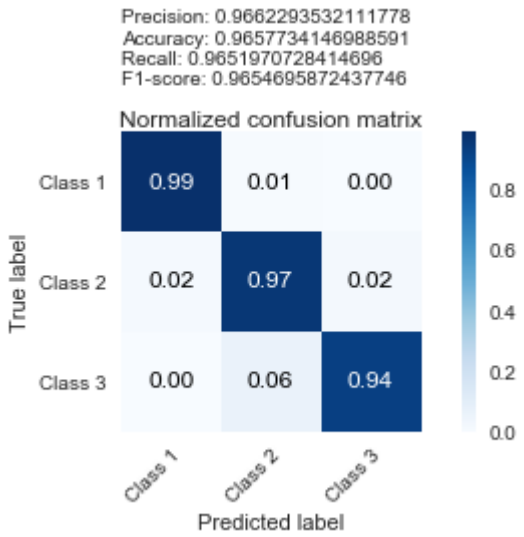
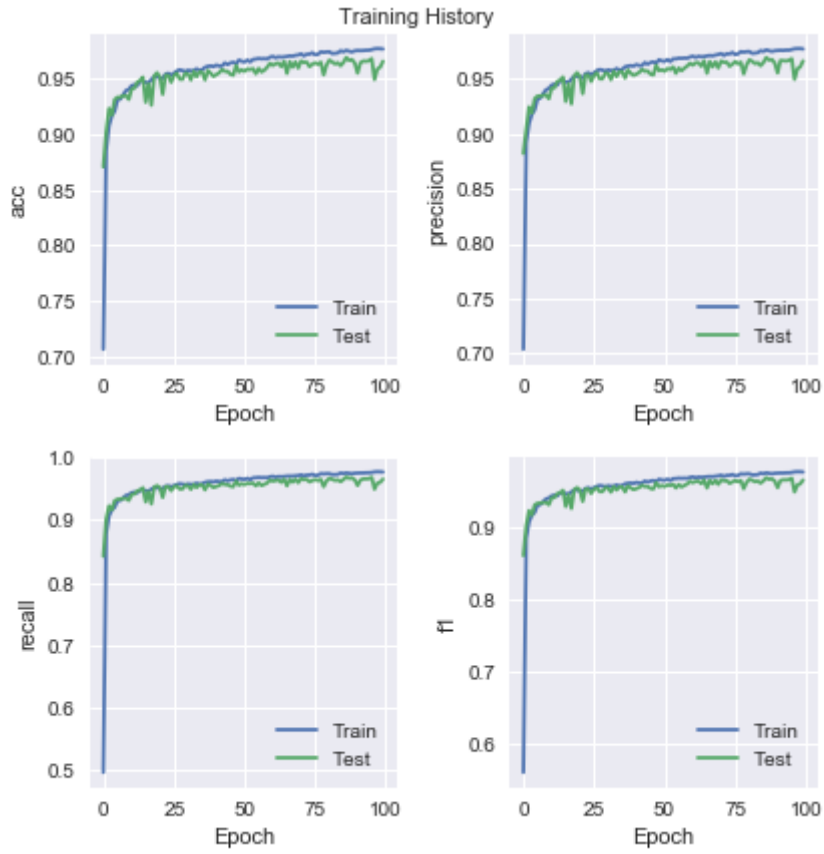
 0.0088 - acc: 0.9962 - precision: 0.9962 - recall: 0.9962 - f1: 0.9
962 - val_loss: 0.0518 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 81/100
2884/2884 [==============================] - 3s 942us/step - loss:
 0.0089 - acc: 0.9969 - precision: 0.9969 - recall: 0.9969 - f1: 0.9
969 - val_loss: 0.0574 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 82/100
2884/2884 [==============================] - 3s 953us/step - loss:
 0.0093 - acc: 0.9955 - precision: 0.9955 - recall: 0.9955 - f1: 0.9
955 - val_loss: 0.0587 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 83/100
2884/2884 [==============================] - 3s 945us/step - loss:
 0.0267 - acc: 0.9886 - precision: 0.9888 - recall: 0.9886 - f1: 0.9
887 - val_loss: 0.2942 - val_acc: 0.8959 - val_precision: 0.9007 - v
al_recall: 0.8919 - val_f1: 0.8962
Epoch 84/100
2884/2884 [==============================] - 3s 953us/step - loss:
 0.0269 - acc: 0.9920 - precision: 0.9920 - recall: 0.9920 - f1: 0.9
920 - val_loss: 0.0958 - val_acc: 0.9784 - val_precision: 0.9784 - v
al_recall: 0.9784 - val_f1: 0.9784
Epoch 85/100
2884/2884 [==============================] - 3s 1ms/step - loss: 0.0
191 - acc: 0.9917 - precision: 0.9917 - recall: 0.9913 - f1: 0.9915
 - val_loss: 0.0562 - val_acc: 0.9862 - val_precision: 0.9862 - val_
recall: 0.9862 - val_f1: 0.9862
Epoch 86/100
2884/2884 [==============================] - 3s 1ms/step - loss: 0.0
098 - acc: 0.9955 - precision: 0.9955 - recall: 0.9955 - f1: 0.9955
 - val_loss: 0.0591 - val_acc: 0.9862 - val_precision: 0.9862 - val_
recall: 0.9862 - val_f1: 0.9862
Epoch 87/100
2884/2884 [==============================] - 3s 981us/step - loss:
 0.0089 - acc: 0.9962 - precision: 0.9962 - recall: 0.9962 - f1: 0.9
962 - val_loss: 0.0489 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 88/100
2884/2884 [==============================] - 3s 983us/step - loss:
 0.0113 - acc: 0.9955 - precision: 0.9955 - recall: 0.9955 - f1: 0.9
955 - val_loss: 0.0505 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 89/100
2884/2884 [==============================] - 3s 988us/step - loss:
 0.0084 - acc: 0.9962 - precision: 0.9962 - recall: 0.9962 - f1: 0.9
962 - val_loss: 0.0619 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 90/100
2884/2884 [==============================] - 3s 990us/step - loss:
 0.0073 - acc: 0.9965 - precision: 0.9965 - recall: 0.9965 - f1: 0.9
965 - val_loss: 0.0584 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 91/100
2884/2884 [==============================] - 3s 976us/step - loss:
 0.0123 - acc: 0.9958 - precision: 0.9958 - recall: 0.9958 - f1: 0.9
958 - val_loss: 0.0688 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 92/100
2884/2884 [==============================] - 3s 979us/step - loss:
 0.0204 - acc: 0.9927 - precision: 0.9927 - recall: 0.9927 - f1: 0.9
```

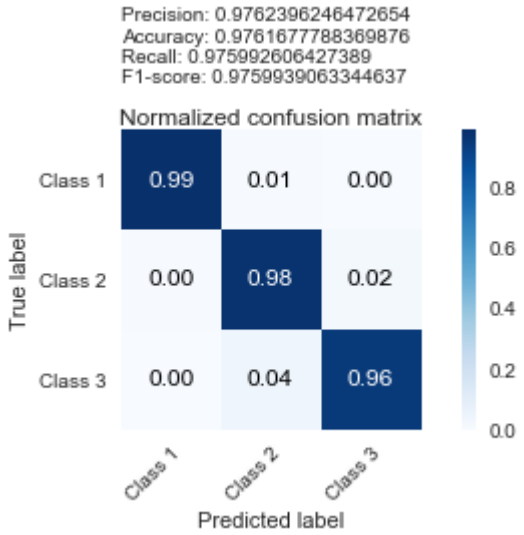
```
927 - val_loss: 0.1049 - val_acc: 0.9745 - val_precision: 0.9745 - v
al_recall: 0.9745 - val_f1: 0.9745
Epoch 93/100
2884/2884 [==============================] - 3s 980us/step - loss:
 0.0168 - acc: 0.9938 - precision: 0.9938 - recall: 0.9938 - f1: 0.9
938 - val_loss: 0.0648 - val_acc: 0.9804 - val_precision: 0.9804 - v
al_recall: 0.9804 - val_f1: 0.9804
Epoch 94/100
2884/2884 [==============================] - 3s 998us/step - loss:
 0.0087 - acc: 0.9965 - precision: 0.9965 - recall: 0.9965 - f1: 0.9
965 - val_loss: 0.0740 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Epoch 95/100
2884/2884 [==============================] - 3s 998us/step - loss:
 0.0071 - acc: 0.9965 - precision: 0.9965 - recall: 0.9965 - f1: 0.9
965 - val_loss: 0.0589 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 96/100
2884/2884 [==============================] - 3s 992us/step - loss:
 0.0063 - acc: 0.9965 - precision: 0.9965 - recall: 0.9965 - f1: 0.9
965 - val_loss: 0.0664 - val_acc: 0.9862 - val_precision: 0.9862 - v
al_recall: 0.9862 - val_f1: 0.9862
Epoch 97/100
2884/2884 [==============================] - 3s 991us/step - loss:
 0.0074 - acc: 0.9969 - precision: 0.9969 - recall: 0.9969 - f1: 0.9
969 - val_loss: 0.0538 - val_acc: 0.9882 - val_precision: 0.9882 - v
al_recall: 0.9882 - val_f1: 0.9882
Epoch 98/100
2884/2884 [==============================] - 3s 990us/step - loss:
 0.0063 - acc: 0.9965 - precision: 0.9965 - recall: 0.9965 - f1: 0.9
965 - val_loss: 0.0551 - val_acc: 0.9902 - val_precision: 0.9902 - v
al_recall: 0.9902 - val_f1: 0.9902
Epoch 99/100
2884/2884 [==============================] - 3s 989us/step - loss:
 0.0091 - acc: 0.9958 - precision: 0.9958 - recall: 0.9958 - f1: 0.9
958 - val_loss: 0.0611 - val_acc: 0.9843 - val_precision: 0.9843 - v
al_recall: 0.9843 - val_f1: 0.9843
Epoch 100/100
2884/2884 [==============================] - 3s 973us/step - loss:
 0.0253 - acc: 0.9906 - precision: 0.9906 - recall: 0.9903 - f1: 0.9
905 - val_loss: 0.0676 - val_acc: 0.9823 - val_precision: 0.9823 - v
al_recall: 0.9823 - val_f1: 0.9823
Normalized confusion matrix
```

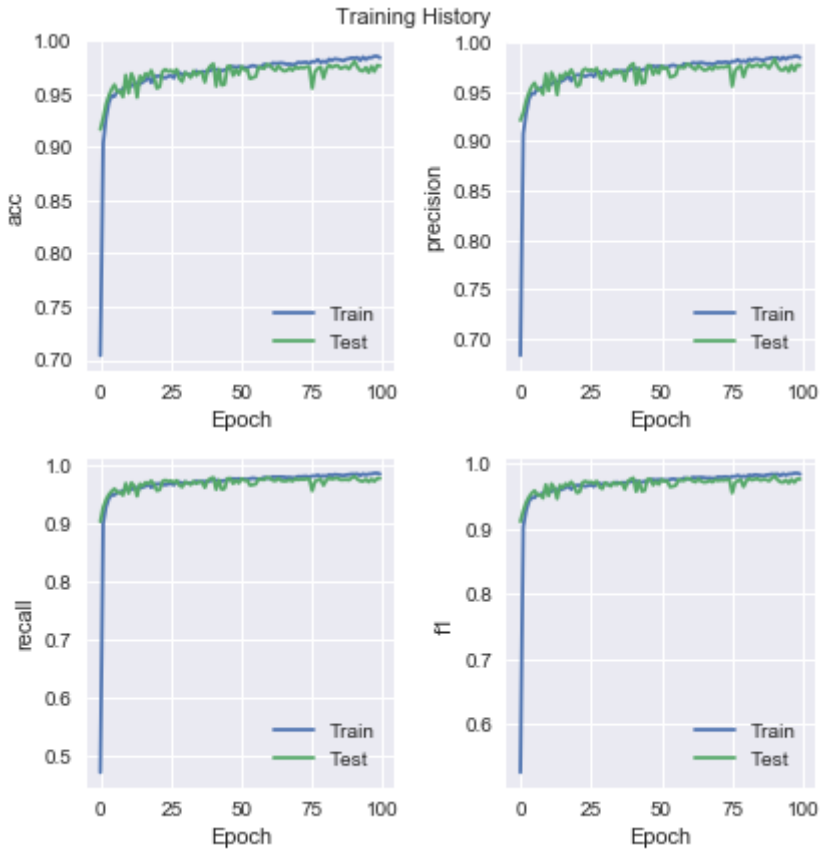

Precision: 0.9336051806376174
Accuracy: 0.9337639459776864
Recall: 0.9335942012565995
F1-score: 0.9335825894649424
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.97
0.03
0.00
0.04
0.90
0.06
0.00
0.07
0.93
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

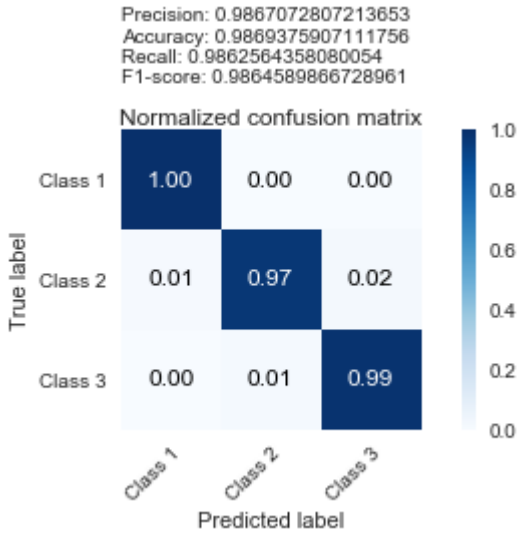

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
25
50
75
100

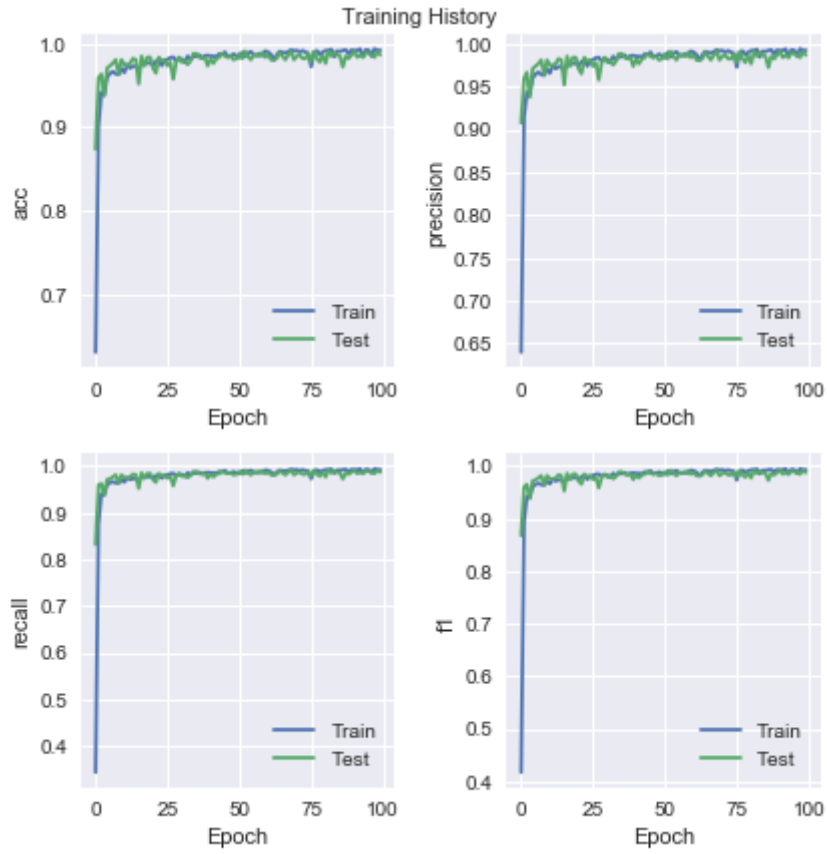

Precision: 0.9662293532111778
Accuracy: 0.9657734146988591
Recall: 0.9651970728414696
F1-score: 0.9654695872437746
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.99
0.01
0.00
0.02
0.97
0.02
0.00
0.06
0.94
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

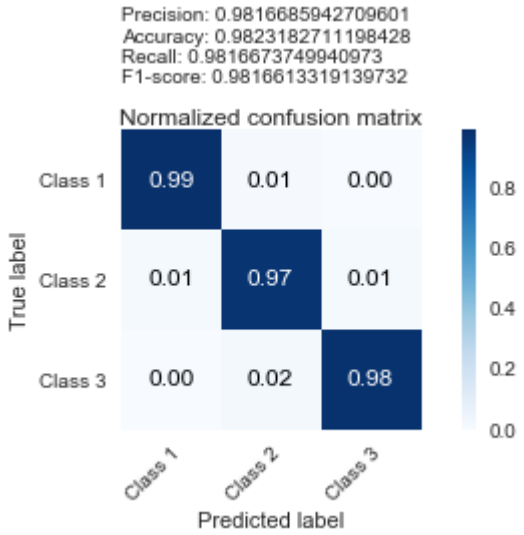

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
25
50
75
100

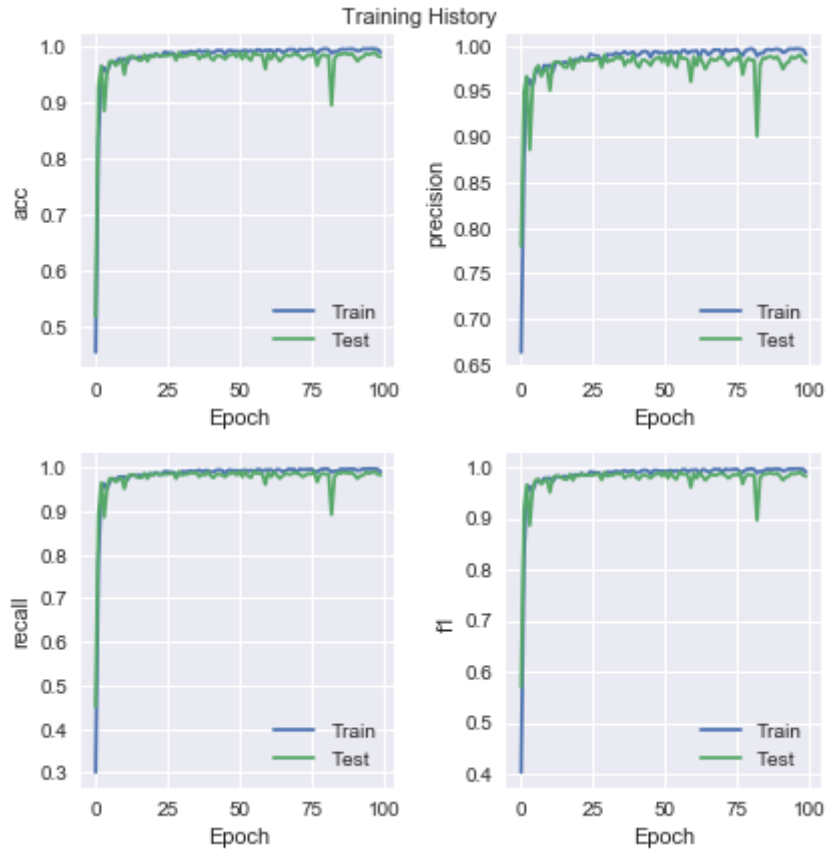

Precision: 0.9762396246472654
Accuracy: 0.9761677788369876
Recall: 0.97592606427389
F1-score: 0.9759939063344637
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.99
0.01
0.00
0.00
0.98
0.02
0.00
0.04
0.96
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label


Training History
acc
precision
recall
f1
Train
Test
Epoch


Precision: 0.9867072807213653
Accuracy: 0.9869375907111756
Recall: 0.9862564358080054
F1-score: 0.9864589866728961
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
0.01
0.97
0.02
0.00
0.01
0.99
Class 1
Class 2
Class 3
Predicted label
1.0
0.8
0.6
0.4
0.2
0.0


Training History
acc
precision
recall
f1
Train
Test
Epoch


Precision: 0.9816685942709601
Accuracy: 0.9823182711198428
Recall: 0.9816673749940973
F1-score: 0.9816613319139732
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.99
0.01
0.00
0.01
0.97
0.01
0.00
0.02
0.98
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label


Training History
acc
precision
recall
f1
Train
Test
Epoch

So it was found from the above calculation the best model performance was obtained from the best image size = (28 * 28). Using that I run a new loop with different activation functions and optimizers to find which combination gives the best performance. The results are as follows.

In [63]:

```
sx=28
sy=28

MAX_X = img1_gr.shape[0]
MAX_Y = img1_gr.shape[1]

class1_data=[]
class2_data=[]
class3_data=[]

for x_coord in np.arange(0,MAX_X-sx,sx):
    for y_coord in np.arange(0,MAX_Y-sy,sy):
        class1_data.append(img1_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
        class2_data.append(img2_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])
        class3_data.append(img3_gr[x_coord:x_coord+sx, y_coord:y_coord+sy])


X = np.vstack([class1_data, class2_data, class3_data])

labels = np.array([0]*len(class1_data) + [1]*len(class2_data) + [2]*len(class3_d
ata))

y = OneHotEncoder().fit_transform(labels.reshape(-1,1))

# Model validation strategy

X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.15, random_stat
e=42, shuffle=True)
y_test_class=prob_to_class(y_test)
X_train_ch=X_train.reshape(-1,sx,sy,1)
X_test_ch=X_test.reshape(-1,sx,sy,1)
input_shape = (sx,sy,1)



activation_funcs = ['linear', 'sigmoid', 'tanh', 'relu']
optimizers = ['Adam', 'RMSprop', 'SGD', 'Adadelta', 'Adagrad', 'Adamax', 'Nadam'
]

for act in activation_funcs:
    for opt in optimizers:
        # A neural network classifier is created to identify the class of the im
ages
        model=Sequential()
        model.add(InputLayer(input_shape=input_shape))
        model.add(Conv2D(20, (4, 4), input_shape=input_shape, activation=act))
        model.add(Conv2D(10, (3,3), input_shape=input_shape, activation=act))
        model.add(MaxPooling2D(pool_size=(2, 2)))
        model.add(Flatten())
        model.add(Dense(3,activation=act))
        optimizer=opt
        model.compile(loss='categorical_crossentropy', optimizer=optimizer, metr
ics=['accuracy', precision,recall,f1])
        model.summary()

#try another optimizer
        optimizer=opt
        model.compile(loss='categorical_crossentropy', optimizer=optimizer, metr
ics=['accuracy', precision,recall,f1])
```

```
        model.summary()
        history=model.fit(X_train_ch,y_train, validation_data=(X_test_ch,y_test
),epochs=50)

        #Show the summary of the model performance and confusion matrix
        model_test_summary(model)
        plt.savefig('model_test_summary'+act+'_'+opt+'.png', dpi = 300)

        # Plot it training history
        plot_train_history(history)
        plt.savefig('plot_train_history_'+act+'_'+opt+'.png', dpi = 300)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_22 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_40 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_41 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_19 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_21 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_22 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_40 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_41 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_19 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_21 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 904us/step - loss:
4.9841 - acc: 0.2561 - precision: 0.2093 - recall: 0.3743 - f1: 0.26
30 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 2/50
3901/3901 [==============================] - 3s 734us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 3/50
3901/3901 [==============================] - 3s 736us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 4/50
3901/3901 [==============================] - 3s 745us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 5/50
3901/3901 [==============================] - 3s 750us/step - loss:
```

```
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 6/50
3901/3901 [==============================] - 3s 745us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 7/50
3901/3901 [==============================] - 3s 744us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 8/50
3901/3901 [==============================] - 3s 732us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 9/50
3901/3901 [==============================] - 3s 735us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 10/50
3901/3901 [==============================] - 3s 738us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 11/50
3901/3901 [==============================] - 3s 739us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 12/50
3901/3901 [==============================] - 3s 747us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 13/50
3901/3901 [==============================] - 3s 736us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
40 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 14/50
3901/3901 [==============================] - 3s 740us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
40 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 15/50
3901/3901 [==============================] - 3s 744us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
40 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 16/50
3901/3901 [==============================] - 3s 734us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 17/50
3901/3901 [==============================] - 3s 751us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
```

```
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 18/50
3901/3901 [==============================] - 3s 738us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 19/50
3901/3901 [==============================] - 3s 745us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 20/50
3901/3901 [==============================] - 3s 741us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 21/50
3901/3901 [==============================] - 3s 745us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 22/50
3901/3901 [==============================] - 3s 742us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 23/50
3901/3901 [==============================] - 3s 739us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 24/50
3901/3901 [==============================] - 3s 740us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 25/50
3901/3901 [==============================] - 3s 729us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 26/50
3901/3901 [==============================] - 3s 741us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 27/50
3901/3901 [==============================] - 3s 732us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 28/50
3901/3901 [==============================] - 3s 738us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 29/50
3901/3901 [==============================] - 3s 736us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
```

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l_recall: 0.6763 - val_f1: 0.4523
Epoch 30/50
3901/3901 [==============================] - 3s 741us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 31/50
3901/3901 [==============================] - 3s 734us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 32/50
3901/3901 [==============================] - 3s 735us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 33/50
3901/3901 [==============================] - 3s 740us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 34/50
3901/3901 [==============================] - 3s 758us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 35/50
3901/3901 [==============================] - 3s 732us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
40 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 36/50
3901/3901 [==============================] - 3s 733us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 37/50
3901/3901 [==============================] - 3s 730us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 38/50
3901/3901 [==============================] - 3s 731us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 39/50
3901/3901 [==============================] - 3s 739us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 40/50
3901/3901 [==============================] - 3s 750us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
40 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 41/50
3901/3901 [==============================] - 3s 741us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
```

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Epoch 42/50
3901/3901 [==============================] - 3s 737us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 43/50
3901/3901 [==============================] - 3s 737us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 44/50
3901/3901 [==============================] - 3s 736us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 45/50
3901/3901 [==============================] - 3s 737us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 46/50
3901/3901 [==============================] - 3s 749us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 47/50
3901/3901 [==============================] - 3s 737us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 48/50
3901/3901 [==============================] - 3s 738us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 49/50
3901/3901 [==============================] - 3s 743us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3333 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Epoch 50/50
3901/3901 [==============================] - 3s 738us/step - loss:
8.5776 - acc: 0.3330 - precision: 0.3334 - recall: 0.6650 - f1: 0.44
41 - val_loss: 8.5620 - val_acc: 0.3106 - val_precision: 0.3397 - va
l_recall: 0.6763 - val_f1: 0.4523
Normalized confusion matrix

/opt/netapps/thermocalc/2018/anaconda/lib/python3.6/site-packages/sk
learn/metrics/classification.py:1135: UndefinedMetricWarning: Precis
ion is ill-defined and being set to 0.0 in labels with no predicted
samples.
  'precision', 'predicted', average, warn_for)
/opt/netapps/thermocalc/2018/anaconda/lib/python3.6/site-packages/sk
learn/metrics/classification.py:1135: UndefinedMetricWarning: F-scor
e is ill-defined and being set to 0.0 in labels with no predicted sa
mples.
  'precision', 'predicted', average, warn_for)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_23 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_42 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_43 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_20 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_22 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
```


```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_23 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_42 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_43 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_20 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_22 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
```


```
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 920us/step - loss:
7.9173 - acc: 0.3279 - precision: 0.3328 - recall: 0.4806 - f1: 0.38
19 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 2/50
3901/3901 [==============================] - 3s 743us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3363 - recall: 0.6624 - f1: 0.44
61 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 3/50
3901/3901 [==============================] - 3s 735us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 4/50
3901/3901 [==============================] - 3s 730us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 5/50
3901/3901 [==============================] - 3s 732us/step - loss:
```

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5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 6/50
3901/3901 [==============================] - 3s 733us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 7/50
3901/3901 [==============================] - 3s 739us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 8/50
3901/3901 [==============================] - 3s 734us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 9/50
3901/3901 [==============================] - 3s 745us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 10/50
3901/3901 [==============================] - 3s 731us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 11/50
3901/3901 [==============================] - 3s 734us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3367 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 12/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3367 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 13/50
3901/3901 [==============================] - 3s 753us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 14/50
3901/3901 [==============================] - 3s 738us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 15/50
3901/3901 [==============================] - 3s 732us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
61 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 16/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 17/50
3901/3901 [==============================] - 3s 743us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
```

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62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 18/50
3901/3901 [==============================] - 3s 742us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 19/50
3901/3901 [==============================] - 3s 727us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 20/50
3901/3901 [==============================] - 3s 730us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 21/50
3901/3901 [==============================] - 3s 740us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 22/50
3901/3901 [==============================] - 3s 752us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3363 - recall: 0.6624 - f1: 0.44
61 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 23/50
3901/3901 [==============================] - 3s 738us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 24/50
3901/3901 [==============================] - 3s 740us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 25/50
3901/3901 [==============================] - 3s 741us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 26/50
3901/3901 [==============================] - 3s 730us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 27/50
3901/3901 [==============================] - 3s 744us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 28/50
3901/3901 [==============================] - 3s 760us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3367 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 29/50
3901/3901 [==============================] - 3s 771us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
```

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l_recall: 0.6851 - val_f1: 0.4637
Epoch 30/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 31/50
3901/3901 [==============================] - 3s 746us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
61 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 32/50
3901/3901 [==============================] - 3s 728us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 33/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 34/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 35/50
3901/3901 [==============================] - 3s 729us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 36/50
3901/3901 [==============================] - 3s 739us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 37/50
3901/3901 [==============================] - 3s 732us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3364 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 38/50
3901/3901 [==============================] - 3s 762us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 39/50
3901/3901 [==============================] - 3s 745us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 40/50
3901/3901 [==============================] - 3s 742us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 41/50
3901/3901 [==============================] - 3s 730us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
```

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Epoch 42/50
3901/3901 [==============================] - 3s 743us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 43/50
3901/3901 [==============================] - 3s 748us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 44/50
3901/3901 [==============================] - 3s 737us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 45/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 46/50
3901/3901 [==============================] - 3s 758us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 47/50
3901/3901 [==============================] - 3s 736us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
63 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 48/50
3901/3901 [==============================] - 3s 753us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 49/50
3901/3901 [==============================] - 3s 730us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3366 - recall: 0.6624 - f1: 0.44
64 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Epoch 50/50
3901/3901 [==============================] - 3s 740us/step - loss:
5.3548 - acc: 0.3115 - precision: 0.3365 - recall: 0.6624 - f1: 0.44
62 - val_loss: 4.9594 - val_acc: 0.3440 - val_precision: 0.3505 - va
l_recall: 0.6851 - val_f1: 0.4637
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_24 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_44 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_45 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_21 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_23 (Dense)             (None, 3)                 3633
=================================================================
```

```
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_24 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_44 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_45 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_21 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_23 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 906us/step - loss:
6.8828 - acc: 0.3384 - precision: 0.3309 - recall: 0.6511 - f1: 0.43
42 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 2/50
3901/3901 [==============================] - 3s 742us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 3/50
3901/3901 [==============================] - 3s 744us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 4/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 5/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 6/50
3901/3901 [==============================] - 3s 749us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 7/50
3901/3901 [==============================] - 3s 735us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 8/50
3901/3901 [==============================] - 3s 722us/step - loss:
```

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9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 9/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 10/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 11/50
3901/3901 [==============================] - 3s 729us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 12/50
3901/3901 [==============================] - 3s 738us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 13/50
3901/3901 [==============================] - 3s 758us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 14/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 15/50
3901/3901 [==============================] - 3s 749us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 16/50
3901/3901 [==============================] - 3s 737us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 17/50
3901/3901 [==============================] - 3s 743us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 18/50
3901/3901 [==============================] - 3s 746us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 19/50
3901/3901 [==============================] - 3s 733us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 20/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
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33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 21/50
3901/3901 [==============================] - 3s 729us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 22/50
3901/3901 [==============================] - 3s 723us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 23/50
3901/3901 [==============================] - 3s 722us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 24/50
3901/3901 [==============================] - 3s 735us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 25/50
3901/3901 [==============================] - 3s 738us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 26/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 27/50
3901/3901 [==============================] - 3s 737us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 28/50
3901/3901 [==============================] - 3s 735us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 29/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 30/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 31/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 32/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
```

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l_recall: 0.6763 - val_f1: 0.4509
Epoch 33/50
3901/3901 [==============================] - 3s 732us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 34/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 35/50
3901/3901 [==============================] - 3s 721us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 36/50
3901/3901 [==============================] - 3s 722us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 37/50
3901/3901 [==============================] - 3s 722us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 38/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 39/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 40/50
3901/3901 [==============================] - 3s 718us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 41/50
3901/3901 [==============================] - 3s 720us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 42/50
3901/3901 [==============================] - 3s 721us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 43/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 44/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
```

```
Epoch 45/50
3901/3901 [==============================] - 3s 722us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 46/50
3901/3901 [==============================] - 3s 723us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 47/50
3901/3901 [==============================] - 3s 719us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 48/50
3901/3901 [==============================] - 3s 716us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 49/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Epoch 50/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.1312 - acc: 0.3368 - precision: 0.3325 - recall: 0.6650 - f1: 0.44
33 - val_loss: 9.1001 - val_acc: 0.3135 - val_precision: 0.3382 - va
l_recall: 0.6763 - val_f1: 0.4509
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_25 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_46 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_47 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_22 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_22 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_24 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_25 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_46 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_47 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_22 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
```

```
flatten_22 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_24 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 932us/step - loss:
8.4601 - acc: 0.3315 - precision: 0.3242 - recall: 0.2676 - f1: 0.28
63 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 2/50
3901/3901 [==============================] - 3s 738us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3195 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 3/50
3901/3901 [==============================] - 3s 729us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 4/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 5/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 6/50
3901/3901 [==============================] - 3s 735us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 7/50
3901/3901 [==============================] - 3s 740us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 8/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 9/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 10/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 11/50
3901/3901 [==============================] - 3s 727us/step - loss:
```

```
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 12/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 13/50
3901/3901 [==============================] - 3s 732us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 14/50
3901/3901 [==============================] - 3s 729us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3199 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 15/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 16/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 17/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3194 - recall: 0.3109 - f1: 0.31
50 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 18/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 19/50
3901/3901 [==============================] - 3s 734us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 20/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3195 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 21/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3201 - recall: 0.3109 - f1: 0.31
54 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 22/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3195 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 23/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
```

```
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 24/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 25/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 26/50
3901/3901 [==============================] - 3s 723us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 27/50
3901/3901 [==============================] - 3s 733us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3193 - recall: 0.3109 - f1: 0.31
50 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 28/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 29/50
3901/3901 [==============================] - 3s 732us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 30/50
3901/3901 [==============================] - 3s 723us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3201 - recall: 0.3109 - f1: 0.31
54 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 31/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3202 - recall: 0.3109 - f1: 0.31
54 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 32/50
3901/3901 [==============================] - 3s 735us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 33/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3200 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 34/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 35/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
```

```
l_recall: 0.2758 - val_f1: 0.2817
Epoch 36/50
3901/3901 [==============================] - 3s 728us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3191 - recall: 0.3109 - f1: 0.31
49 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 37/50
3901/3901 [==============================] - 3s 727us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 38/50
3901/3901 [==============================] - 3s 725us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3200 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 39/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 40/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3199 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 41/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 42/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3201 - recall: 0.3109 - f1: 0.31
54 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 43/50
3901/3901 [==============================] - 3s 723us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3200 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 44/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3200 - recall: 0.3109 - f1: 0.31
54 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 45/50
3901/3901 [==============================] - 3s 730us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3199 - recall: 0.3109 - f1: 0.31
53 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 46/50
3901/3901 [==============================] - 3s 722us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3197 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 47/50
3901/3901 [==============================] - 3s 726us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
```

```
Epoch 48/50
3901/3901 [==============================] - 3s 724us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3191 - recall: 0.3109 - f1: 0.31
49 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 49/50
3901/3901 [==============================] - 3s 731us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3196 - recall: 0.3109 - f1: 0.31
51 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Epoch 50/50
3901/3901 [==============================] - 3s 729us/step - loss:
9.2056 - acc: 0.3368 - precision: 0.3198 - recall: 0.3109 - f1: 0.31
52 - val_loss: 9.2170 - val_acc: 0.3135 - val_precision: 0.2881 - va
l_recall: 0.2758 - val_f1: 0.2817
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_26 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_48 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_23 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_23 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_25 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_26 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_48 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_23 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_23 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_25 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 918us/step - loss:
8.3071 - acc: 0.3261 - precision: 0.3185 - recall: 0.5901 - f1: 0.41
22 - val_loss: 5.2167 - val_acc: 0.3237 - val_precision: 0.3384 - va
l_recall: 0.6749 - val_f1: 0.4507
Epoch 2/50
```

```
3901/3901 [==============================] - 3s 729us/step - loss:
5.4003 - acc: 0.3145 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 3/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
35 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 4/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3326 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 5/50
3901/3901 [==============================] - 3s 726us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 6/50
3901/3901 [==============================] - 3s 724us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 7/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 8/50
3901/3901 [==============================] - 3s 724us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 9/50
3901/3901 [==============================] - 3s 726us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 10/50
3901/3901 [==============================] - 3s 741us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 11/50
3901/3901 [==============================] - 3s 749us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
35 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 12/50
3901/3901 [==============================] - 3s 727us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 13/50
3901/3901 [==============================] - 3s 731us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
35 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 14/50
3901/3901 [==============================] - 3s 724us/step - loss:
```

```
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 15/50
3901/3901 [==============================] - 3s 727us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 16/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 17/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 18/50
3901/3901 [==============================] - 3s 725us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 19/50
3901/3901 [==============================] - 3s 724us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 20/50
3901/3901 [==============================] - 3s 732us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 21/50
3901/3901 [==============================] - 3s 728us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
35 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 22/50
3901/3901 [==============================] - 3s 729us/step - loss:
5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.44
34 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - va
l_recall: 0.6749 - val_f1: 0.4510
Epoch 23/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 24/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 25/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 26/50
3901/3901 [==============================] - 3s 723us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
```

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434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 27/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 28/50
3901/3901 [==============================] - 3s 723us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 29/50
3901/3901 [==============================] - 3s 720us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 30/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 31/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 32/50
3901/3901 [==============================] - 3s 726us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 33/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 34/50
3901/3901 [==============================] - 3s 723us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 35/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 36/50
3901/3901 [==============================] - 3s 731us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 37/50
3901/3901 [==============================] - 3s 726us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 38/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
```

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al_recall: 0.6749 - val_f1: 0.4510
Epoch 39/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 40/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 41/50
3901/3901 [==============================] - 3s 728us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 42/50
3901/3901 [==============================] - 3s 727us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 43/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 44/50
3901/3901 [==============================] - 3s 727us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 45/50
3901/3901 [==============================] - 3s 727us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 46/50
3901/3901 [==============================] - 3s 731us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
435 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 47/50
3901/3901 [==============================] - 3s 750us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 48/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 49/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
Epoch 50/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4002 - acc: 0.3276 - precision: 0.3327 - recall: 0.6647 - f1: 0.4
434 - val_loss: 5.2167 - val_acc: 0.3266 - val_precision: 0.3386 - v
al_recall: 0.6749 - val_f1: 0.4510
```

```
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_27 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_51 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_24 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_24 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_26 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_27 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_51 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_24 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_24 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_26 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 949us/step - loss: 1
0.4522 - acc: 0.3230 - precision: 0.3386 - recall: 0.6547 - f1: 0.44
63 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 2/50
3901/3901 [==============================] - 3s 736us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 3/50
3901/3901 [==============================] - 3s 739us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 4/50
3901/3901 [==============================] - 3s 733us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 5/50
```

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3901/3901 [==============================] - 3s 730us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 6/50
3901/3901 [==============================] - 3s 744us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 7/50
3901/3901 [==============================] - 3s 737us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 8/50
3901/3901 [==============================] - 3s 734us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 9/50
3901/3901 [==============================] - 3s 738us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 10/50
3901/3901 [==============================] - 3s 731us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3424 - recall: 0.6591 - f1: 0.45
06 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 11/50
3901/3901 [==============================] - 3s 732us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 12/50
3901/3901 [==============================] - 3s 735us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 13/50
3901/3901 [==============================] - 3s 742us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 14/50
3901/3901 [==============================] - 3s 725us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 15/50
3901/3901 [==============================] - 3s 729us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 16/50
3901/3901 [==============================] - 3s 742us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 17/50
3901/3901 [==============================] - 3s 753us/step - loss: 1
```

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0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 18/50
3901/3901 [==============================] - 3s 741us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 19/50
3901/3901 [==============================] - 3s 742us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3419 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 20/50
3901/3901 [==============================] - 3s 745us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 21/50
3901/3901 [==============================] - 3s 725us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 22/50
3901/3901 [==============================] - 3s 732us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 23/50
3901/3901 [==============================] - 3s 729us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 24/50
3901/3901 [==============================] - 3s 730us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 25/50
3901/3901 [==============================] - 3s 729us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 26/50
3901/3901 [==============================] - 3s 731us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 27/50
3901/3901 [==============================] - 3s 732us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 28/50
3901/3901 [==============================] - 3s 727us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 29/50
3901/3901 [==============================] - 3s 729us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
```

```
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 30/50
3901/3901 [==============================] - 3s 728us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 31/50
3901/3901 [==============================] - 3s 728us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 32/50
3901/3901 [==============================] - 3s 724us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 33/50
3901/3901 [==============================] - 3s 727us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
02 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 34/50
3901/3901 [==============================] - 3s 731us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 35/50
3901/3901 [==============================] - 3s 726us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
05 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 36/50
3901/3901 [==============================] - 3s 724us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 37/50
3901/3901 [==============================] - 3s 762us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 38/50
3901/3901 [==============================] - 3s 778us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 39/50
3901/3901 [==============================] - 3s 740us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 40/50
3901/3901 [==============================] - 3s 737us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 41/50
3901/3901 [==============================] - 3s 737us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
```

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al_recall: 0.6851 - val_f1: 0.4703
Epoch 42/50
3901/3901 [==============================] - 3s 738us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 43/50
3901/3901 [==============================] - 3s 735us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3422 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 44/50
3901/3901 [==============================] - 3s 742us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 45/50
3901/3901 [==============================] - 3s 738us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 46/50
3901/3901 [==============================] - 3s 760us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 47/50
3901/3901 [==============================] - 3s 766us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3420 - recall: 0.6591 - f1: 0.45
03 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 48/50
3901/3901 [==============================] - 3s 738us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3423 - recall: 0.6591 - f1: 0.45
05 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 49/50
3901/3901 [==============================] - 3s 742us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3424 - recall: 0.6591 - f1: 0.45
06 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Epoch 50/50
3901/3901 [==============================] - 3s 744us/step - loss: 1
0.6889 - acc: 0.3250 - precision: 0.3421 - recall: 0.6591 - f1: 0.45
04 - val_loss: 11.0651 - val_acc: 0.3614 - val_precision: 0.3581 - v
al_recall: 0.6851 - val_f1: 0.4703
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_28 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_52 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_53 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_25 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_25 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_27 (Dense)             (None, 3)                 3633
```

```
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_28 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_52 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_53 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_25 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_25 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_27 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 956us/step - loss:
 6.1430 - acc: 0.3315 - precision: 0.3227 - recall: 0.4724 - f1: 0.3
737 - val_loss: 5.8952 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 2/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.3384 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 3/50
3901/3901 [==============================] - 3s 729us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 4/50
3901/3901 [==============================] - 3s 729us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 5/50
3901/3901 [==============================] - 3s 744us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 6/50
3901/3901 [==============================] - 3s 752us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 7/50
3901/3901 [==============================] - 3s 749us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 8/50
```

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3901/3901 [==============================] - 3s 751us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 9/50
3901/3901 [==============================] - 3s 751us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 10/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 11/50
3901/3901 [==============================] - 3s 743us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 12/50
3901/3901 [==============================] - 3s 733us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 13/50
3901/3901 [==============================] - 3s 743us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 14/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 15/50
3901/3901 [==============================] - 3s 733us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 16/50
3901/3901 [==============================] - 3s 739us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 17/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 18/50
3901/3901 [==============================] - 3s 746us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 19/50
3901/3901 [==============================] - 3s 744us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 20/50
3901/3901 [==============================] - 3s 746us/step - loss:
```

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 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 21/50
3901/3901 [==============================] - 3s 755us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 22/50
3901/3901 [==============================] - 3s 739us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 23/50
3901/3901 [==============================] - 3s 751us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 24/50
3901/3901 [==============================] - 3s 741us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 25/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 26/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 27/50
3901/3901 [==============================] - 3s 741us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 28/50
3901/3901 [==============================] - 3s 738us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 29/50
3901/3901 [==============================] - 3s 742us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 30/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 31/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 32/50
3901/3901 [==============================] - 3s 737us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
```

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281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 33/50
3901/3901 [==============================] - 3s 734us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 34/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 35/50
3901/3901 [==============================] - 3s 732us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 36/50
3901/3901 [==============================] - 3s 725us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 37/50
3901/3901 [==============================] - 3s 732us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 38/50
3901/3901 [==============================] - 3s 732us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 39/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 40/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 41/50
3901/3901 [==============================] - 3s 743us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 42/50
3901/3901 [==============================] - 3s 745us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 43/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 44/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
```

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al_recall: 0.3628 - val_f1: 0.3628
Epoch 45/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 46/50
3901/3901 [==============================] - 3s 740us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 47/50
3901/3901 [==============================] - 3s 785us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 48/50
3901/3901 [==============================] - 3s 754us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 49/50
3901/3901 [==============================] - 3s 746us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 50/50
3901/3901 [==============================] - 3s 750us/step - loss:
 5.4085 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 6.1525 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_29 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_54 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_55 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_26 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_26 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_28 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_29 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_54 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_55 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_26 (MaxPooling (None, 11, 11, 10)        0
```

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_________________________________________________________________
flatten_26 (Flatten)         (None, 1210)              0         
_________________________________________________________________
dense_28 (Dense)             (None, 3)                 3633      
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
027 - acc: 0.3268 - precision: 0.3325 - recall: 0.9859 - f1: 0.4966
 - val_loss: 1.0988 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0987 - acc: 0.3258 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0985 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 776us/step - loss:
 1.0987 - acc: 0.3225 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0987 - acc: 0.3320 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3245 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 792us/step - loss:
 1.0986 - acc: 0.3312 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3933 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 756us/step - loss:
 1.0987 - acc: 0.3373 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 792us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 756us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
```

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3901/3901 [==============================] - 3s 761us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 749us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 752us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0986 - acc: 0.3212 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3962 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
3901/3901 [==============================] - 3s 752us/step - loss:
 1.0986 - acc: 0.3356 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0986 - acc: 0.3345 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 3s 755us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 756us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 760us/step - loss:
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 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 770us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0987 - acc: 0.3320 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 772us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 3s 780us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
```

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000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 3s 757us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 3s 745us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 42/50
3901/3901 [==============================] - 3s 745us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 3s 744us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 44/50
3901/3901 [==============================] - 3s 746us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 45/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0986 - acc: 0.3220 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 46/50
3901/3901 [==============================] - 3s 748us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 47/50
3901/3901 [==============================] - 3s 749us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
```

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al_recall: 1.0000 - val_f1: 0.5000
Epoch 48/50
3901/3901 [==============================] - 3s 748us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 49/50
3901/3901 [==============================] - 3s 752us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 50/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_30 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_56 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_57 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_27 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_27 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_29 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_30 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_56 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_57 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_27 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_27 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_29 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 970us/step - loss:
 1.1061 - acc: 0.3304 - precision: 0.3327 - recall: 0.9826 - f1: 0.4
961 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
```

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Epoch 2/50
3901/3901 [==============================] - 3s 741us/step - loss:
 1.0993 - acc: 0.3345 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 752us/step - loss:
 1.0996 - acc: 0.3368 - precision: 0.3334 - recall: 0.9974 - f1: 0.4
997 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 744us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 745us/step - loss:
 1.1013 - acc: 0.3368 - precision: 0.3330 - recall: 0.9967 - f1: 0.4
991 - val_loss: 1.0983 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 746us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 750us/step - loss:
 1.0993 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 743us/step - loss:
 1.1009 - acc: 0.3368 - precision: 0.3354 - recall: 0.9877 - f1: 0.5
000 - val_loss: 1.0984 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 746us/step - loss:
 1.0990 - acc: 0.3368 - precision: 0.3335 - recall: 1.0000 - f1: 0.5
002 - val_loss: 1.0980 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 748us/step - loss:
 1.0982 - acc: 0.3368 - precision: 0.3337 - recall: 0.9990 - f1: 0.5
002 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 746us/step - loss:
 1.0984 - acc: 0.3368 - precision: 0.3341 - recall: 0.9944 - f1: 0.4
998 - val_loss: 1.0967 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
```

```
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0966 - acc: 0.3486 - precision: 0.3339 - recall: 0.9885 - f1: 0.4
987 - val_loss: 1.0892 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 745us/step - loss:
 1.0848 - acc: 0.3707 - precision: 0.3437 - recall: 0.9154 - f1: 0.4
968 - val_loss: 1.1001 - val_acc: 0.3004 - val_precision: 0.3382 - v
al_recall: 0.6763 - val_f1: 0.4509
Epoch 16/50
3901/3901 [==============================] - 3s 748us/step - loss:
 1.0544 - acc: 0.4294 - precision: 0.4252 - recall: 0.4755 - f1: 0.4
005 - val_loss: 1.2901 - val_acc: 0.3237 - val_precision: 0.3745 - v
al_recall: 0.3208 - val_f1: 0.3453
Epoch 17/50
3901/3901 [==============================] - 3s 748us/step - loss:
 1.0152 - acc: 0.4668 - precision: 0.1226 - recall: 0.0315 - f1: 0.0
453 - val_loss: 0.9770 - val_acc: 0.4194 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 18/50
3901/3901 [==============================] - 3s 752us/step - loss:
 0.9781 - acc: 0.4886 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.9359 - val_acc: 0.4848 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 19/50
3901/3901 [==============================] - 3s 748us/step - loss:
 0.9328 - acc: 0.5211 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.9135 - val_acc: 0.4020 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 20/50
3901/3901 [==============================] - 3s 745us/step - loss:
 0.8995 - acc: 0.5496 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.7870 - val_acc: 0.7213 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 21/50
3901/3901 [==============================] - 3s 747us/step - loss:
 0.8561 - acc: 0.5732 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.7663 - val_acc: 0.6241 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 22/50
3901/3901 [==============================] - 3s 747us/step - loss:
 0.8237 - acc: 0.5863 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.7068 - val_acc: 0.6865 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 23/50
3901/3901 [==============================] - 3s 748us/step - loss:
 0.7901 - acc: 0.5957 - precision: 0.0082 - recall: 0.0010 - f1: 0.0
018 - val_loss: 0.7872 - val_acc: 0.6981 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 24/50
3901/3901 [==============================] - 3s 747us/step - loss:
 0.7545 - acc: 0.6245 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.6386 - val_acc: 0.7315 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 25/50
3901/3901 [==============================] - 3s 750us/step - loss:
 0.7199 - acc: 0.6324 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.6252 - val_acc: 0.6197 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 26/50
3901/3901 [==============================] - 3s 748us/step - loss:
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 0.7195 - acc: 0.6383 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.6177 - val_acc: 0.8229 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 27/50
3901/3901 [==============================] - 3s 746us/step - loss:
 0.6697 - acc: 0.6734 - precision: 0.0000e+00 - recall: 0.0000e+00 -
f1: 0.0000e+00 - val_loss: 0.5738 - val_acc: 0.8258 - val_precision:
0.0000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 28/50
3901/3901 [==============================] - 3s 747us/step - loss:
 0.6628 - acc: 0.6729 - precision: 0.0164 - recall: 5.1269e-04 - f1:
9.9431e-04 - val_loss: 0.6599 - val_acc: 0.5225 - val_precision: 0.0
000e+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 29/50
3901/3901 [==============================] - 3s 749us/step - loss:
 0.6346 - acc: 0.6624 - precision: 0.0246 - recall: 7.6903e-04 - f1:
0.0015 - val_loss: 0.5434 - val_acc: 0.8389 - val_precision: 0.0000e
+00 - val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 30/50
3901/3901 [==============================] - 3s 745us/step - loss:
 0.6157 - acc: 0.6998 - precision: 0.0246 - recall: 0.0010 - f1: 0.0
020 - val_loss: 0.5422 - val_acc: 0.7678 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 31/50
3901/3901 [==============================] - 3s 749us/step - loss:
 0.5926 - acc: 0.7101 - precision: 0.0328 - recall: 0.0015 - f1: 0.0
029 - val_loss: 0.6710 - val_acc: 0.6096 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 32/50
3901/3901 [==============================] - 3s 749us/step - loss:
 0.5742 - acc: 0.7111 - precision: 0.0574 - recall: 0.0046 - f1: 0.0
078 - val_loss: 0.5257 - val_acc: 0.6125 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 33/50
3901/3901 [==============================] - 3s 749us/step - loss:
 0.5649 - acc: 0.7242 - precision: 0.0246 - recall: 0.0010 - f1: 0.0
020 - val_loss: 0.6882 - val_acc: 0.5051 - val_precision: 0.9289 - v
al_recall: 0.0450 - val_f1: 0.0851
Epoch 34/50
3901/3901 [==============================] - 3s 748us/step - loss:
 0.5400 - acc: 0.7544 - precision: 0.0574 - recall: 0.0054 - f1: 0.0
095 - val_loss: 0.5189 - val_acc: 0.6052 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 35/50
3901/3901 [==============================] - 3s 750us/step - loss:
 0.5135 - acc: 0.7806 - precision: 0.0738 - recall: 0.0036 - f1: 0.0
068 - val_loss: 0.4456 - val_acc: 0.8882 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 36/50
3901/3901 [==============================] - 3s 750us/step - loss:
 0.5132 - acc: 0.7806 - precision: 0.0246 - recall: 7.6903e-04 - f1:
0.0015 - val_loss: 0.4932 - val_acc: 0.8911 - val_precision: 0.4180
 - val_recall: 0.0131 - val_f1: 0.0253
Epoch 37/50
3901/3901 [==============================] - 3s 762us/step - loss:
 0.4707 - acc: 0.8095 - precision: 0.0574 - recall: 0.0031 - f1: 0.0
057 - val_loss: 0.4815 - val_acc: 0.6197 - val_precision: 0.1393 - v
al_recall: 0.0044 - val_f1: 0.0084
Epoch 38/50
3901/3901 [==============================] - 3s 743us/step - loss:
 0.4571 - acc: 0.8075 - precision: 0.0492 - recall: 0.0021 - f1: 0.0
```

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039 - val_loss: 0.3842 - val_acc: 0.9390 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 39/50
3901/3901 [==============================] - 3s 744us/step - loss:
 0.4298 - acc: 0.8357 - precision: 0.0164 - recall: 0.0010 - f1: 0.0
019 - val_loss: 0.3773 - val_acc: 0.8984 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 40/50
3901/3901 [==============================] - 3s 752us/step - loss:
 0.4130 - acc: 0.8441 - precision: 0.0246 - recall: 0.0015 - f1: 0.0
029 - val_loss: 0.4518 - val_acc: 0.6459 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 41/50
3901/3901 [==============================] - 3s 758us/step - loss:
 0.3917 - acc: 0.8521 - precision: 0.0738 - recall: 0.0046 - f1: 0.0
086 - val_loss: 0.3913 - val_acc: 0.8708 - val_precision: 0.6502 - v
al_recall: 0.0232 - val_f1: 0.0447
Epoch 42/50
3901/3901 [==============================] - 3s 748us/step - loss:
 0.3713 - acc: 0.8711 - precision: 0.1395 - recall: 0.0056 - f1: 0.0
108 - val_loss: 0.2909 - val_acc: 0.9507 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 43/50
3901/3901 [==============================] - 3s 756us/step - loss:
 0.3523 - acc: 0.8749 - precision: 0.1633 - recall: 0.0074 - f1: 0.0
140 - val_loss: 0.3141 - val_acc: 0.8940 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 44/50
3901/3901 [==============================] - 3s 759us/step - loss:
 0.3444 - acc: 0.8775 - precision: 0.1805 - recall: 0.0092 - f1: 0.0
173 - val_loss: 0.4723 - val_acc: 0.7271 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 45/50
3901/3901 [==============================] - 3s 764us/step - loss:
 0.3232 - acc: 0.8987 - precision: 0.0984 - recall: 0.0046 - f1: 0.0
087 - val_loss: 0.3426 - val_acc: 0.8766 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 46/50
3901/3901 [==============================] - 3s 767us/step - loss:
 0.3122 - acc: 0.8957 - precision: 0.1641 - recall: 0.0087 - f1: 0.0
160 - val_loss: 0.2593 - val_acc: 0.9448 - val_precision: 0.0464 - v
al_recall: 0.0015 - val_f1: 0.0028
Epoch 47/50
3901/3901 [==============================] - 3s 746us/step - loss:
 0.3085 - acc: 0.9011 - precision: 0.1559 - recall: 0.0069 - f1: 0.0
130 - val_loss: 0.2358 - val_acc: 0.9318 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 48/50
3901/3901 [==============================] - 3s 741us/step - loss:
 0.2949 - acc: 0.9075 - precision: 0.1723 - recall: 0.0092 - f1: 0.0
172 - val_loss: 0.2477 - val_acc: 0.9231 - val_precision: 0.0000e+00
- val_recall: 0.0000e+00 - val_f1: 0.0000e+00
Epoch 49/50
3901/3901 [==============================] - 3s 746us/step - loss:
 0.2835 - acc: 0.9136 - precision: 0.2461 - recall: 0.0108 - f1: 0.0
203 - val_loss: 0.2300 - val_acc: 0.9521 - val_precision: 0.1858 - v
al_recall: 0.0058 - val_f1: 0.0113
Epoch 50/50
3901/3901 [==============================] - 3s 747us/step - loss:
 0.2778 - acc: 0.9064 - precision: 0.2625 - recall: 0.0113 - f1: 0.0
214 - val_loss: 0.1955 - val_acc: 0.9507 - val_precision: 0.1858 - v
```

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al_recall: 0.0058 - val_f1: 0.0113
Normalized confusion matrix

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_31 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_58 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_59 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_28 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_28 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_30 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0

_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_31 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_58 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_59 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_28 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_28 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_30 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0

_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 976us/step - loss:
 1.1007 - acc: 0.3330 - precision: 0.3328 - recall: 0.9951 - f1: 0.4
987 - val_loss: 1.1012 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.1006 - acc: 0.3304 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1003 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 749us/step - loss:
 1.1001 - acc: 0.3271 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0996 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 774us/step - loss:
 1.0997 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1034 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
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Epoch 5/50
3901/3901 [==============================] - 3s 771us/step - loss:
 1.1002 - acc: 0.3212 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1003 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 790us/step - loss:
 1.0991 - acc: 0.3212 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 769us/step - loss:
 1.0989 - acc: 0.3443 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 766us/step - loss:
 1.0993 - acc: 0.3202 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0989 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 766us/step - loss:
 1.0991 - acc: 0.3304 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0998 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0990 - acc: 0.3302 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1001 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0989 - acc: 0.3220 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0991 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0991 - acc: 0.3253 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0994 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0990 - acc: 0.3286 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0996 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0989 - acc: 0.3266 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0997 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0990 - acc: 0.3230 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1000 - val_acc: 0.2758 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0989 - acc: 0.3271 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1004 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
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3901/3901 [==============================] - 3s 764us/step - loss:
 1.0989 - acc: 0.3340 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.1001 - val_acc: 0.3454 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 776us/step - loss:
 1.0990 - acc: 0.3230 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0988 - acc: 0.3243 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 3s 774us/step - loss:
 1.0988 - acc: 0.3358 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 757us/step - loss:
 1.0988 - acc: 0.3335 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0990 - val_acc: 0.3454 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0988 - acc: 0.3366 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 778us/step - loss:
 1.0987 - acc: 0.3371 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 774us/step - loss:
 1.0988 - acc: 0.3345 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 775us/step - loss:
 1.0988 - acc: 0.3294 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0997 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 783us/step - loss:
 1.0987 - acc: 0.3327 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 785us/step - loss:
 1.0988 - acc: 0.3340 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0988 - acc: 0.3353 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3527 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
3901/3901 [==============================] - 3s 751us/step - loss:
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 1.0987 - acc: 0.3291 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 3s 780us/step - loss:
 1.0987 - acc: 0.3238 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0994 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 3s 776us/step - loss:
 1.0987 - acc: 0.3317 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0994 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 3s 765us/step - loss:
 1.0987 - acc: 0.3312 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0995 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0987 - acc: 0.3330 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0994 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0987 - acc: 0.3327 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0987 - acc: 0.3320 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 3s 751us/step - loss:
 1.0987 - acc: 0.3373 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0987 - acc: 0.3315 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 3s 751us/step - loss:
 1.0987 - acc: 0.3302 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
```

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000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 42/50
3901/3901 [==============================] - 3s 755us/step - loss:
 1.0987 - acc: 0.3340 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 3s 774us/step - loss:
 1.0987 - acc: 0.3245 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 44/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0987 - acc: 0.3320 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 45/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0987 - acc: 0.3358 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0994 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 46/50
3901/3901 [==============================] - 3s 771us/step - loss:
 1.0987 - acc: 0.3238 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 47/50
3901/3901 [==============================] - 3s 779us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 48/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0987 - acc: 0.3366 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 49/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 50/50
3901/3901 [==============================] - 3s 765us/step - loss:
 1.0987 - acc: 0.3253 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_32 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_60 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_61 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_29 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_29 (Flatten)         (None, 1210)              0
_________________________________________________________________
```

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dense_31 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0

_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_32 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_60 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_61 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_29 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_29 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_31 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0

_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 990us/step - loss:
 1.1042 - acc: 0.3445 - precision: 0.3337 - recall: 0.9300 - f1: 0.4
862 - val_loss: 1.1037 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 747us/step - loss:
 1.0994 - acc: 0.3335 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0989 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 757us/step - loss:
 1.0988 - acc: 0.3261 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 751us/step - loss:
 1.0987 - acc: 0.3340 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 752us/step - loss:
 1.0986 - acc: 0.3348 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 760us/step - loss:
 1.0986 - acc: 0.3343 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 750us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
```

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Epoch 8/50
3901/3901 [==============================] - 3s 776us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 781us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 812us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 781us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 778us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 753us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 750us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 793us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
3901/3901 [==============================] - 3s 800us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 776us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 824us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
```

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3901/3901 [==============================] - 3s 764us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 767us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 766us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
3901/3901 [==============================] - 3s 764us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 3s 768us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 3s 767us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 3s 780us/step - loss:
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 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 3s 769us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 3s 769us/step - loss:
 1.0983 - acc: 0.3368 - precision: 0.3338 - recall: 0.9982 - f1: 0.5
002 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 3s 746us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 3s 750us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 3s 758us/step - loss:
 1.0995 - acc: 0.3368 - precision: 0.3333 - recall: 0.9972 - f1: 0.4
995 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 3s 751us/step - loss:
 1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 3s 749us/step - loss:
 1.0988 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 3s 766us/step - loss:
 1.0987 - acc: 0.3368 - precision: 0.3333 - recall: 0.9997 - f1: 0.4
999 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0980 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 42/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0983 - acc: 0.3368 - precision: 0.3332 - recall: 0.9946 - f1: 0.4
990 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 3s 761us/step - loss:
 1.0960 - acc: 0.3432 - precision: 0.3326 - recall: 0.9951 - f1: 0.4
985 - val_loss: 1.0891 - val_acc: 0.2772 - val_precision: 0.3369 - v
al_recall: 1.0000 - val_f1: 0.5040
Epoch 44/50
3901/3901 [==============================] - 3s 762us/step - loss:
 1.0845 - acc: 0.3484 - precision: 0.3424 - recall: 0.9797 - f1: 0.5
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069 - val_loss: 1.0738 - val_acc: 0.3991 - val_precision: 0.3462 - v
al_recall: 0.9913 - val_f1: 0.5132
Epoch 45/50
3901/3901 [==============================] - 3s 767us/step - loss:
 1.0711 - acc: 0.3645 - precision: 0.3572 - recall: 0.9587 - f1: 0.5
199 - val_loss: 1.0466 - val_acc: 0.4833 - val_precision: 0.3613 - v
al_recall: 0.9869 - val_f1: 0.5289
Epoch 46/50
3901/3901 [==============================] - 3s 756us/step - loss:
 1.0446 - acc: 0.4217 - precision: 0.3823 - recall: 0.8969 - f1: 0.5
347 - val_loss: 1.0832 - val_acc: 0.3614 - val_precision: 0.3541 - v
al_recall: 0.6328 - val_f1: 0.4534
Epoch 47/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0130 - acc: 0.4819 - precision: 0.4347 - recall: 0.7552 - f1: 0.5
474 - val_loss: 0.9893 - val_acc: 0.4978 - val_precision: 0.4632 - v
al_recall: 0.6517 - val_f1: 0.5408
Epoch 48/50
3901/3901 [==============================] - 3s 764us/step - loss:
 0.9786 - acc: 0.5127 - precision: 0.5066 - recall: 0.6427 - f1: 0.5
644 - val_loss: 0.9346 - val_acc: 0.5457 - val_precision: 0.5654 - v
al_recall: 0.5718 - val_f1: 0.5668
Epoch 49/50
3901/3901 [==============================] - 3s 763us/step - loss:
 0.9274 - acc: 0.5450 - precision: 0.5583 - recall: 0.5160 - f1: 0.5
294 - val_loss: 0.8796 - val_acc: 0.6125 - val_precision: 0.5292 - v
al_recall: 0.3977 - val_f1: 0.4492
Epoch 50/50
3901/3901 [==============================] - 3s 761us/step - loss:
 0.8568 - acc: 0.5965 - precision: 0.5681 - recall: 0.4243 - f1: 0.4
790 - val_loss: 0.7095 - val_acc: 0.6865 - val_precision: 0.6751 - v
al_recall: 0.4702 - val_f1: 0.5487
Normalized confusion matrix


/opt/netapps/thermocalc/2018/anaconda/lib/python3.6/site-packages/ma
tplotlib/pyplot.py:528: RuntimeWarning: More than 20 figures have be
en opened. Figures created through the pyplot interface (`matplotli
b.pyplot.figure`) are retained until explicitly closed and may consu
me too much memory. (To control this warning, see the rcParam `figur
e.max_open_warning`).
  max_open_warning, RuntimeWarning)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_33 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_62 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_63 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_30 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_32 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
```


```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_33 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_62 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_63 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_30 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_32 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
```


```
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 994us/step - loss:
1.1059 - acc: 0.3225 - precision: 0.3339 - recall: 0.9956 - f1: 0.49
98 - val_loss: 1.0990 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 756us/step - loss:
1.0988 - acc: 0.3317 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0986 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0987 - acc: 0.3215 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 748us/step - loss:
1.0987 - acc: 0.3307 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 758us/step - loss:
```

```
1.0987 - acc: 0.3335 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 757us/step - loss:
1.0986 - acc: 0.3312 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 753us/step - loss:
1.0986 - acc: 0.3194 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3875 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 750us/step - loss:
1.0986 - acc: 0.3415 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 745us/step - loss:
1.0986 - acc: 0.3432 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 749us/step - loss:
1.0986 - acc: 0.3343 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 752us/step - loss:
1.0986 - acc: 0.3415 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 753us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 750us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 760us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
```

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00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 754us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 3s 761us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 760us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 771us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 839us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 738us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 717us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 707us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 707us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 703us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
```

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l_recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 3s 705us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 3s 718us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 3s 718us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 3s 702us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 3s 714us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0997 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 3s 709us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 3s 716us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 3s 704us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 3s 706us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0995 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 3s 717us/step - loss:
1.0984 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0999 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 3s 711us/step - loss:
1.0981 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
```

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Epoch 42/50
3901/3901 [==============================] - 3s 706us/step - loss:
1.0982 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.1001 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 3s 709us/step - loss:
1.0976 - acc: 0.3233 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0981 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 44/50
3901/3901 [==============================] - 3s 704us/step - loss:
1.0962 - acc: 0.3238 - precision: 0.3338 - recall: 0.9992 - f1: 0.50
04 - val_loss: 1.0958 - val_acc: 0.3091 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 45/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0910 - acc: 0.3297 - precision: 0.3360 - recall: 0.9997 - f1: 0.50
30 - val_loss: 1.0853 - val_acc: 0.2917 - val_precision: 0.3408 - va
l_recall: 0.9985 - val_f1: 0.5082
Epoch 46/50
3901/3901 [==============================] - 3s 740us/step - loss:
1.0838 - acc: 0.2720 - precision: 0.3400 - recall: 0.9954 - f1: 0.50
68 - val_loss: 1.0765 - val_acc: 0.2642 - val_precision: 0.3407 - va
l_recall: 0.9985 - val_f1: 0.5080
Epoch 47/50
3901/3901 [==============================] - 3s 723us/step - loss:
1.0725 - acc: 0.3468 - precision: 0.3458 - recall: 0.9867 - f1: 0.51
20 - val_loss: 1.0608 - val_acc: 0.4064 - val_precision: 0.3509 - va
l_recall: 0.9797 - val_f1: 0.5166
Epoch 48/50
3901/3901 [==============================] - 3s 722us/step - loss:
1.0454 - acc: 0.4250 - precision: 0.3683 - recall: 0.9367 - f1: 0.52
77 - val_loss: 1.0181 - val_acc: 0.4557 - val_precision: 0.4003 - va
l_recall: 0.8708 - val_f1: 0.5484
Epoch 49/50
3901/3901 [==============================] - 3s 715us/step - loss:
1.0122 - acc: 0.4801 - precision: 0.4445 - recall: 0.7293 - f1: 0.54
46 - val_loss: 0.9624 - val_acc: 0.5414 - val_precision: 0.5574 - va
l_recall: 0.5849 - val_f1: 0.5687
Epoch 50/50
3901/3901 [==============================] - 3s 717us/step - loss:
0.9297 - acc: 0.5532 - precision: 0.5518 - recall: 0.3848 - f1: 0.43
76 - val_loss: 0.8998 - val_acc: 0.5385 - val_precision: 0.5415 - va
l_recall: 0.3135 - val_f1: 0.3915
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_34 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_64 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_65 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_31 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_31 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_33 (Dense)             (None, 3)                 3633
=================================================================
```

```
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_34 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_64 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_65 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_31 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_31 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_33 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 985us/step - loss:
1.1046 - acc: 0.3168 - precision: 0.3318 - recall: 0.9785 - f1: 0.49
45 - val_loss: 1.1031 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 726us/step - loss:
1.0990 - acc: 0.3371 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0990 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0987 - acc: 0.3302 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.1004 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 715us/step - loss:
1.0989 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 719us/step - loss:
1.0987 - acc: 0.3322 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0987 - acc: 0.3371 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0992 - val_acc: 0.3730 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 706us/step - loss:
1.0986 - acc: 0.3361 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 730us/step - loss:
```

```
1.0986 - acc: 0.3279 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0995 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 719us/step - loss:
1.0986 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0986 - acc: 0.3343 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0993 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0997 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 709us/step - loss:
1.0987 - acc: 0.3286 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0996 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 716us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 724us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 716us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0991 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0992 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 709us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0995 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 712us/step - loss:
1.0988 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0985 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
```

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00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 716us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 715us/step - loss:
1.0984 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.1000 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 707us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0988 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 713us/step - loss:
1.0980 - acc: 0.3366 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.1000 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 711us/step - loss:
1.0979 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0982 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 710us/step - loss:
1.0969 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0969 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 709us/step - loss:
1.0945 - acc: 0.3363 - precision: 0.3339 - recall: 0.9997 - f1: 0.50
06 - val_loss: 1.0925 - val_acc: 0.3135 - val_precision: 0.3371 - va
l_recall: 1.0000 - val_f1: 0.5042
Epoch 29/50
3901/3901 [==============================] - 3s 714us/step - loss:
1.0866 - acc: 0.3240 - precision: 0.3388 - recall: 0.9974 - f1: 0.50
58 - val_loss: 1.0714 - val_acc: 0.3788 - val_precision: 0.3422 - va
l_recall: 0.9971 - val_f1: 0.5095
Epoch 30/50
3901/3901 [==============================] - 3s 719us/step - loss:
1.0781 - acc: 0.3732 - precision: 0.3439 - recall: 0.9803 - f1: 0.50
90 - val_loss: 1.0624 - val_acc: 0.3977 - val_precision: 0.3443 - va
l_recall: 0.9971 - val_f1: 0.5118
Epoch 31/50
3901/3901 [==============================] - 3s 727us/step - loss:
1.0622 - acc: 0.3917 - precision: 0.3512 - recall: 0.9708 - f1: 0.51
55 - val_loss: 1.0426 - val_acc: 0.3599 - val_precision: 0.3902 - va
l_recall: 0.8911 - val_f1: 0.5426
Epoch 32/50
3901/3901 [==============================] - 3s 716us/step - loss:
1.0358 - acc: 0.4414 - precision: 0.4354 - recall: 0.6124 - f1: 0.49
54 - val_loss: 0.9886 - val_acc: 0.5835 - val_precision: 0.6430 - va
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l_recall: 0.5922 - val_f1: 0.6136
Epoch 33/50
3901/3901 [==============================] - 3s 710us/step - loss:
0.9458 - acc: 0.5745 - precision: 0.4547 - recall: 0.2551 - f1: 0.30
23 - val_loss: 0.8644 - val_acc: 0.6212 - val_precision: 0.4974 - va
l_recall: 0.1364 - val_f1: 0.2103
Epoch 34/50
3901/3901 [==============================] - 3s 707us/step - loss:
0.8196 - acc: 0.6327 - precision: 0.4725 - recall: 0.1548 - f1: 0.22
72 - val_loss: 0.7343 - val_acc: 0.6851 - val_precision: 0.5363 - va
l_recall: 0.2177 - val_f1: 0.3050
Epoch 35/50
3901/3901 [==============================] - 3s 741us/step - loss:
0.7446 - acc: 0.6516 - precision: 0.5096 - recall: 0.1861 - f1: 0.26
55 - val_loss: 0.7376 - val_acc: 0.5951 - val_precision: 0.4647 - va
l_recall: 0.1393 - val_f1: 0.2089
Epoch 36/50
3901/3901 [==============================] - 3s 721us/step - loss:
0.6982 - acc: 0.6632 - precision: 0.5093 - recall: 0.2056 - f1: 0.28
67 - val_loss: 0.6462 - val_acc: 0.7199 - val_precision: 0.5402 - va
l_recall: 0.2163 - val_f1: 0.3022
Epoch 37/50
3901/3901 [==============================] - 3s 784us/step - loss:
0.6774 - acc: 0.6673 - precision: 0.5262 - recall: 0.2179 - f1: 0.30
05 - val_loss: 0.6162 - val_acc: 0.7242 - val_precision: 0.5556 - va
l_recall: 0.2148 - val_f1: 0.3020
Epoch 38/50
3901/3901 [==============================] - 3s 747us/step - loss:
0.6647 - acc: 0.6716 - precision: 0.5261 - recall: 0.2435 - f1: 0.32
52 - val_loss: 0.6097 - val_acc: 0.7271 - val_precision: 0.5083 - va
l_recall: 0.1553 - val_f1: 0.2310
Epoch 39/50
3901/3901 [==============================] - 3s 768us/step - loss:
0.6473 - acc: 0.6780 - precision: 0.5209 - recall: 0.2310 - f1: 0.31
21 - val_loss: 0.5986 - val_acc: 0.7257 - val_precision: 0.5411 - va
l_recall: 0.2192 - val_f1: 0.3059
Epoch 40/50
3901/3901 [==============================] - 3s 750us/step - loss:
0.6466 - acc: 0.6767 - precision: 0.5306 - recall: 0.2481 - f1: 0.32
89 - val_loss: 0.6013 - val_acc: 0.7286 - val_precision: 0.5416 - va
l_recall: 0.2380 - val_f1: 0.3238
Epoch 41/50
3901/3901 [==============================] - 3s 747us/step - loss:
0.6395 - acc: 0.6747 - precision: 0.5272 - recall: 0.2625 - f1: 0.34
47 - val_loss: 0.6011 - val_acc: 0.7112 - val_precision: 0.5275 - va
l_recall: 0.2119 - val_f1: 0.2949
Epoch 42/50
3901/3901 [==============================] - 3s 698us/step - loss:
0.6273 - acc: 0.6826 - precision: 0.5212 - recall: 0.2489 - f1: 0.33
11 - val_loss: 0.6113 - val_acc: 0.7141 - val_precision: 0.5143 - va
l_recall: 0.2569 - val_f1: 0.3364
Epoch 43/50
3901/3901 [==============================] - 3s 685us/step - loss:
0.6278 - acc: 0.6788 - precision: 0.5227 - recall: 0.2671 - f1: 0.34
57 - val_loss: 0.5731 - val_acc: 0.7315 - val_precision: 0.5476 - va
l_recall: 0.2221 - val_f1: 0.3067
Epoch 44/50
3901/3901 [==============================] - 3s 680us/step - loss:
0.6176 - acc: 0.6839 - precision: 0.5238 - recall: 0.2597 - f1: 0.34
00 - val_loss: 0.5839 - val_acc: 0.7141 - val_precision: 0.5373 - va
l_recall: 0.2192 - val_f1: 0.3024
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Epoch 45/50
3901/3901 [==============================] - 3s 695us/step - loss:
0.6071 - acc: 0.6942 - precision: 0.5230 - recall: 0.2499 - f1: 0.33
13 - val_loss: 0.5940 - val_acc: 0.7170 - val_precision: 0.5389 - va
l_recall: 0.2671 - val_f1: 0.3498
Epoch 46/50
3901/3901 [==============================] - 3s 698us/step - loss:
0.6061 - acc: 0.6875 - precision: 0.5271 - recall: 0.2612 - f1: 0.34
23 - val_loss: 0.5652 - val_acc: 0.7446 - val_precision: 0.5484 - va
l_recall: 0.2337 - val_f1: 0.3198
Epoch 47/50
3901/3901 [==============================] - 3s 687us/step - loss:
0.5944 - acc: 0.7006 - precision: 0.5226 - recall: 0.2548 - f1: 0.33
55 - val_loss: 0.5970 - val_acc: 0.6996 - val_precision: 0.5296 - va
l_recall: 0.2351 - val_f1: 0.3157
Epoch 48/50
3901/3901 [==============================] - 3s 690us/step - loss:
0.5903 - acc: 0.6965 - precision: 0.5250 - recall: 0.2487 - f1: 0.33
01 - val_loss: 0.5474 - val_acc: 0.7460 - val_precision: 0.5427 - va
l_recall: 0.2235 - val_f1: 0.3056
Epoch 49/50
3901/3901 [==============================] - 3s 692us/step - loss:
0.5755 - acc: 0.6998 - precision: 0.5221 - recall: 0.2381 - f1: 0.32
12 - val_loss: 0.5639 - val_acc: 0.7329 - val_precision: 0.5214 - va
l_recall: 0.2221 - val_f1: 0.3012
Epoch 50/50
3901/3901 [==============================] - 3s 681us/step - loss:
0.5687 - acc: 0.7032 - precision: 0.5299 - recall: 0.2489 - f1: 0.33
09 - val_loss: 0.5283 - val_acc: 0.7591 - val_precision: 0.5554 - va
l_recall: 0.2293 - val_f1: 0.3147
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_35 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_66 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_67 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_32 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_32 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_34 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_35 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_66 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_67 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_32 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
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flatten_32 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_34 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
018 - acc: 0.3161 - precision: 0.3323 - recall: 0.9872 - f1: 0.4964
- val_loss: 1.0986 - val_acc: 0.3237 - val_precision: 0.3333 - val_r
ecall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 3s 704us/step - loss:
1.0987 - acc: 0.3235 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3237 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 3s 729us/step - loss:
1.0986 - acc: 0.3356 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 3s 725us/step - loss:
1.0986 - acc: 0.3271 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 3s 729us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 3s 714us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 3s 735us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 3s 720us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 3s 717us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 3s 699us/step - loss:
1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.50
00 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - va
l_recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 3s 721us/step - loss:
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 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 3s 766us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0989 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 3s 754us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 3s 751us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0987 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 3s 723us/step - loss:
 1.0987 - acc: 0.3381 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 3s 699us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 17/50
3901/3901 [==============================] - 3s 704us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 3s 702us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 3s 700us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 3s 700us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 3s 703us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
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000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 3s 722us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 3s 763us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 3s 700us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 3s 697us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 3s 708us/step - loss:
 1.0986 - acc: 0.3281 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 3s 716us/step - loss:
 1.0986 - acc: 0.3286 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3672 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 3s 705us/step - loss:
 1.0986 - acc: 0.3525 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3628 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3307 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 3s 698us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 3s 699us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
```

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al_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 3s 696us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 3s 711us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 3s 741us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 3s 726us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 3s 727us/step - loss:
 1.0986 - acc: 0.3438 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 3s 721us/step - loss:
 1.0986 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3237 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 42/50
3901/3901 [==============================] - 3s 701us/step - loss:
 1.1093 - acc: 0.3276 - precision: 0.3335 - recall: 0.9977 - f1: 0.4
998 - val_loss: 1.0986 - val_acc: 0.2961 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 3s 708us/step - loss:
 1.0986 - acc: 0.3366 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 44/50
3901/3901 [==============================] - 3s 693us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 45/50
3901/3901 [==============================] - 3s 696us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 46/50
3901/3901 [==============================] - 3s 695us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 47/50
3901/3901 [==============================] - 3s 739us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
```

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Epoch 48/50
3901/3901 [==============================] - 3s 759us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 49/50
3901/3901 [==============================] - 3s 734us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 50/50
3901/3901 [==============================] - 3s 708us/step - loss:
 1.0986 - acc: 0.3368 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0986 - val_acc: 0.3135 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_36 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_68 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_69 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_33 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_33 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_35 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_36 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_68 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_69 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_33 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_33 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_35 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 982us/step - loss:
 5.4000 - acc: 0.3294 - precision: 0.3258 - recall: 0.3394 - f1: 0.3
291 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 2/50
```

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3901/3901 [==============================] - 3s 689us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 3/50
3901/3901 [==============================] - 3s 748us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 4/50
3901/3901 [==============================] - 3s 722us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 5/50
3901/3901 [==============================] - 3s 712us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 6/50
3901/3901 [==============================] - 3s 687us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 7/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 8/50
3901/3901 [==============================] - 3s 706us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 9/50
3901/3901 [==============================] - 3s 705us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 10/50
3901/3901 [==============================] - 3s 686us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 11/50
3901/3901 [==============================] - 3s 689us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 12/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 13/50
3901/3901 [==============================] - 3s 706us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 14/50
3901/3901 [==============================] - 3s 688us/step - loss:
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 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 15/50
3901/3901 [==============================] - 3s 707us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 16/50
3901/3901 [==============================] - 3s 698us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 17/50
3901/3901 [==============================] - 3s 732us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 18/50
3901/3901 [==============================] - 3s 689us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 19/50
3901/3901 [==============================] - 3s 698us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 20/50
3901/3901 [==============================] - 3s 730us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 21/50
3901/3901 [==============================] - 3s 709us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 22/50
3901/3901 [==============================] - 3s 705us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 23/50
3901/3901 [==============================] - 3s 741us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 24/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 25/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 26/50
3901/3901 [==============================] - 3s 718us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
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281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 27/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 28/50
3901/3901 [==============================] - 3s 723us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 29/50
3901/3901 [==============================] - 3s 714us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 30/50
3901/3901 [==============================] - 3s 720us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 31/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 32/50
3901/3901 [==============================] - 3s 721us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 33/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 34/50
3901/3901 [==============================] - 3s 709us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 35/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 36/50
3901/3901 [==============================] - 3s 719us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 37/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 38/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
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al_recall: 0.3628 - val_f1: 0.3628
Epoch 39/50
3901/3901 [==============================] - 3s 742us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 40/50
3901/3901 [==============================] - 3s 735us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 41/50
3901/3901 [==============================] - 3s 734us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 42/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 43/50
3901/3901 [==============================] - 3s 726us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 44/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 45/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 46/50
3901/3901 [==============================] - 3s 724us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 47/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 48/50
3901/3901 [==============================] - 3s 700us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 49/50
3901/3901 [==============================] - 3s 707us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
Epoch 50/50
3901/3901 [==============================] - 3s 708us/step - loss:
 5.2887 - acc: 0.3281 - precision: 0.3281 - recall: 0.3281 - f1: 0.3
281 - val_loss: 5.8484 - val_acc: 0.3628 - val_precision: 0.3628 - v
al_recall: 0.3628 - val_f1: 0.3628
```

```
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_37 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_70 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_71 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_34 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_34 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_36 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_37 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_70 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_71 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_34 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_34 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_36 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 995us/step - loss:
 5.4599 - acc: 0.3250 - precision: 0.3254 - recall: 0.3881 - f1: 0.3
463 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 2/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 3/50
3901/3901 [==============================] - 3s 708us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 4/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 5/50
```

```
3901/3901 [==============================] - 3s 724us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 6/50
3901/3901 [==============================] - 3s 731us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 7/50
3901/3901 [==============================] - 3s 712us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 8/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 9/50
3901/3901 [==============================] - 3s 736us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3338 - recall: 0.6624 - f1: 0.4
439 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 10/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 11/50
3901/3901 [==============================] - 3s 749us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 12/50
3901/3901 [==============================] - 3s 728us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 13/50
3901/3901 [==============================] - 3s 728us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 14/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 15/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 16/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 17/50
3901/3901 [==============================] - 3s 713us/step - loss:
```

```
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 18/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 19/50
3901/3901 [==============================] - 3s 719us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 20/50
3901/3901 [==============================] - 3s 741us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 21/50
3901/3901 [==============================] - 3s 727us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 22/50
3901/3901 [==============================] - 3s 708us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 23/50
3901/3901 [==============================] - 3s 709us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 24/50
3901/3901 [==============================] - 3s 708us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 25/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 26/50
3901/3901 [==============================] - 3s 720us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 27/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 28/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 29/50
3901/3901 [==============================] - 3s 703us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
```

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440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 30/50
3901/3901 [==============================] - 3s 722us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 31/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3341 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 32/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 33/50
3901/3901 [==============================] - 3s 728us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 34/50
3901/3901 [==============================] - 3s 762us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 35/50
3901/3901 [==============================] - 3s 722us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 36/50
3901/3901 [==============================] - 3s 709us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 37/50
3901/3901 [==============================] - 3s 720us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 38/50
3901/3901 [==============================] - 3s 726us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 39/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3341 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 40/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 41/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
```

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al_recall: 0.6865 - val_f1: 0.4616
Epoch 42/50
3901/3901 [==============================] - 3s 746us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 43/50
3901/3901 [==============================] - 3s 719us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
441 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 44/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 45/50
3901/3901 [==============================] - 3s 719us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 46/50
3901/3901 [==============================] - 3s 718us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 47/50
3901/3901 [==============================] - 3s 719us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 48/50
3901/3901 [==============================] - 3s 721us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 49/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3339 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Epoch 50/50
3901/3901 [==============================] - 3s 718us/step - loss:
 5.4292 - acc: 0.3194 - precision: 0.3340 - recall: 0.6624 - f1: 0.4
440 - val_loss: 5.0530 - val_acc: 0.3498 - val_precision: 0.3478 - v
al_recall: 0.6865 - val_f1: 0.4616
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_38 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_72 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_73 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_35 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_35 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_37 (Dense)             (None, 3)                 3633
```

```
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_38 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_72 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_73 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_35 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_35 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_37 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
527 - acc: 0.3345 - precision: 0.3322 - recall: 0.6537 - f1: 0.4402
 - val_loss: 5.0531 - val_acc: 0.3237 - val_precision: 0.3465 - val_
recall: 0.6851 - val_f1: 0.4602
Epoch 2/50
3901/3901 [==============================] - 3s 710us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3344 - recall: 0.6619 - f1: 0.4
443 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 3/50
3901/3901 [==============================] - 3s 714us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 4/50
3901/3901 [==============================] - 3s 710us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3344 - recall: 0.6619 - f1: 0.4
443 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 5/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3344 - recall: 0.6619 - f1: 0.4
443 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 6/50
3901/3901 [==============================] - 3s 706us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 7/50
3901/3901 [==============================] - 3s 705us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 8/50
```

```
3901/3901 [==============================] - 3s 712us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 9/50
3901/3901 [==============================] - 3s 709us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 10/50
3901/3901 [==============================] - 3s 710us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 11/50
3901/3901 [==============================] - 3s 701us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 12/50
3901/3901 [==============================] - 3s 700us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 13/50
3901/3901 [==============================] - 3s 732us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 14/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 15/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 16/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3344 - recall: 0.6619 - f1: 0.4
443 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 17/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 18/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 19/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 20/50
3901/3901 [==============================] - 3s 712us/step - loss:
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 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 21/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 22/50
3901/3901 [==============================] - 3s 714us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 23/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 24/50
3901/3901 [==============================] - 3s 710us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 25/50
3901/3901 [==============================] - 3s 718us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 26/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 27/50
3901/3901 [==============================] - 3s 716us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 28/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 29/50
3901/3901 [==============================] - 3s 714us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 30/50
3901/3901 [==============================] - 3s 713us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 31/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 32/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
```

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445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 33/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 34/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 35/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 36/50
3901/3901 [==============================] - 3s 711us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 37/50
3901/3901 [==============================] - 3s 710us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3344 - recall: 0.6619 - f1: 0.4
443 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 38/50
3901/3901 [==============================] - 3s 704us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 39/50
3901/3901 [==============================] - 3s 715us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 40/50
3901/3901 [==============================] - 3s 717us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 41/50
3901/3901 [==============================] - 3s 730us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 42/50
3901/3901 [==============================] - 3s 763us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 43/50
3901/3901 [==============================] - 3s 729us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 44/50
3901/3901 [==============================] - 3s 728us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
```

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al_recall: 0.6851 - val_f1: 0.4602
Epoch 45/50
3901/3901 [==============================] - 3s 701us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 46/50
3901/3901 [==============================] - 3s 706us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 47/50
3901/3901 [==============================] - 3s 697us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 48/50
3901/3901 [==============================] - 3s 687us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 49/50
3901/3901 [==============================] - 3s 693us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3345 - recall: 0.6619 - f1: 0.4
444 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Epoch 50/50
3901/3901 [==============================] - 3s 700us/step - loss:
 5.4292 - acc: 0.3350 - precision: 0.3346 - recall: 0.6619 - f1: 0.4
445 - val_loss: 5.0530 - val_acc: 0.3237 - val_precision: 0.3465 - v
al_recall: 0.6851 - val_f1: 0.4602
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_39 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_74 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_75 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_36 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_36 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_38 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_39 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_74 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_75 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_36 (MaxPooling (None, 11, 11, 10)        0
```

```
_________________________________________________________________
flatten_36 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_38 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 4s 1ms/step - loss: 2.8
358 - acc: 0.4258 - precision: 0.3935 - recall: 0.2979 - f1: 0.3089
 - val_loss: 7.4625 - val_acc: 0.3237 - val_precision: 0.3375 - val_
recall: 0.3237 - val_f1: 0.3303
Epoch 2/50
3901/3901 [==============================] - 3s 696us/step - loss:
 9.7804 - acc: 0.3350 - precision: 0.3432 - recall: 0.3348 - f1: 0.3
389 - val_loss: 12.3094 - val_acc: 0.3237 - val_precision: 0.3314 -
 val_recall: 0.3237 - val_f1: 0.3275
Epoch 3/50
3901/3901 [==============================] - 3s 699us/step - loss:
 9.9971 - acc: 0.4137 - precision: 0.3652 - recall: 0.4250 - f1: 0.3
888 - val_loss: 5.0530 - val_acc: 0.6067 - val_precision: 0.4456 - v
al_recall: 0.6647 - val_f1: 0.5328
Epoch 4/50
3901/3901 [==============================] - 3s 712us/step - loss:
 5.3176 - acc: 0.6224 - precision: 0.5156 - recall: 0.6311 - f1: 0.5
660 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 5/50
3901/3901 [==============================] - 3s 705us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5175 - recall: 0.6311 - f1: 0.5
678 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 6/50
3901/3901 [==============================] - 3s 721us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5184 - recall: 0.6311 - f1: 0.5
680 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 7/50
3901/3901 [==============================] - 3s 701us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5185 - recall: 0.6311 - f1: 0.5
678 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 8/50
3901/3901 [==============================] - 3s 733us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5168 - recall: 0.6311 - f1: 0.5
672 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 9/50
3901/3901 [==============================] - 3s 753us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5182 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 10/50
3901/3901 [==============================] - 3s 806us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 11/50
```

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3901/3901 [==============================] - 3s 831us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5175 - recall: 0.6311 - f1: 0.5
675 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 12/50
3901/3901 [==============================] - 3s 820us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 13/50
3901/3901 [==============================] - 3s 763us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5187 - recall: 0.6311 - f1: 0.5
683 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 14/50
3901/3901 [==============================] - 3s 786us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5181 - recall: 0.6311 - f1: 0.5
677 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 15/50
3901/3901 [==============================] - 3s 723us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5174 - recall: 0.6311 - f1: 0.5
674 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 16/50
3901/3901 [==============================] - 3s 773us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5180 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 17/50
3901/3901 [==============================] - 4s 926us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5176 - recall: 0.6311 - f1: 0.5
676 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 18/50
3901/3901 [==============================] - 3s 811us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5177 - recall: 0.6311 - f1: 0.5
675 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5180 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5183 - recall: 0.6311 - f1: 0.5680
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5174 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
```

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176 - acc: 0.6232 - precision: 0.5182 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5180 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5191 - recall: 0.6311 - f1: 0.5684
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5179 - recall: 0.6311 - f1: 0.5680
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5183 - recall: 0.6311 - f1: 0.5680
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5173 - recall: 0.6311 - f1: 0.5674
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5184 - recall: 0.6311 - f1: 0.5682
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5170 - recall: 0.6311 - f1: 0.5673
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5177 - recall: 0.6311 - f1: 0.5675
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5170 - recall: 0.6311 - f1: 0.5673
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5676
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5167 - recall: 0.6311 - f1: 0.5671
```

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 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5179 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5184 - recall: 0.6311 - f1: 0.5681
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5180 - recall: 0.6311 - f1: 0.5679
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5175 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5165 - recall: 0.6311 - f1: 0.5671
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5175 - recall: 0.6311 - f1: 0.5676
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5177 - recall: 0.6311 - f1: 0.5677
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5678
 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - val_
recall: 0.6647 - val_f1: 0.5979
Epoch 46/50
3901/3901 [==============================] - 4s 982us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5177 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 47/50
3901/3901 [==============================] - 4s 975us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5180 - recall: 0.6311 - f1: 0.5
679 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
```

```
al_recall: 0.6647 - val_f1: 0.5979
Epoch 48/50
3901/3901 [==============================] - 4s 982us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5172 - recall: 0.6311 - f1: 0.5
674 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 49/50
3901/3901 [==============================] - 4s 956us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5181 - recall: 0.6311 - f1: 0.5
678 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Epoch 50/50
3901/3901 [==============================] - 4s 966us/step - loss:
 5.3176 - acc: 0.6232 - precision: 0.5178 - recall: 0.6311 - f1: 0.5
678 - val_loss: 4.8892 - val_acc: 0.6415 - val_precision: 0.5452 - v
al_recall: 0.6647 - val_f1: 0.5979
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_40 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_76 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_77 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_37 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_37 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_39 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_40 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_76 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_77 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_37 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_37 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_39 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 5s 1ms/step - loss: 5.3
924 - acc: 0.3630 - precision: 0.3280 - recall: 0.6437 - f1: 0.4345
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
```

```
Epoch 2/50
3901/3901 [==============================] - 4s 990us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 3/50
3901/3901 [==============================] - 4s 998us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3321 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 7/50
3901/3901 [==============================] - 4s 967us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 9/50
3901/3901 [==============================] - 4s 967us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 10/50
3901/3901 [==============================] - 4s 965us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3320 - recall: 0.6529 - f1: 0.4
401 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 11/50
3901/3901 [==============================] - 4s 960us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 12/50
3901/3901 [==============================] - 4s 980us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3321 - recall: 0.6529 - f1: 0.4
402 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 13/50
3901/3901 [==============================] - 4s 962us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3320 - recall: 0.6529 - f1: 0.4
402 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 14/50
```

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3901/3901 [==============================] - 4s 993us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4
404 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 15/50
3901/3901 [==============================] - 4s 970us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 19/50
3901/3901 [==============================] - 4s 978us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4
404 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 20/50
3901/3901 [==============================] - 4s 985us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 21/50
3901/3901 [==============================] - 4s 958us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 22/50
3901/3901 [==============================] - 4s 984us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
```

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292 - acc: 0.3884 - precision: 0.3324 - recall: 0.6529 - f1: 0.4405
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 27/50
3901/3901 [==============================] - 4s 990us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3320 - recall: 0.6529 - f1: 0.4402
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 29/50
3901/3901 [==============================] - 4s 982us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 33/50
3901/3901 [==============================] - 4s 976us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4
404 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 34/50
3901/3901 [==============================] - 4s 998us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3324 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 36/50
3901/3901 [==============================] - 4s 997us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4
404 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 37/50
3901/3901 [==============================] - 4s 997us/step - loss:
 5.4292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4
403 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - v
al_recall: 0.6125 - val_f1: 0.4139
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
```

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 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3321 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3323 - recall: 0.6529 - f1: 0.4404
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
recall: 0.6125 - val_f1: 0.4139
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.4
292 - acc: 0.3884 - precision: 0.3322 - recall: 0.6529 - f1: 0.4403
 - val_loss: 6.0121 - val_acc: 0.3861 - val_precision: 0.3126 - val_
```

```
recall: 0.6125 - val_f1: 0.4139
Normalized confusion matrix

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_41 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_78 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_79 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_38 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_38 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_40 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_41 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_78 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_79 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_38 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_38 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_40 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 1ms/step - loss: 5.3
541 - acc: 0.3345 - precision: 0.3342 - recall: 0.6539 - f1: 0.4414
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
```

```
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 10/50
3901/3901 [==============================] - 3s 797us/step - loss:
 5.3383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4
480 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - v
al_recall: 0.6270 - val_f1: 0.4236
Epoch 11/50
3901/3901 [==============================] - 4s 995us/step - loss:
 5.3383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4
481 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - v
al_recall: 0.6270 - val_f1: 0.4236
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 17/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4482
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4482
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
```

```
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4482
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4481
```

```
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3377 - recall: 0.6662 - f1: 0.4482
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3376 - recall: 0.6662 - f1: 0.4481
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
383 - acc: 0.3363 - precision: 0.3375 - recall: 0.6662 - f1: 0.4480
 - val_loss: 5.9887 - val_acc: 0.3120 - val_precision: 0.3199 - val_
recall: 0.6270 - val_f1: 0.4236
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_42 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_80 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_81 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_39 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_39 (Flatten)         (None, 1210)              0
_________________________________________________________________
```

```
dense_41 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_42 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_80 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_81 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_39 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_39 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_41 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 1ms/step - loss: 5.3
957 - acc: 0.3356 - precision: 0.3276 - recall: 0.3230 - f1: 0.3246
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 5/50
3901/3901 [==============================] - 4s 910us/step - loss:
 5.3961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3
336 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - v
al_recall: 0.3062 - val_f1: 0.3072
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
```

```
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3345 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 20/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
```

```
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3337
```

```
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3342 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3344 - recall: 0.3330 - f1: 0.3337
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: 5.3
961 - acc: 0.3368 - precision: 0.3343 - recall: 0.3330 - f1: 0.3336
 - val_loss: 5.0062 - val_acc: 0.3135 - val_precision: 0.3082 - val_
recall: 0.3062 - val_f1: 0.3072
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_43 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_82 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_83 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_40 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_40 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_42 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_43 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_82 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_83 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
```

```
max_pooling2d_40 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_40 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_42 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 2ms/step - loss: nan
- acc: 0.3745 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 999us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
```

```
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 23/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
```

```
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 995us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 923us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 962us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
```

```
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_44 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_84 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_85 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_41 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_41 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_43 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_44 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_84 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_85 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_41 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_41 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_43 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 1ms/step - loss: nan
- acc: 0.3291 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
```

```
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
```

```
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 996us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 26/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
```

```
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 3s 865us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
```

```
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_45 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_86 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_87 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_42 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_42 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_44 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_45 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_86 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_87 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_42 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_42 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_44 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 1ms/step - loss: 1.7
269 - acc: 0.3335 - precision: 0.3312 - recall: 0.9574 - f1: 0.4908
 - val_loss: 1.1465 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
221 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1126 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
035 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1026 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
989 - acc: 0.3397 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0995 - val_acc: 0.3280 - val_precision: 0.3333 - val_
```

```
recall: 1.0000 - val_f1: 0.5000
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
979 - acc: 0.3991 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0989 - val_acc: 0.3788 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
976 - acc: 0.3771 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0983 - val_acc: 0.3716 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
974 - acc: 0.3822 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0985 - val_acc: 0.2975 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
973 - acc: 0.3440 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0980 - val_acc: 0.4412 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
973 - acc: 0.3814 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0979 - val_acc: 0.3120 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
971 - acc: 0.3884 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0977 - val_acc: 0.3004 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
970 - acc: 0.3353 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0979 - val_acc: 0.3599 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
968 - acc: 0.3373 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0971 - val_acc: 0.4935 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
966 - acc: 0.3763 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0971 - val_acc: 0.4819 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
965 - acc: 0.3922 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0972 - val_acc: 0.4253 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
964 - acc: 0.3720 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0968 - val_acc: 0.4557 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
962 - acc: 0.3761 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0966 - val_acc: 0.4644 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
```

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Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
958 - acc: 0.3853 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0962 - val_acc: 0.3091 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
956 - acc: 0.3468 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0960 - val_acc: 0.4514 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
940 - acc: 0.3940 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0919 - val_acc: 0.4601 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
920 - acc: 0.4030 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0903 - val_acc: 0.3396 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
904 - acc: 0.3748 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0881 - val_acc: 0.3440 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
873 - acc: 0.3714 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0855 - val_acc: 0.5515 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
816 - acc: 0.3840 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0705 - val_acc: 0.3048 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
825 - acc: 0.3779 - precision: 0.3345 - recall: 0.9995 - f1: 0.5012
 - val_loss: 1.1202 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
610 - acc: 0.3627 - precision: 0.3337 - recall: 0.9987 - f1: 0.5002
 - val_loss: 1.1648 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
400 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1294 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
167 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1141 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
062 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1063 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 29/50
```

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3901/3901 [==============================] - 4s 1ms/step - loss: 1.1
014 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1026 - val_acc: 0.3237 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
992 - acc: 0.3353 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.1006 - val_acc: 0.3266 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
982 - acc: 0.3402 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0996 - val_acc: 0.3411 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
978 - acc: 0.3604 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0990 - val_acc: 0.3745 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
975 - acc: 0.3943 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0987 - val_acc: 0.4282 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
974 - acc: 0.4025 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0984 - val_acc: 0.3570 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 35/50
3901/3901 [==============================] - 4s 993us/step - loss:
 1.0973 - acc: 0.3509 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0982 - val_acc: 0.3077 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
973 - acc: 0.3350 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0979 - val_acc: 0.2917 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 37/50
3901/3901 [==============================] - 4s 937us/step - loss:
 1.0973 - acc: 0.3335 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0979 - val_acc: 0.2787 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 38/50
3901/3901 [==============================] - 4s 978us/step - loss:
 1.0972 - acc: 0.3209 - precision: 0.3333 - recall: 1.0000 - f1: 0.5
000 - val_loss: 1.0978 - val_acc: 0.2787 - val_precision: 0.3333 - v
al_recall: 1.0000 - val_f1: 0.5000
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
972 - acc: 0.3438 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0977 - val_acc: 0.2729 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
971 - acc: 0.3538 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0977 - val_acc: 0.2787 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
```

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971 - acc: 0.3268 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0976 - val_acc: 0.2801 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
971 - acc: 0.3191 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0976 - val_acc: 0.2743 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
970 - acc: 0.3212 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0975 - val_acc: 0.2830 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
970 - acc: 0.3653 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0974 - val_acc: 0.2787 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
969 - acc: 0.3184 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0973 - val_acc: 0.2816 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
969 - acc: 0.3291 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0973 - val_acc: 0.2859 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
968 - acc: 0.3222 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0973 - val_acc: 0.2859 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
968 - acc: 0.3189 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0971 - val_acc: 0.3004 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
967 - acc: 0.3263 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0971 - val_acc: 0.3324 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: 1.0
967 - acc: 0.3376 - precision: 0.3333 - recall: 1.0000 - f1: 0.5000
 - val_loss: 1.0970 - val_acc: 0.3033 - val_precision: 0.3333 - val_
recall: 1.0000 - val_f1: 0.5000
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_46 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_88 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_89 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_43 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_43 (Flatten)         (None, 1210)              0
```

```
_________________________________________________________________
dense_45 (Dense)             (None, 3)                 3633      
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_46 (InputLayer)        (None, 28, 28, 1)         0         
_________________________________________________________________
conv2d_88 (Conv2D)           (None, 25, 25, 20)        340       
_________________________________________________________________
conv2d_89 (Conv2D)           (None, 23, 23, 10)        1810      
_________________________________________________________________
max_pooling2d_43 (MaxPooling (None, 11, 11, 10)        0         
_________________________________________________________________
flatten_43 (Flatten)         (None, 1210)              0         
_________________________________________________________________
dense_45 (Dense)             (None, 3)                 3633      
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
```

```
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 999us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
```

```
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
```

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3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 3s 847us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 997us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
```

```
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_47 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_90 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_91 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_44 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_44 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_46 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_47 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_90 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_91 (Conv2D)           (None, 23, 23, 10)        1810
```

```
_________________________________________________________________
max_pooling2d_44 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_44 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_46 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 2ms/step - loss: nan
- acc: 0.3258 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
```

```
1: nan
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
```

```
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 26/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 959us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 29/50
3901/3901 [==============================] - 3s 892us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
```

```
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_48 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_92 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_93 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_45 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_45 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_47 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_48 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_92 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_93 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_45 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_45 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_47 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 2ms/step - loss: nan
- acc: 0.3289 - precision: nan - recall: nan - f1: nan - val_loss: n
```

```
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 994us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
```

```
1: nan
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 20/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 23/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
```

```
Epoch 26/50
3901/3901 [==============================] - 3s 866us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
```

```
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
```

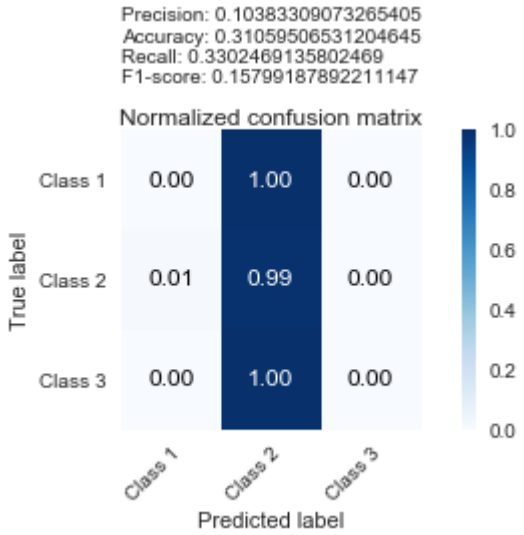
```
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_49 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_94 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_95 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_46 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_46 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_48 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_49 (InputLayer)        (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_94 (Conv2D)           (None, 25, 25, 20)        340
_________________________________________________________________
conv2d_95 (Conv2D)           (None, 23, 23, 10)        1810
_________________________________________________________________
max_pooling2d_46 (MaxPooling (None, 11, 11, 10)        0
_________________________________________________________________
flatten_46 (Flatten)         (None, 1210)              0
_________________________________________________________________
dense_48 (Dense)             (None, 3)                 3633
=================================================================
Total params: 5,783
Trainable params: 5,783
Non-trainable params: 0
_________________________________________________________________
Train on 3901 samples, validate on 689 samples
Epoch 1/50
3901/3901 [==============================] - 6s 2ms/step - loss: nan
- acc: 0.3858 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 2/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 3/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 4/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
```

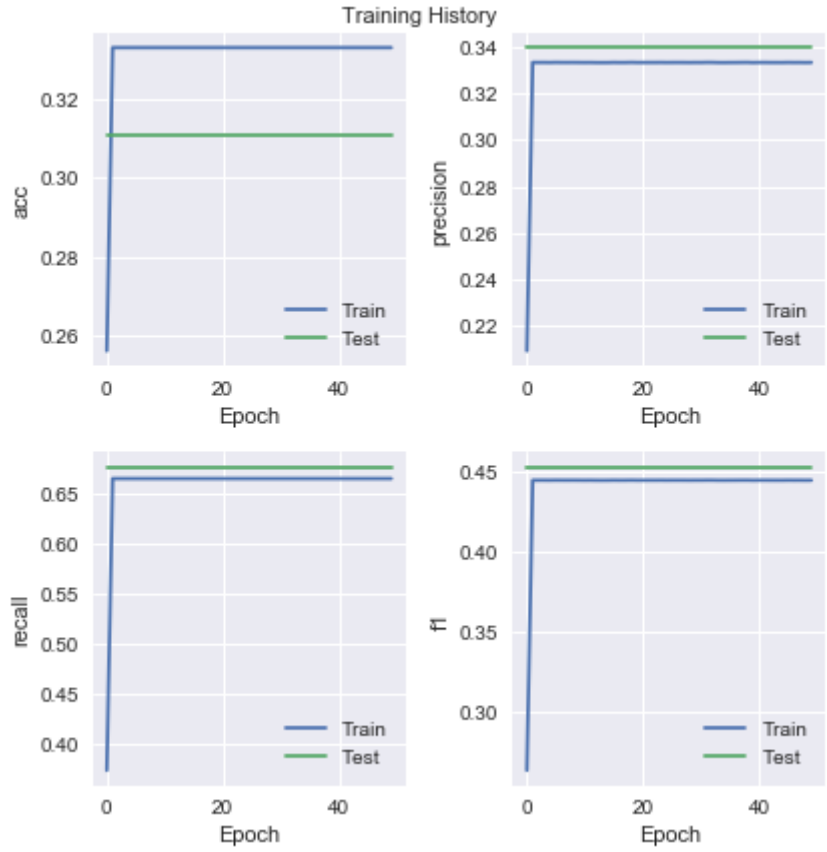
```
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 5/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 6/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 7/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 8/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 9/50
3901/3901 [==============================] - 4s 988us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 10/50
3901/3901 [==============================] - 4s 992us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 11/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 12/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 13/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 14/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 15/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 16/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
```

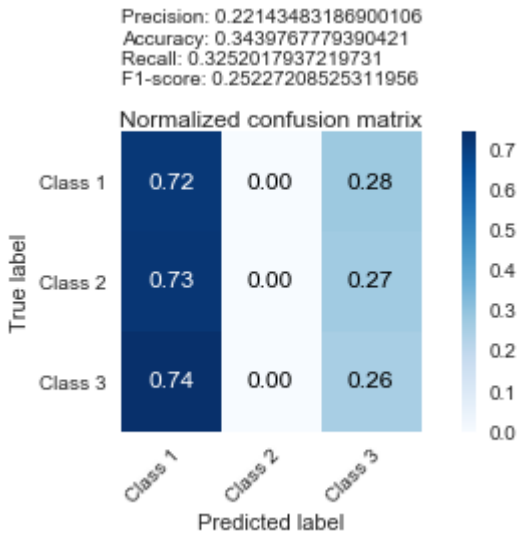
```
1: nan
Epoch 17/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 18/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 19/50
3901/3901 [==============================] - 4s 964us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 20/50
3901/3901 [==============================] - 4s 982us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 21/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 22/50
3901/3901 [==============================] - 4s 963us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 23/50
3901/3901 [==============================] - 3s 835us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 24/50
3901/3901 [==============================] - 4s 945us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 25/50
3901/3901 [==============================] - 4s 977us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 26/50
3901/3901 [==============================] - 4s 998us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 27/50
3901/3901 [==============================] - 4s 978us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
Epoch 28/50
3901/3901 [==============================] - 4s 975us/step - loss: n
an - acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_los
s: nan - val_acc: 0.3628 - val_precision: nan - val_recall: nan - va
l_f1: nan
```

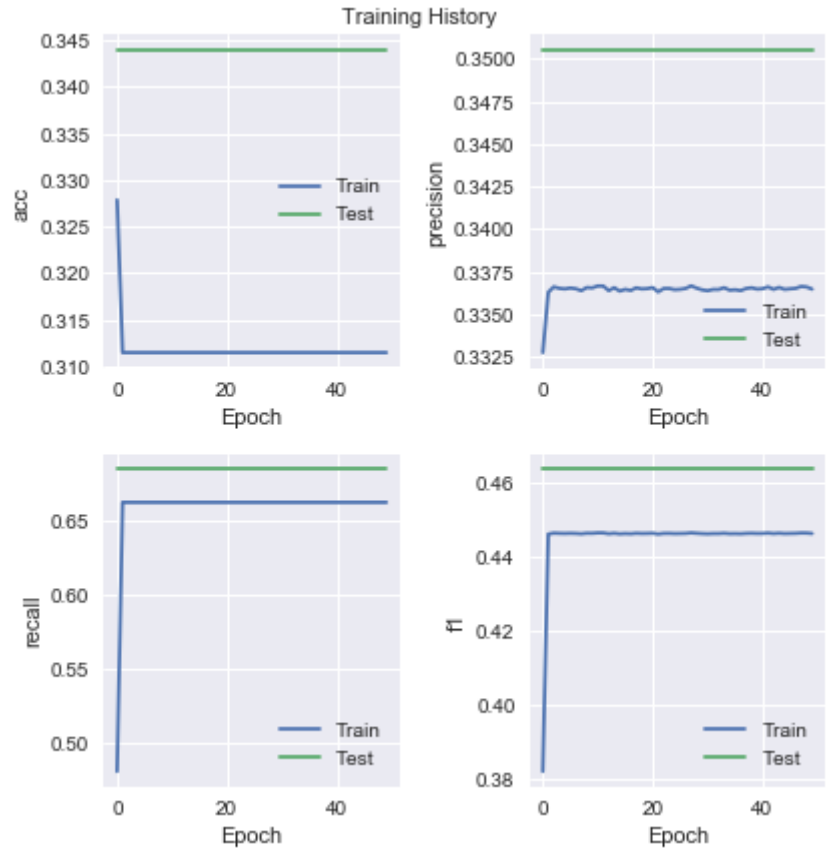
```
Epoch 29/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 30/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 31/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 32/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 33/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 34/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 35/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 36/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 37/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 38/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 39/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 40/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 41/50
```

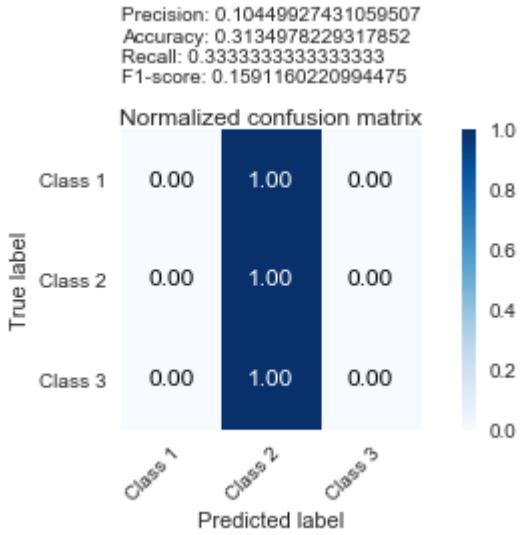
```
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 42/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 43/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 44/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 45/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 46/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 47/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 48/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 49/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Epoch 50/50
3901/3901 [==============================] - 4s 1ms/step - loss: nan
- acc: 0.3281 - precision: nan - recall: nan - f1: nan - val_loss: n
an - val_acc: 0.3628 - val_precision: nan - val_recall: nan - val_f
1: nan
Normalized confusion matrix
```

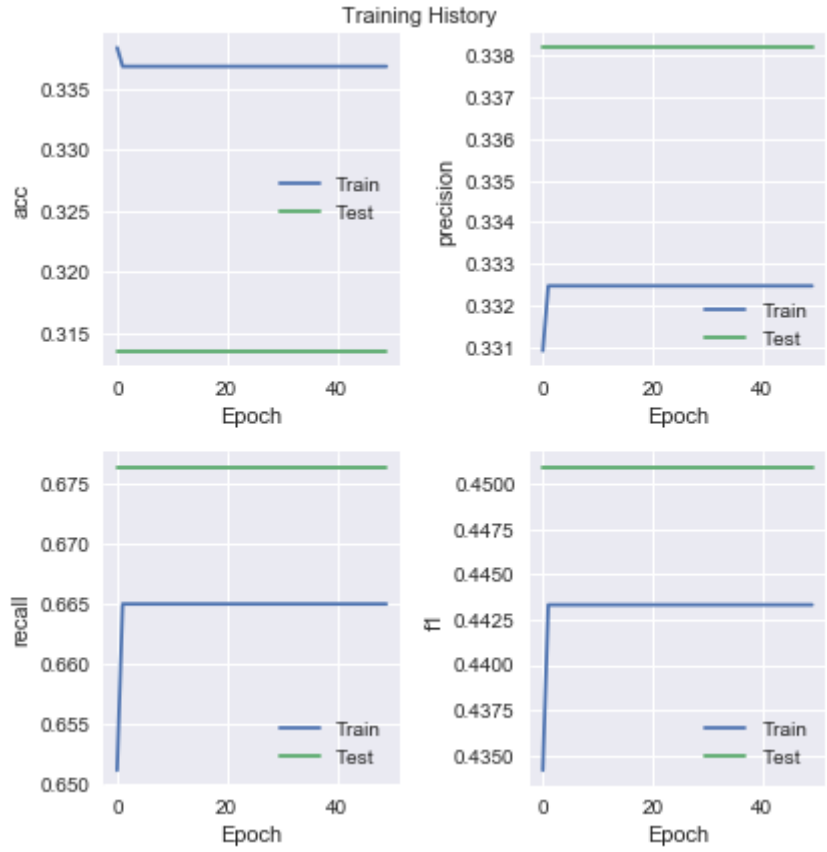

Precision: 0.10383309073265405
Accuracy: 0.31059506531204645
Recall: 0.3302469135802469
F1-score: 0.15799187892211147
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
0.01
0.99
0.00
0.00
1.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

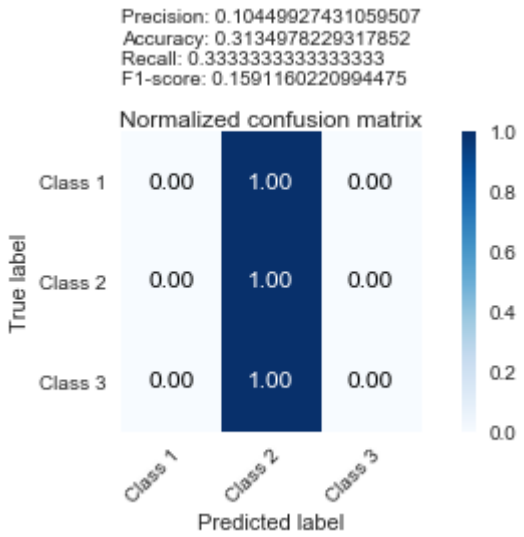

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
20
40

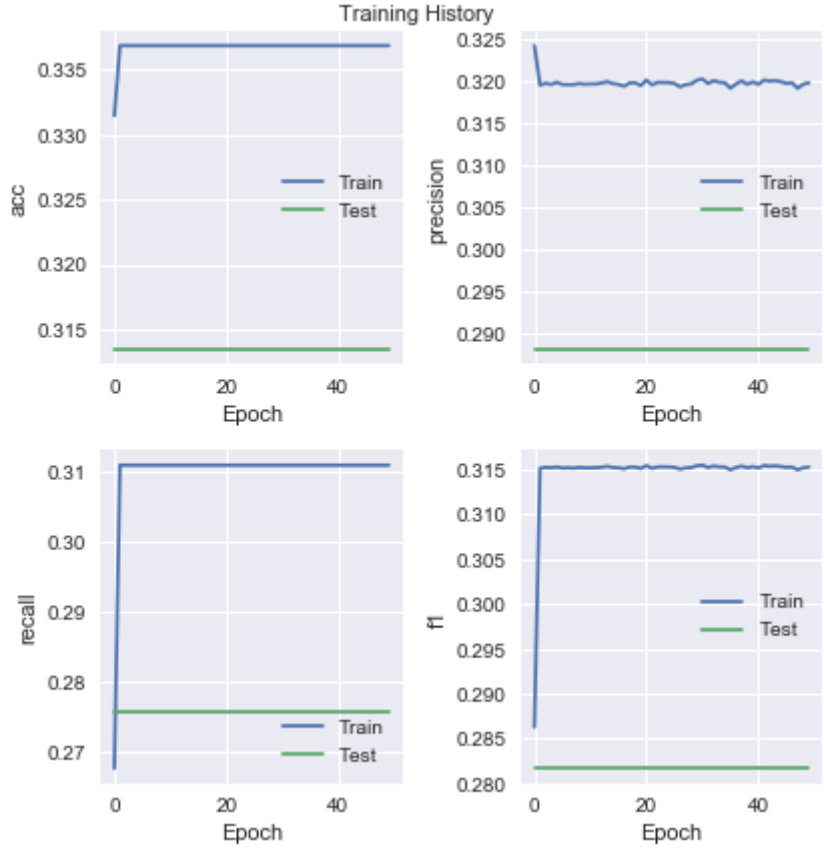

Precision: 0.22143483186900106
Accuracy: 0.3439767779390421
Recall: 0.3252017937219731
F1-score: 0.25227208525311956
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.72
0.00
0.28
0.73
0.00
0.27
0.74
0.00
0.26
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Class 1
Class 2
Class 3
Predicted label

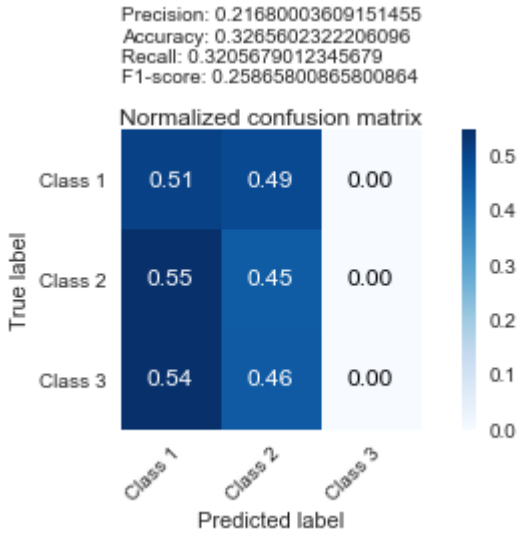

Training History
acc
Epoch
Train
Test
precision
Epoch
Train
Test
recall
Epoch
Train
Test
f1
Epoch
Train
Test

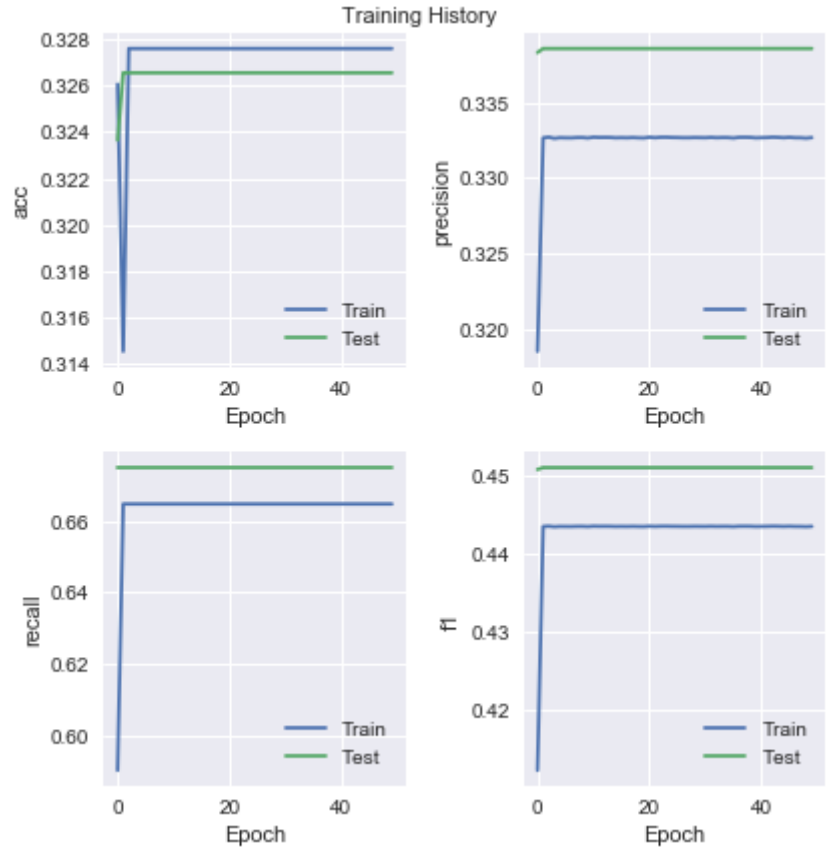

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

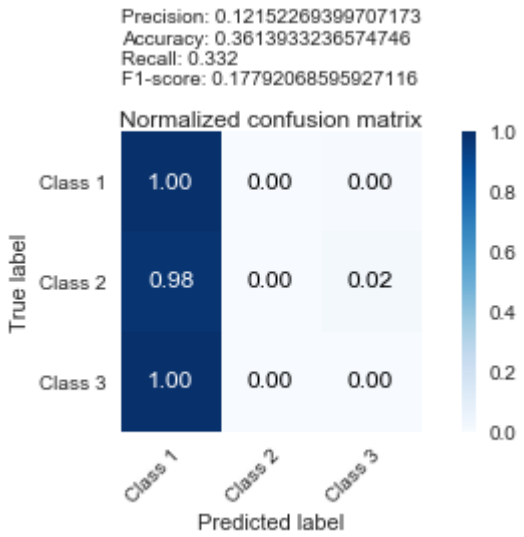

Training History
acc
0.335
0.330
0.325
0.320
0.315
Train
Test
0
20
40
Epoch
precision
0.338
0.337
0.336
0.335
0.334
0.333
0.332
0.331
Train
Test
0
20
40
Epoch
recall
0.675
0.670
0.665
0.660
0.655
0.650
Train
Test
0
20
40
Epoch
f1
0.4500
0.4475
0.4450
0.4425
0.4400
0.4375
0.4350
Train
Test
0
20
40
Epoch

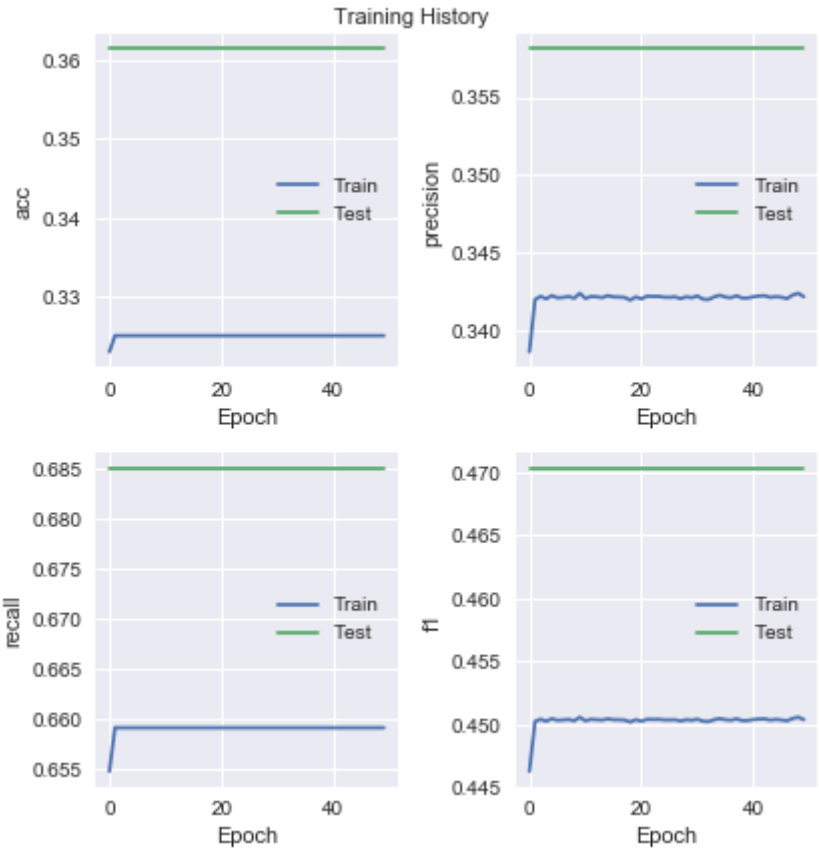

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

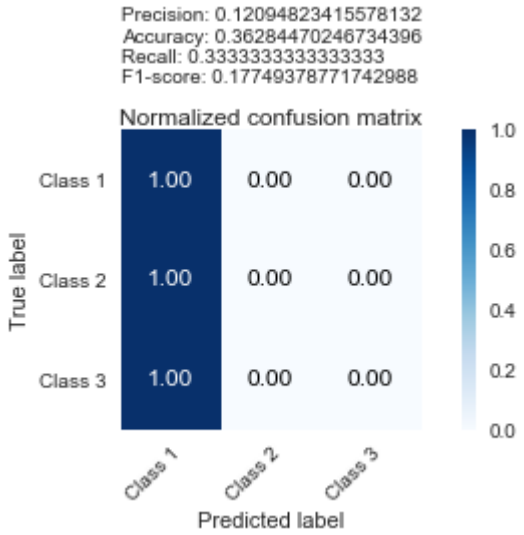

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
20
40

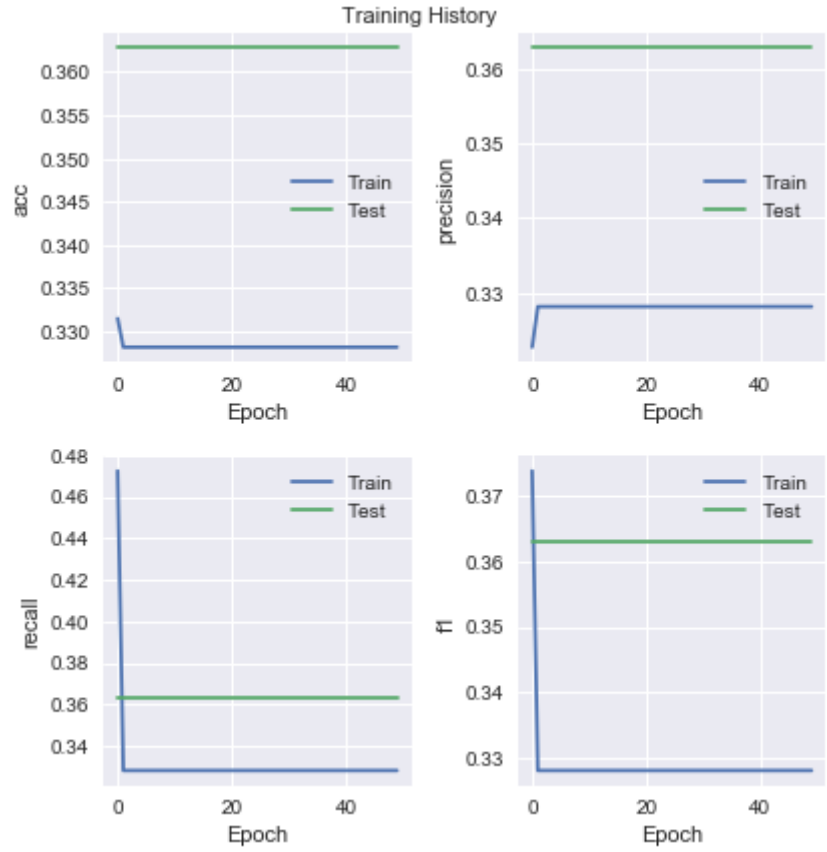

Precision: 0.21680003609151455
Accuracy: 0.3265602322206096
Recall: 0.3205679012345679
F1-score: 0.25865800865800864
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.51
0.49
0.00
0.55
0.45
0.00
0.54
0.46
0.00
0.5
0.4
0.3
0.2
0.1
0.0
Class 1
Class 2
Class 3
Predicted label

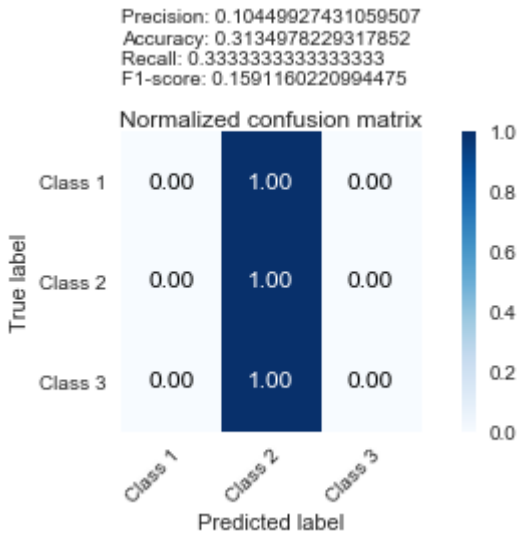

Training History
acc
precision
recall
f1
Epoch
Train
Test

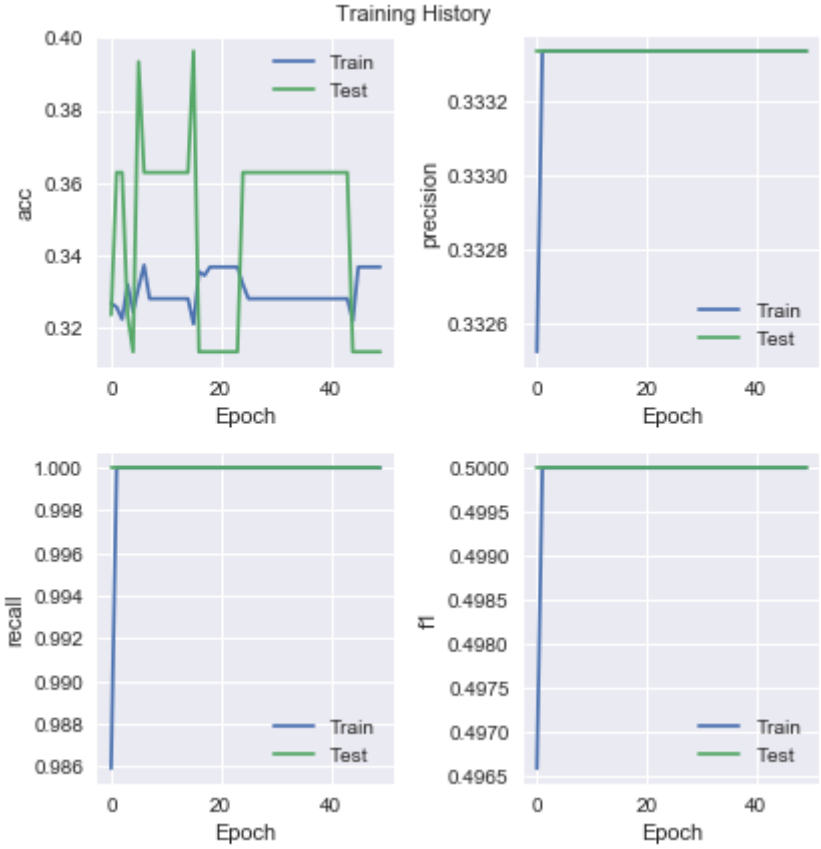

Precision: 0.12152269399707173
Accuracy: 0.3613933236574746
Recall: 0.332
F1-score: 0.17792068595927116
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
0.98
0.00
0.02
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

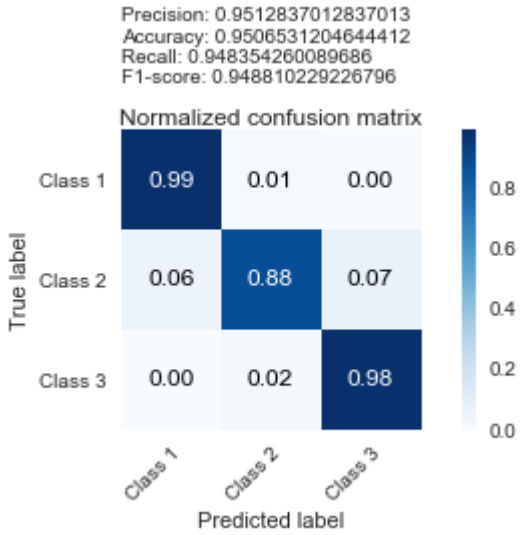

Training History
acc
precision
recall
f1
Train
Test
Epoch

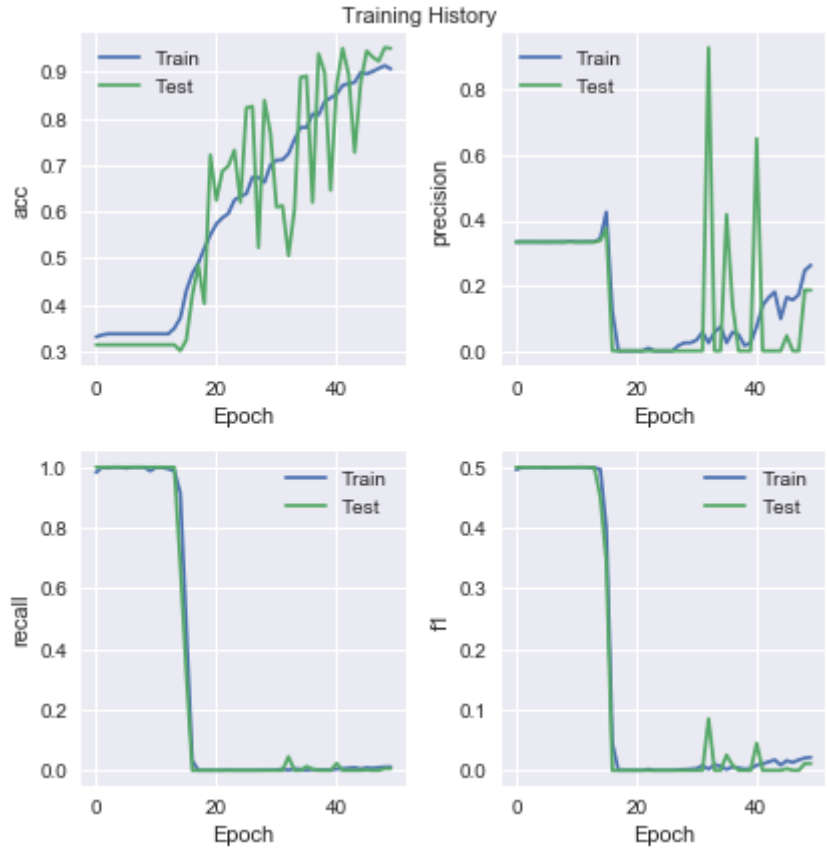

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

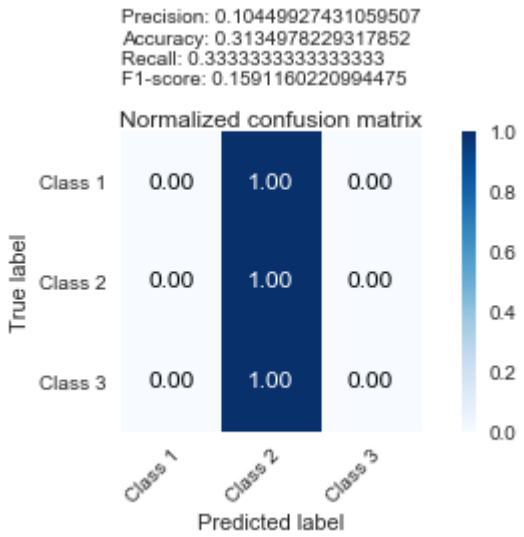

Training History
acc
precision
recall
f1
Train
Test
Epoch

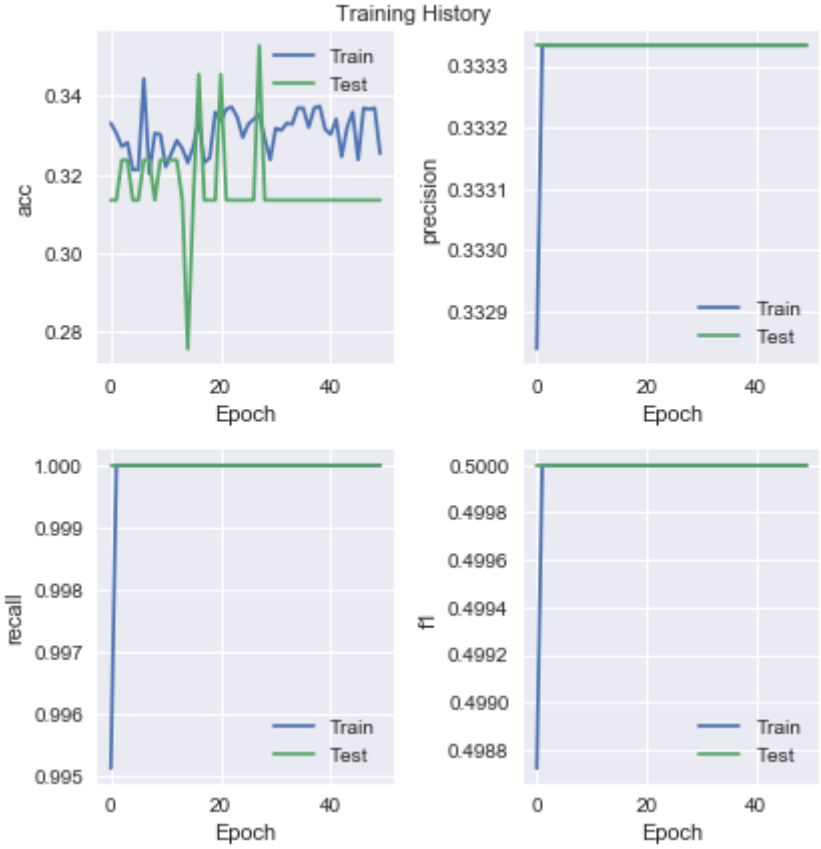

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
Predicted label
1.0
0.8
0.6
0.4
0.2
0.0

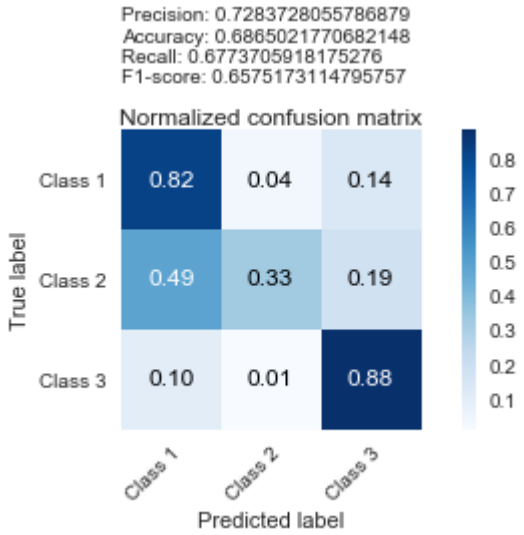

Training History
acc
precision
recall
f1
Epoch
Train
Test

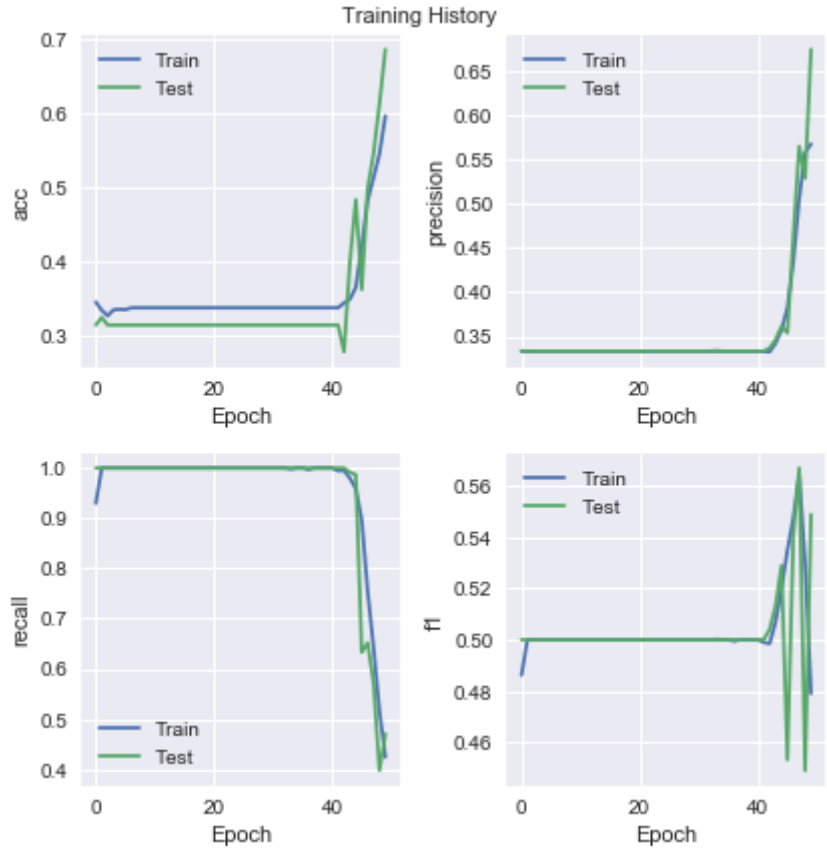

Precision: 0.9512837012837013
Accuracy: 0.9506531204644412
Recall: 0.948354260089686
F1-score: 0.948810229226796
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.99
0.01
0.00
0.06
0.88
0.07
0.00
0.02
0.98
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

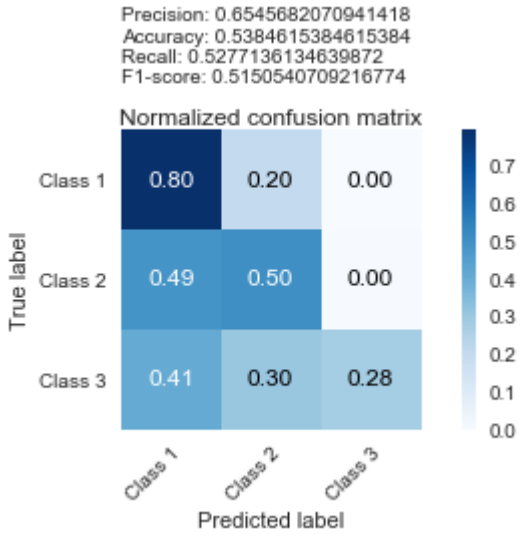

Training History
Train
Test
acc
precision
recall
f1
Epoch
0
20
40

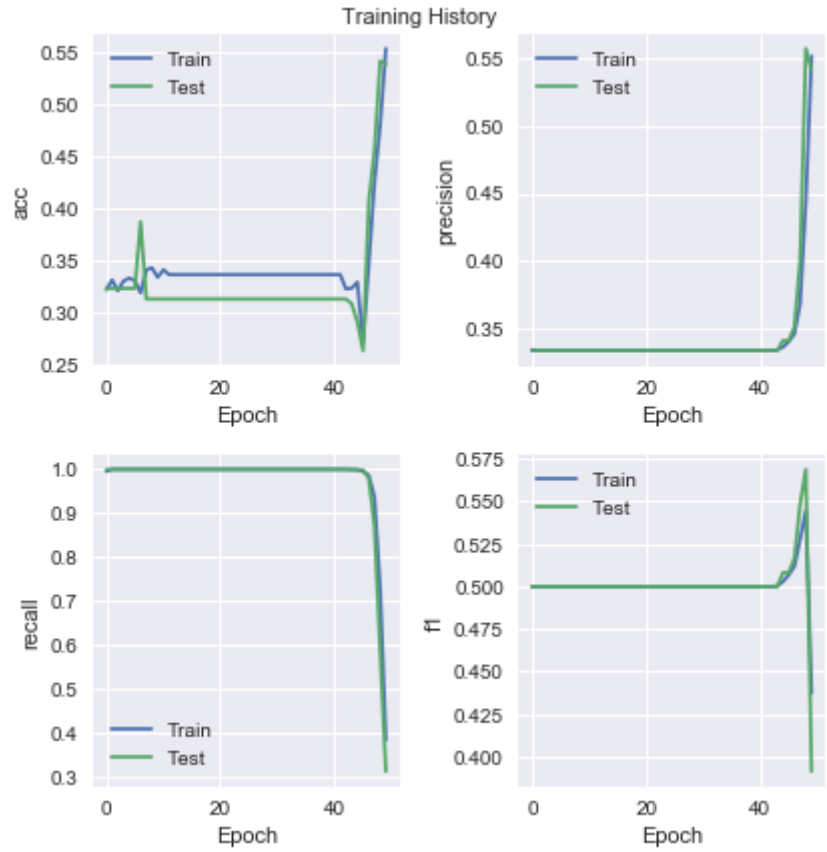

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
Predicted label
1.0
0.8
0.6
0.4
0.2
0.0

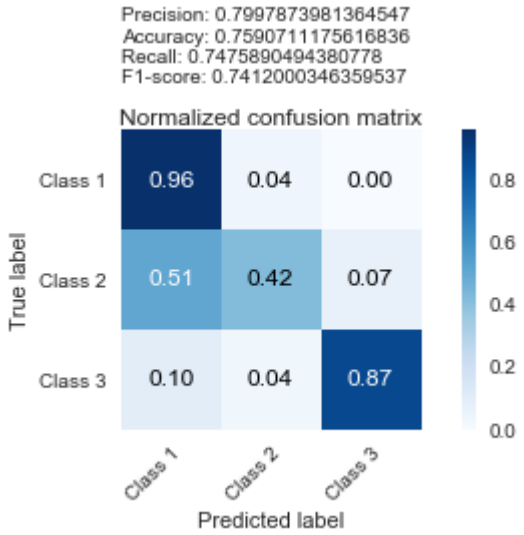

Training History
acc
precision
recall
f1
Train
Test
Epoch

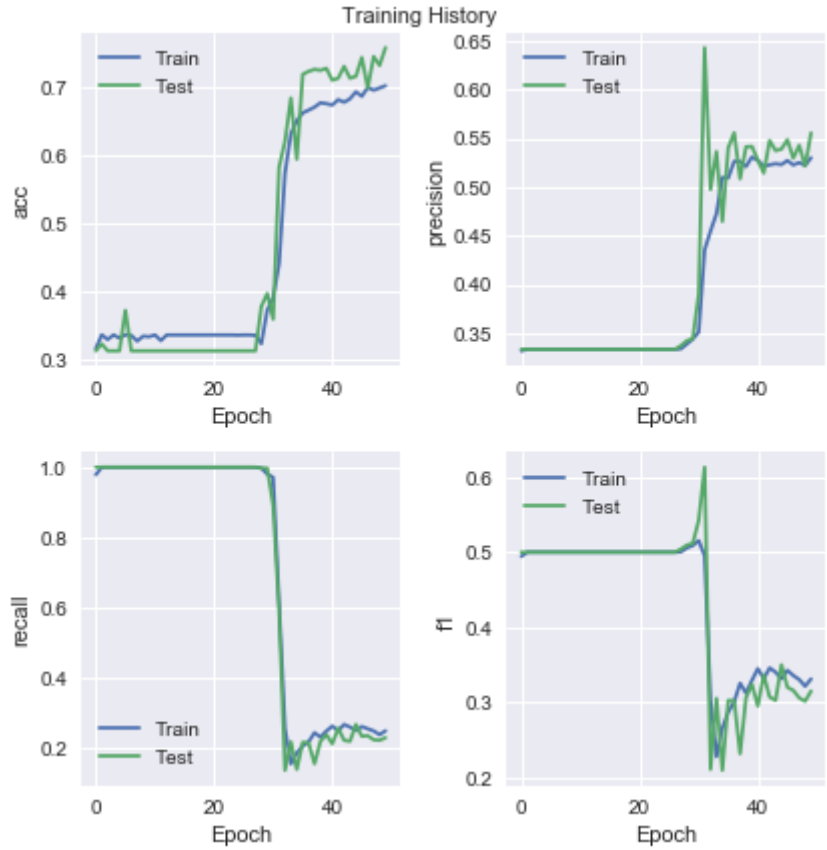

Precision: 0.7283728055786879
Accuracy: 0.6865021770682148
Recall: 0.6773705918175276
F1-score: 0.6575173114795757
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.82
0.04
0.14
0.49
0.33
0.19
0.10
0.01
0.88
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Class 1
Class 2
Class 3
Predicted label

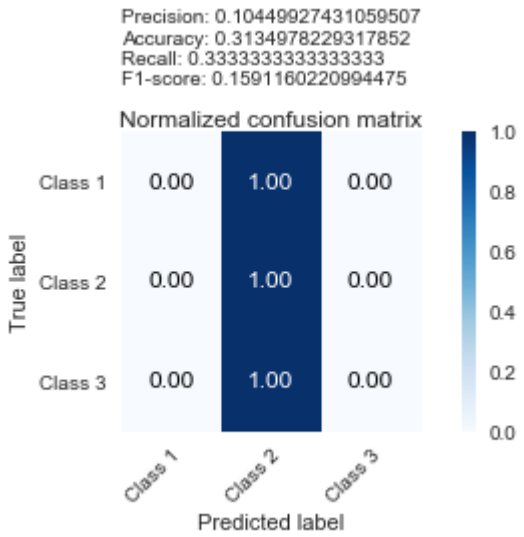

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
20
40

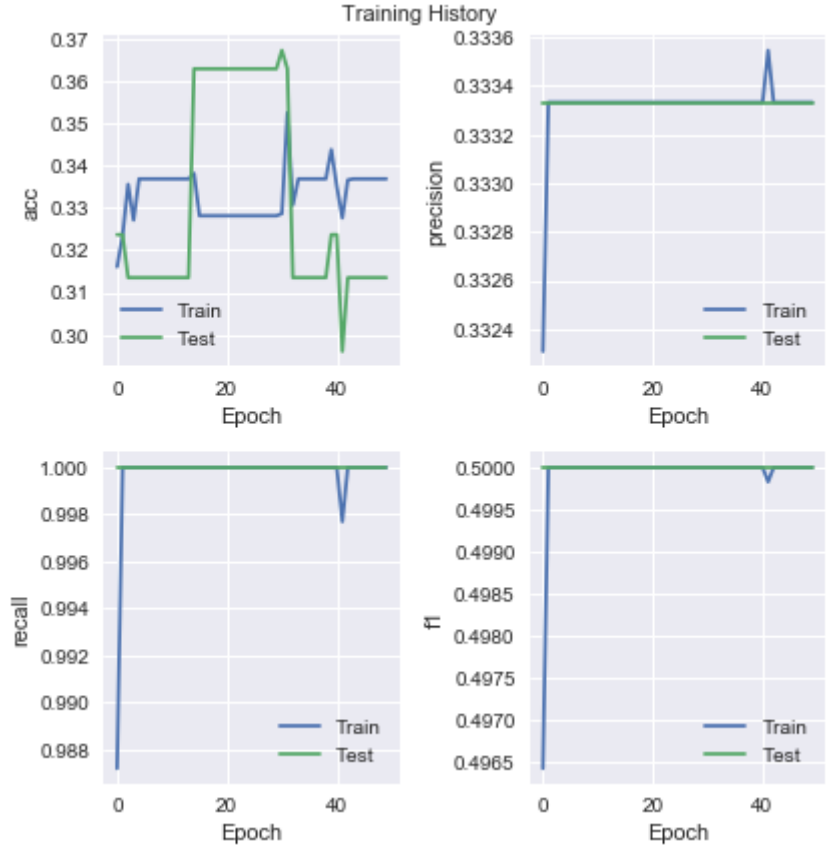

Precision: 0.6545682070941418
Accuracy: 0.5384615384615384
Recall: 0.5277136134639872
F1-score: 0.5150540709216774
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.80
0.20
0.00
0.49
0.50
0.00
0.41
0.30
0.28
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Class 1
Class 2
Class 3
Predicted label

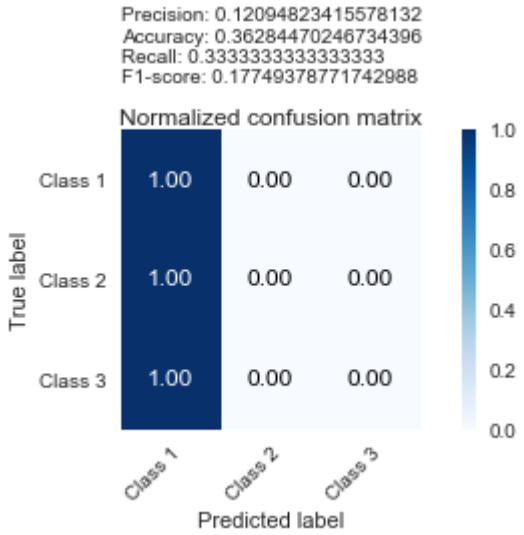

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
20
40

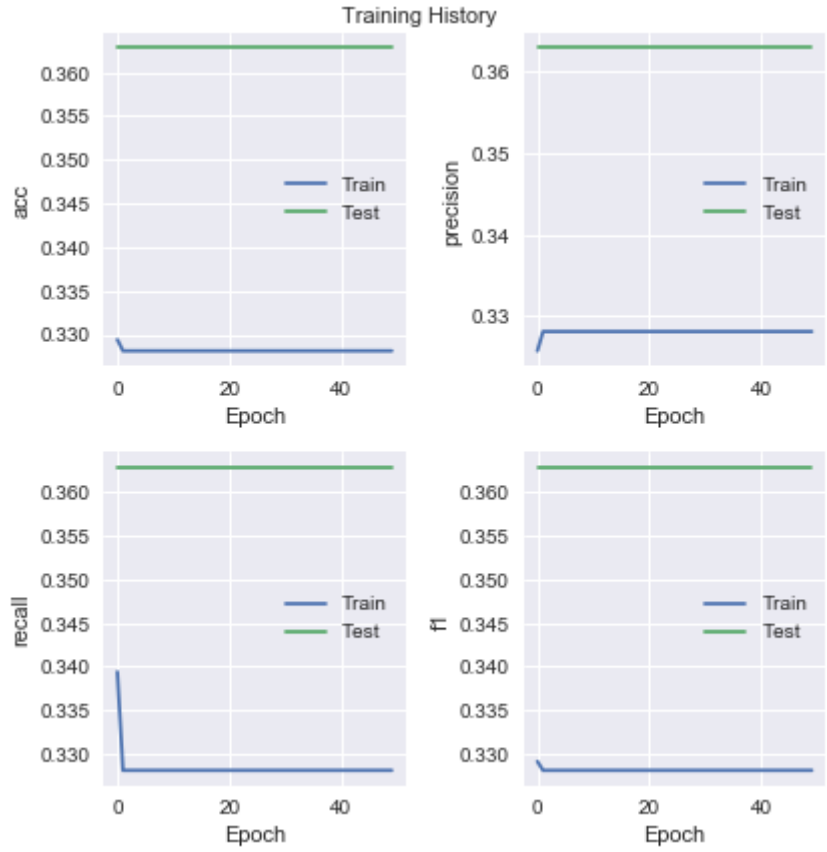

Precision: 0.7997873981364547
Accuracy: 0.7590711175616836
Recall: 0.7475890494380778
F1-score: 0.7412000346359537
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.96
0.04
0.00
0.51
0.42
0.07
0.10
0.04
0.87
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

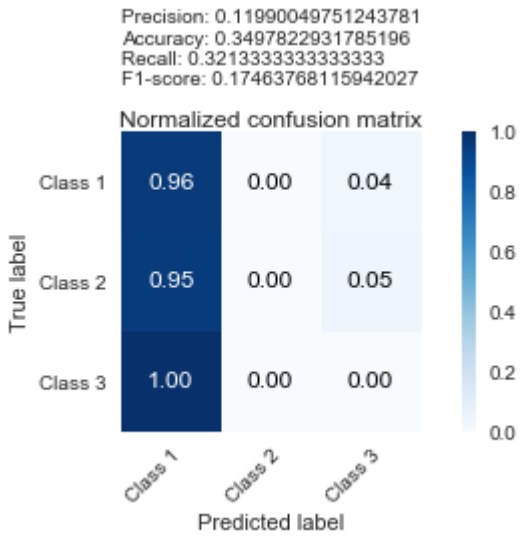

Training History
Train
Test
acc
precision
recall
f1
Epoch
0
20
40

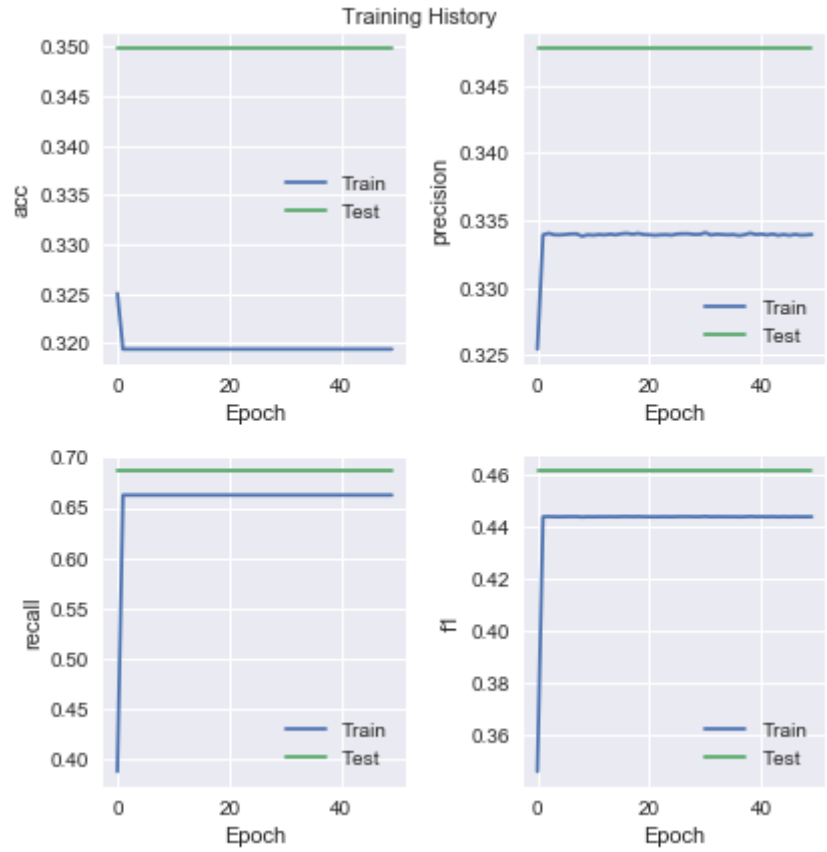

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

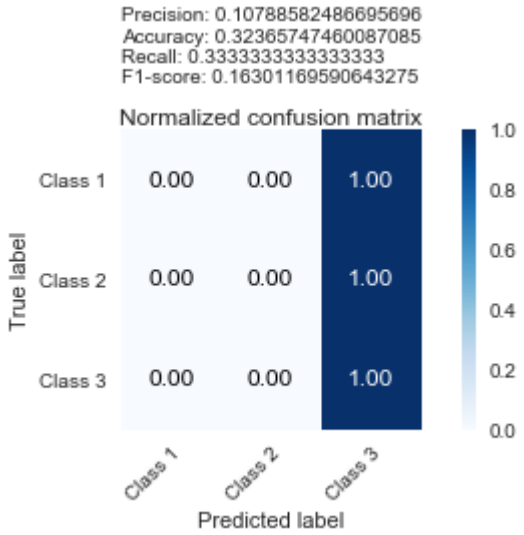

Training History
acc
precision
recall
f1
Train
Test
Epoch

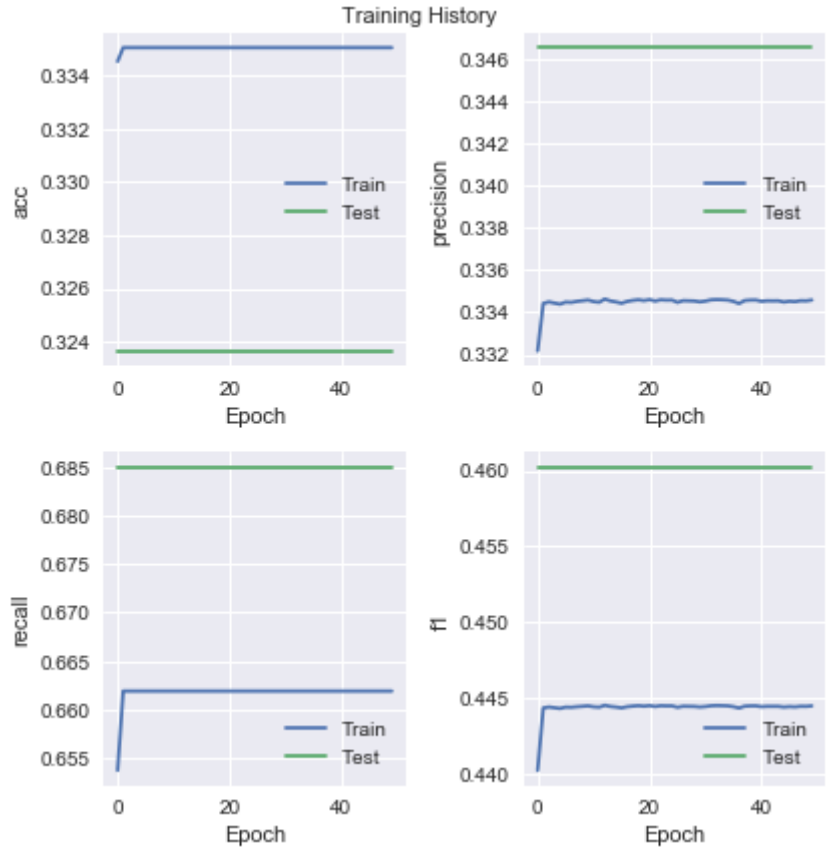

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

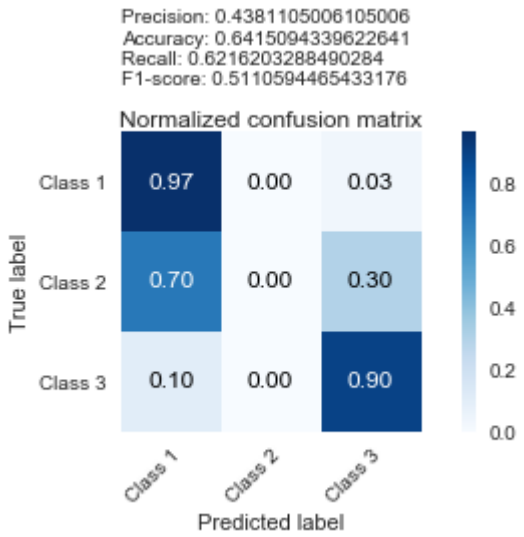

Training History
acc
precision
recall
f1
Train
Test
Epoch
0.360
0.355
0.350
0.345
0.340
0.335
0.330
0.36
0.35
0.34
0.33
0
20
40

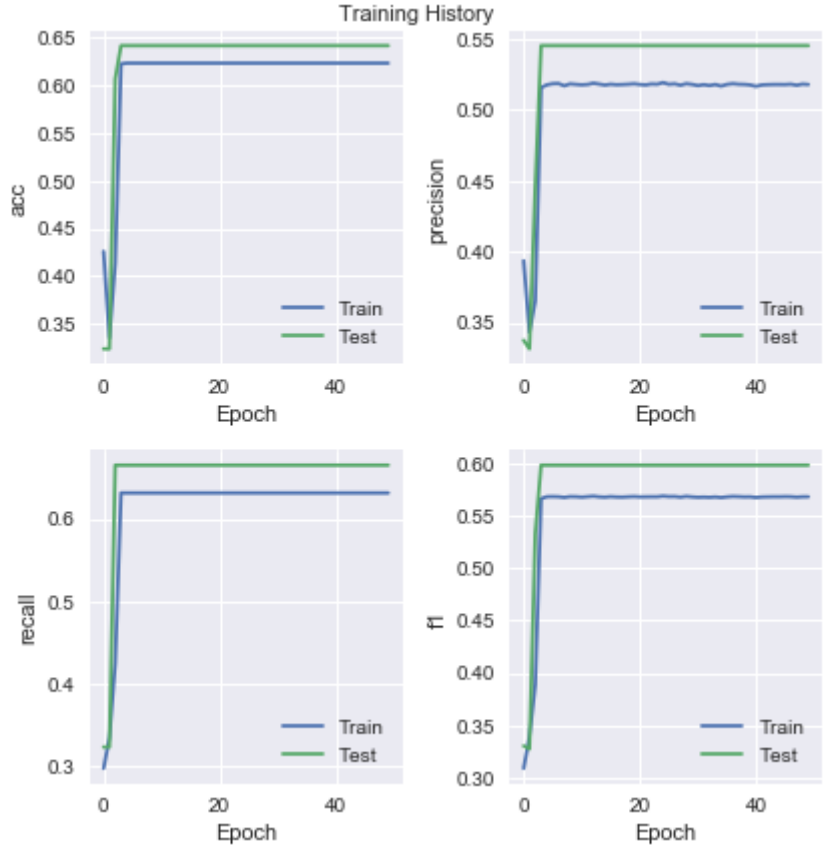

Precision: 0.11990049751243781
Accuracy: 0.3497822931785196
Recall: 0.3213333333333333
F1-score: 0.17463768115942027
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.96
0.00
0.04
0.95
0.00
0.05
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

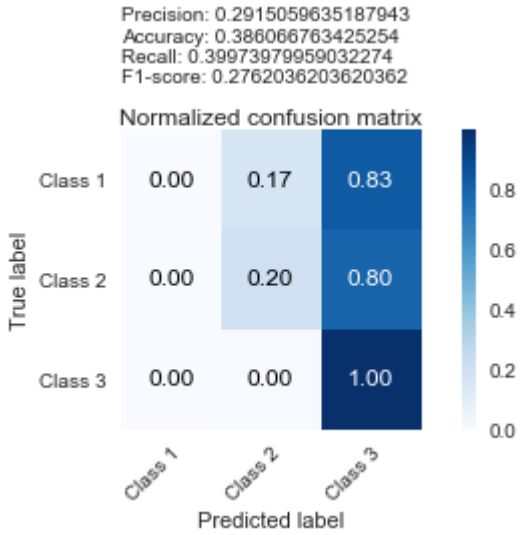

Training History
acc
Epoch
Train
Test
precision
recall
f1

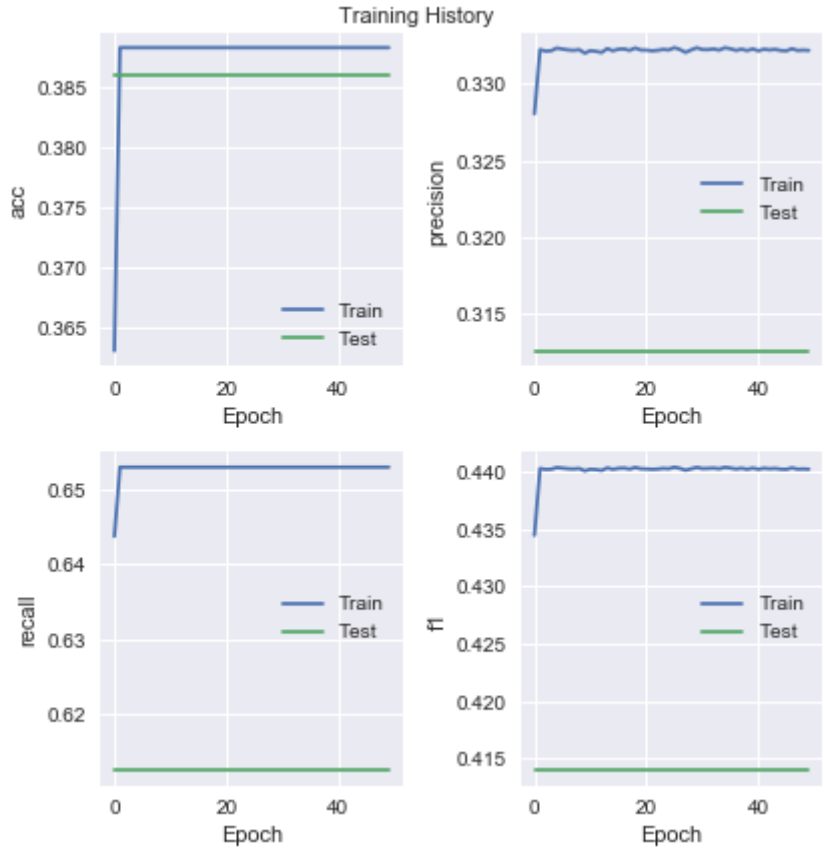

Precision: 0.10788582486695696
Accuracy: 0.32365747460087085
Recall: 0.3333333333333333
F1-score: 0.16301169590643275
Normalized confusion matrix
Class 1
Class 2
Class 3
0.00
0.00
1.00
True label
Predicted label
1.0
0.8
0.6
0.4
0.2
0.0

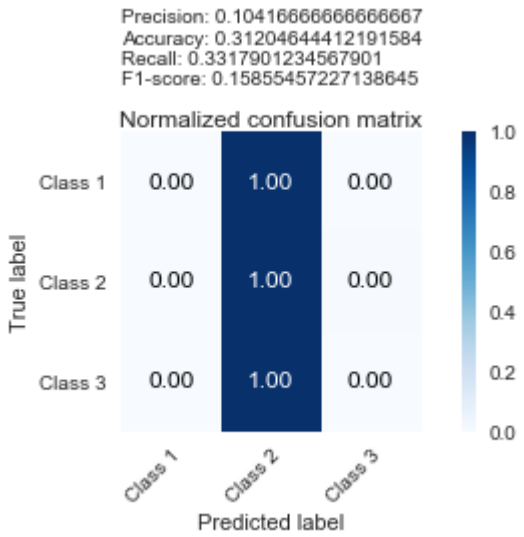

Training History
acc
precision
recall
f1
Epoch
Train
Test

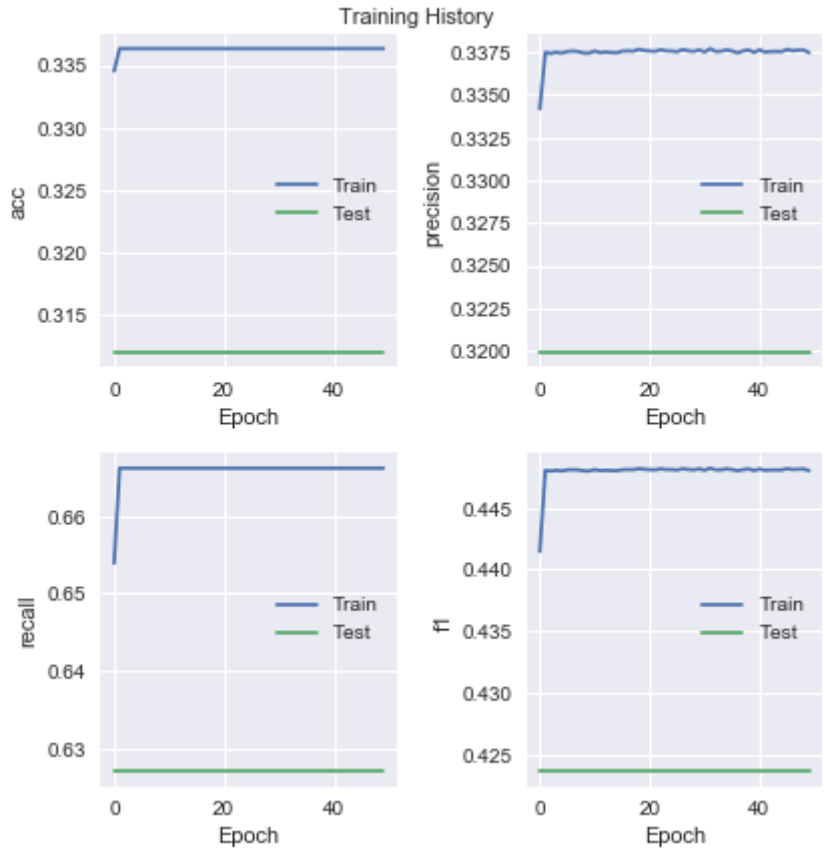

Precision: 0.4381105006105006
Accuracy: 0.6415094339622641
Recall: 0.6216203288490284
F1-score: 0.5110594465433176
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.97
0.00
0.03
0.70
0.00
0.30
0.10
0.00
0.90
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

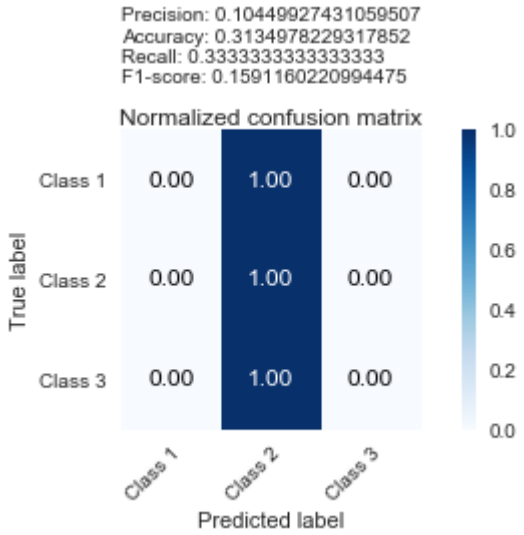

Training History
acc
precision
recall
f1
Train
Test
Epoch

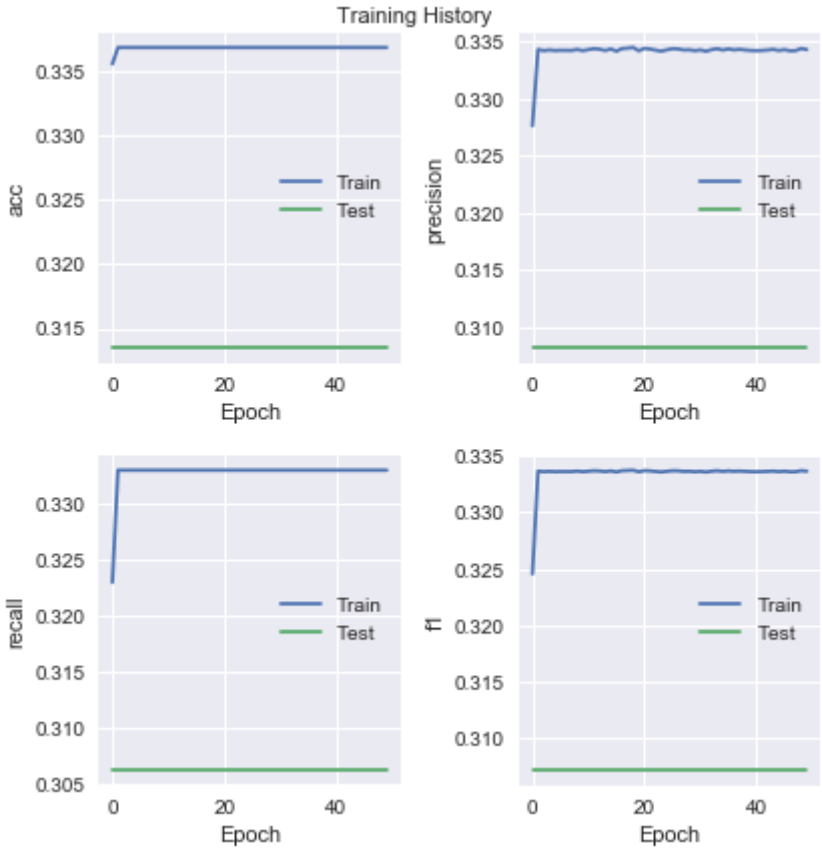

Precision: 0.2915059635187943
Accuracy: 0.386066763425254
Recall: 0.3997397959032274
F1-score: 0.2762036203620362
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
0.17
0.83
0.00
0.20
0.80
0.00
0.00
1.00
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

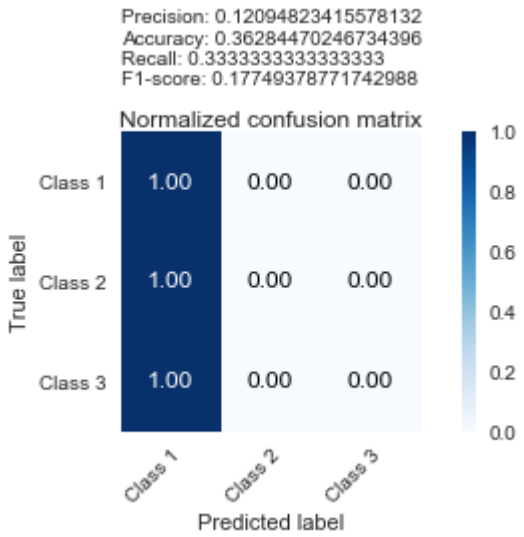

Training History
acc
precision
recall
f1
Train
Test
Epoch
0
20
40
0.385
0.380
0.375
0.370
0.365
0.330
0.325
0.320
0.315
0.65
0.64
0.63
0.62
0.440
0.435
0.430
0.425
0.420
0.415

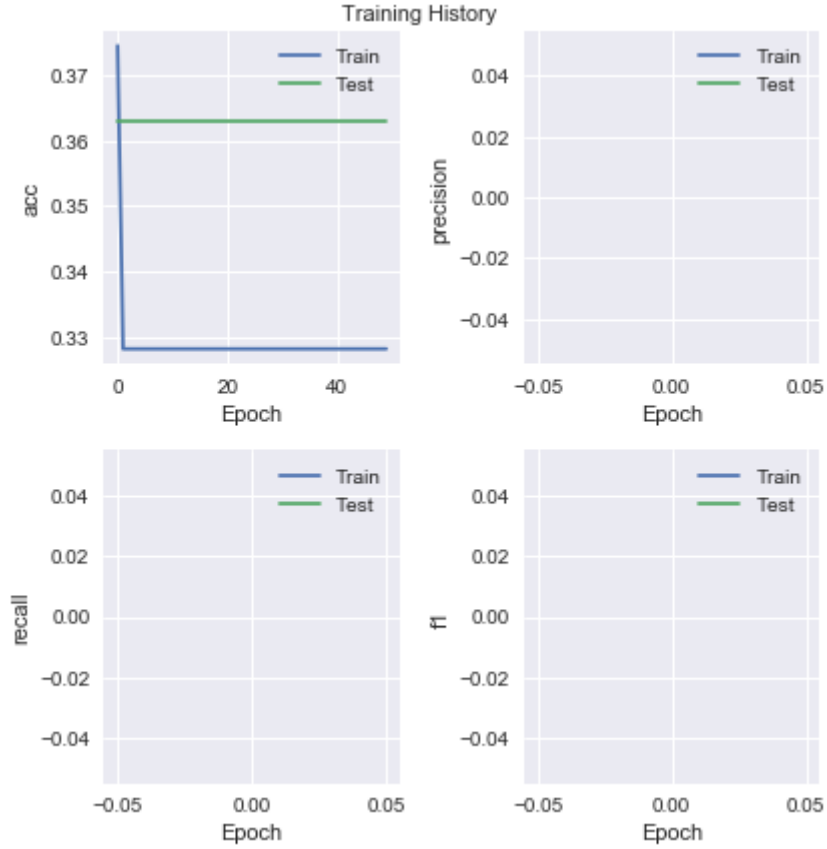

Precision: 0.10416666666666667
Accuracy: 0.31204644412191584
Recall: 0.3317901234567901
F1-score: 0.15855457227138645
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Predicted label

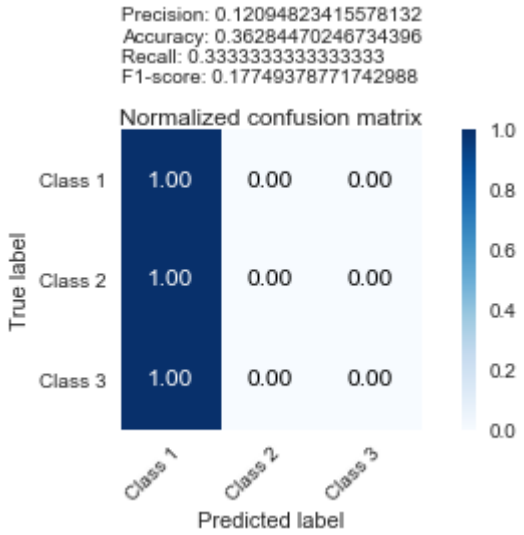

Training History
acc
precision
recall
f1
Train
Test
Epoch

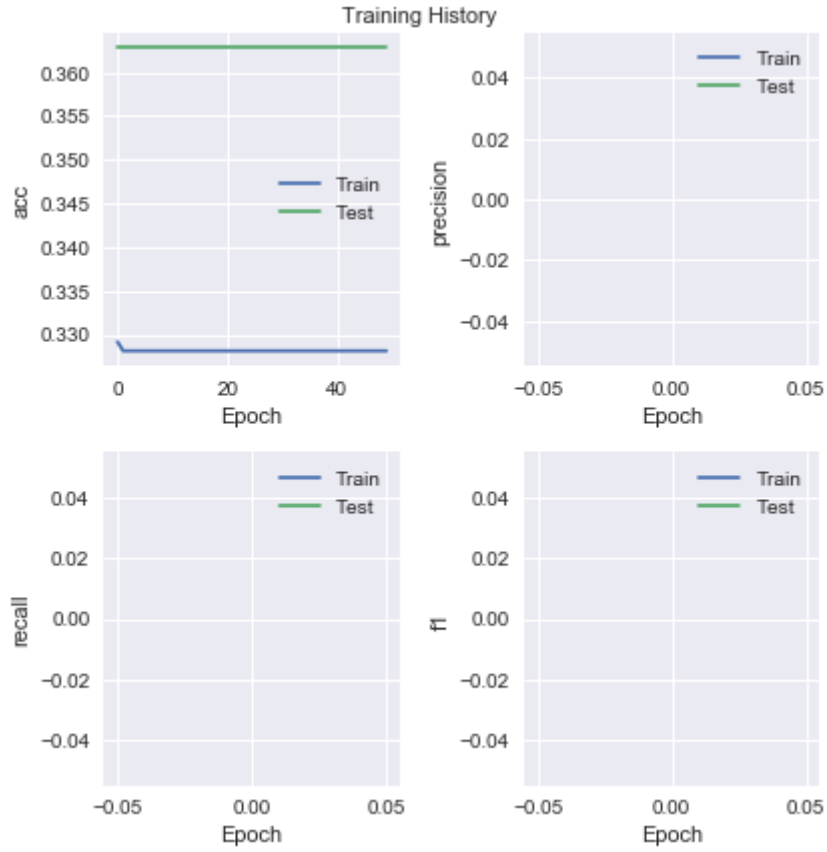

Precision: 0.10449927431059507
Accuracy: 0.3134978229317852
Recall: 0.3333333333333333
F1-score: 0.1591160220994475
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.00
1.00
0.00
Predicted label
1.0
0.8
0.6
0.4
0.2
0.0

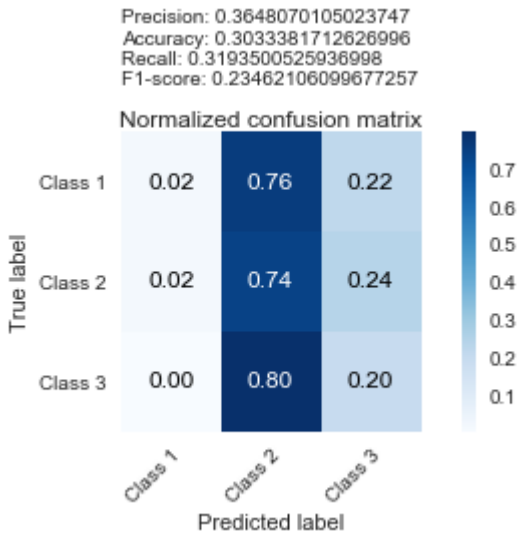

Training History
acc
precision
recall
f1
Train
Test
Epoch

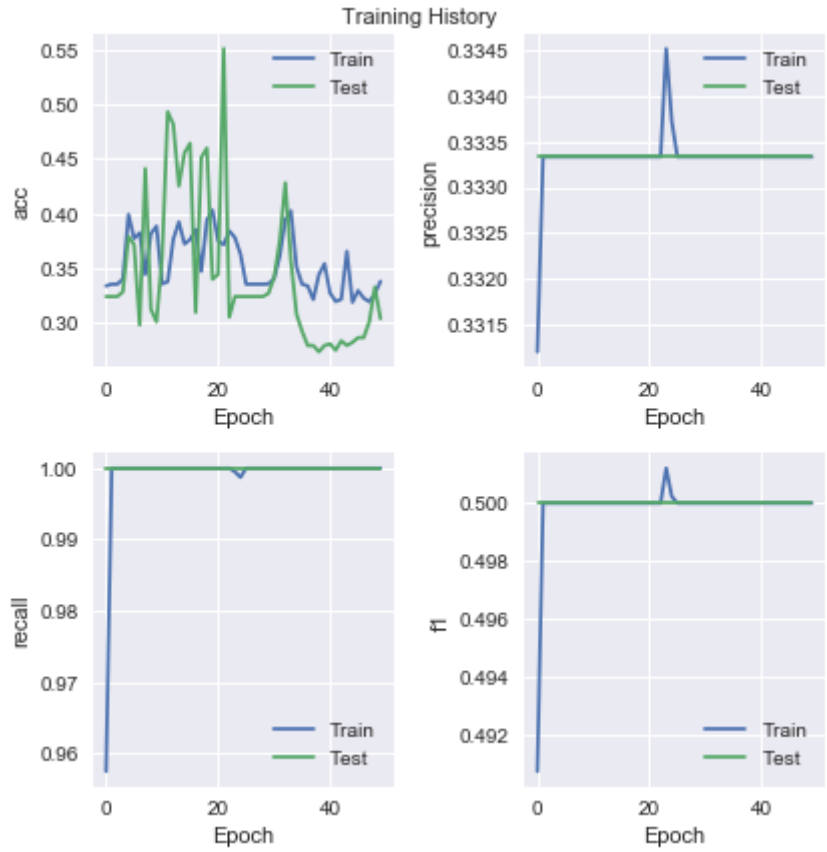

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

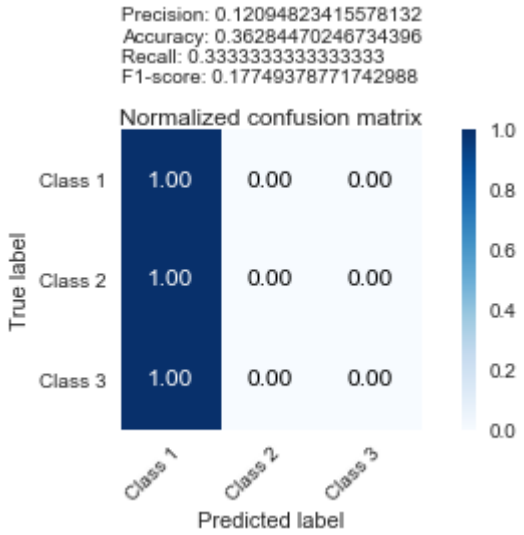

Training History
Train
Test
acc
Epoch
precision
recall
f1

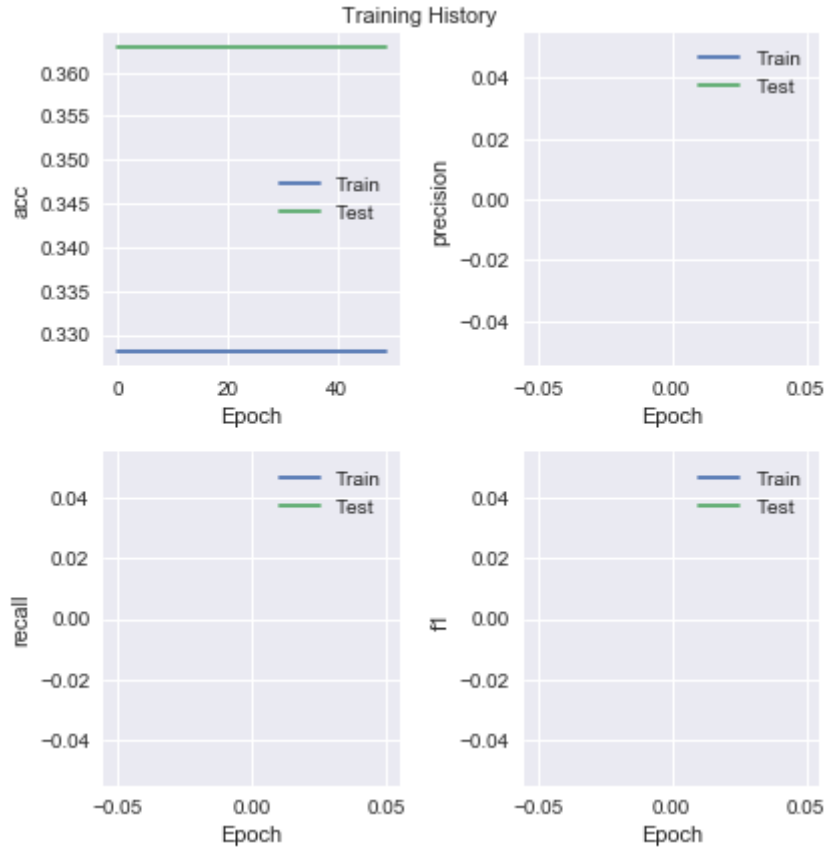

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

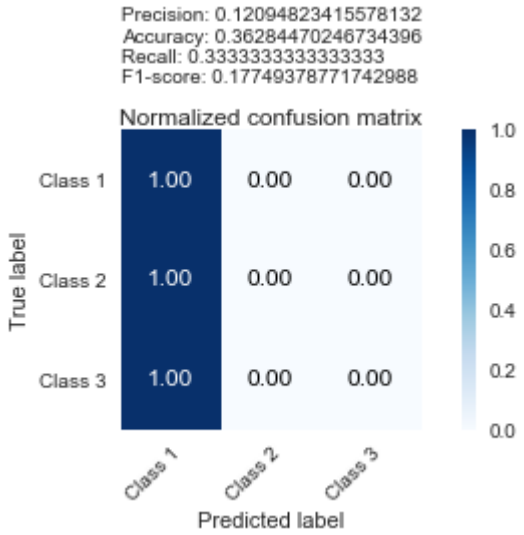

Training History
acc
0.360
0.355
0.350
0.345
0.340
0.335
0.330
Train
Test
0
20
40
Epoch
precision
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
recall
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
f1
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch

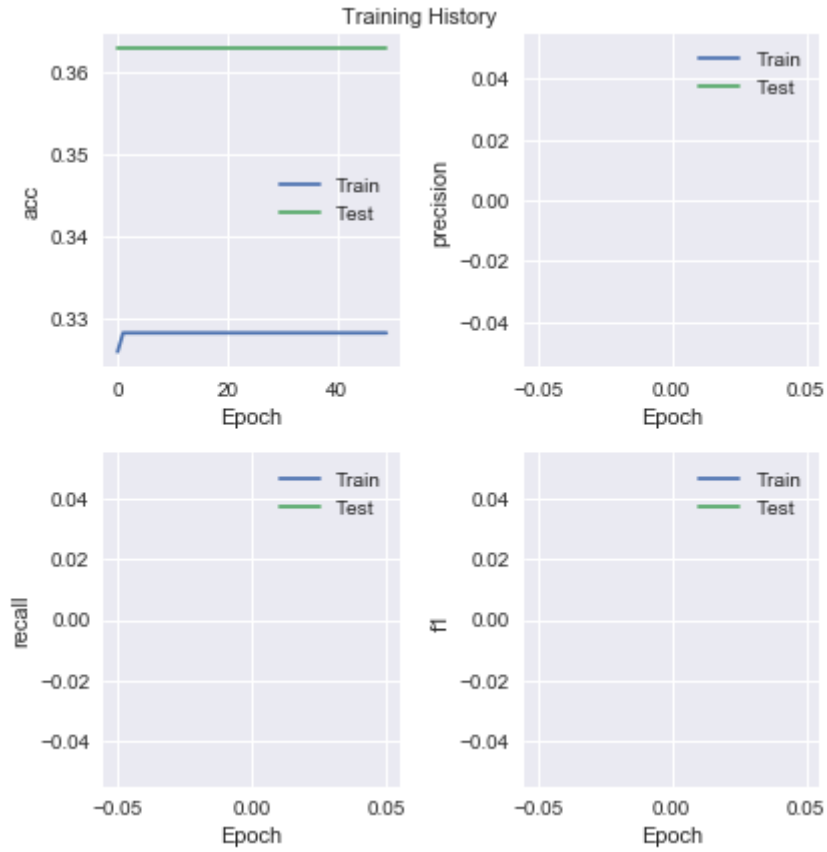

Precision: 0.3648070105023747
Accuracy: 0.3033381712626996
Recall: 0.3193500525936998
F1-score: 0.23462106099677257
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
0.02
0.76
0.22
0.02
0.74
0.24
0.00
0.80
0.20
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Class 1
Class 2
Class 3
Predicted label

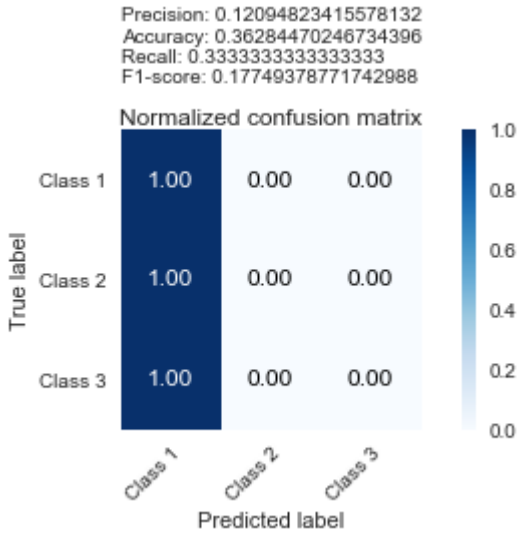

Training History
acc
precision
recall
f1
Train
Test
Epoch

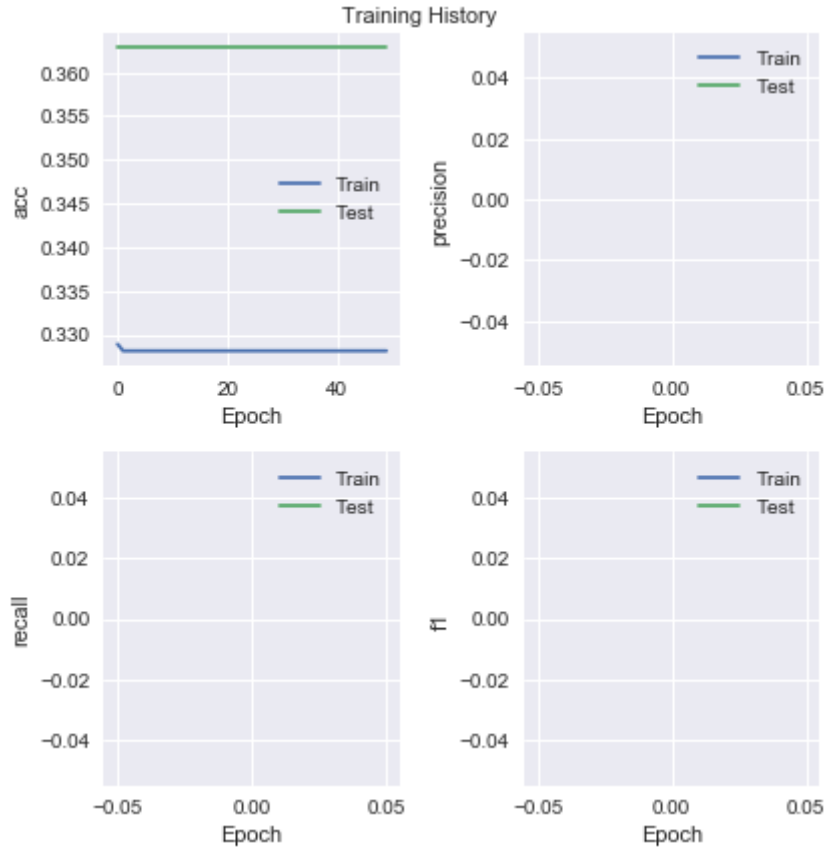

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label

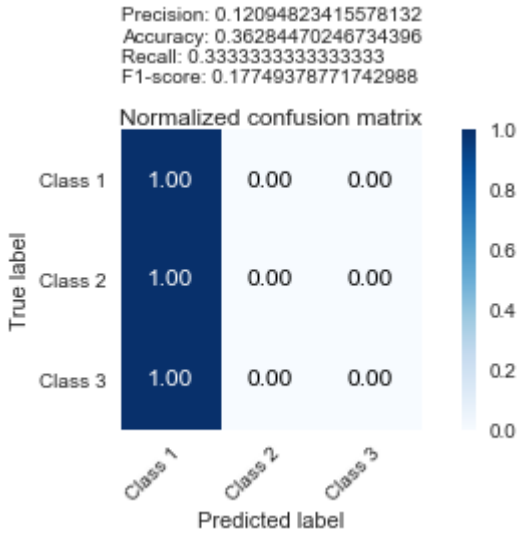

Training History
acc
0.360
0.355
0.350
0.345
0.340
0.335
0.330
Train
Test
0
20
40
Epoch
precision
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
recall
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
f1
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch

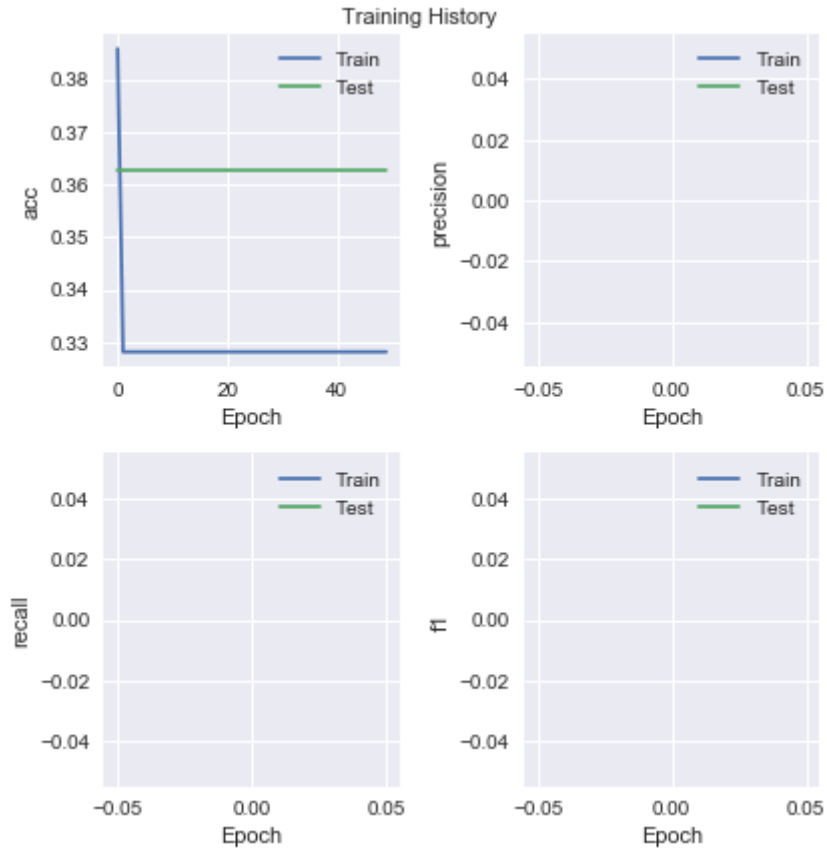

Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label


Training History
acc
0.36
0.35
0.34
0.33
Train
Test
0
20
40
Epoch
precision
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
recall
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
f1
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch


Precision: 0.12094823415578132
Accuracy: 0.36284470246734396
Recall: 0.3333333333333333
F1-score: 0.17749378771742988
Normalized confusion matrix
Class 1
Class 2
Class 3
True label
1.00
0.00
0.00
1.00
0.00
0.00
1.00
0.00
0.00
1.0
0.8
0.6
0.4
0.2
0.0
Class 1
Class 2
Class 3
Predicted label


Training History
acc
0.360
0.355
0.350
0.345
0.340
0.335
0.330
Train
Test
0
20
40
Epoch
precision
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
recall
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch
f1
0.04
0.02
0.00
−0.02
−0.04
Train
Test
−0.05
0.00
0.05
Epoch





Clearly none of the above combinations of activation functions and optimizers help to achieve a precise prediction. Hence the model created by me based on the baseline model provided can be said to be the best model obtained in this project.

In [ ]: