In [3]:

```
import tensorflow as tf
```

In [4]:

```
# Load Data
(x_train, y_train), (x_test, y_test) = tf.keras.datasets.mnist.load_data()
from tensorflow.keras.datasets import fashion_mnist
(fX_train, fY_train), (fX_test, fY_test) = fashion_mnist.load_data()
```

Baseline Model

In [24]:

```
# Baseline model definition
model = tf.keras.Sequential([
                             tf.keras.layers.Flatten(input_shape=(28, 28)),
                             tf.keras.layers.Dense(16, activation='relu'),
                             tf.keras.layers.Dense(16, activation='relu'),
                             tf.keras.layers.Dense(10, activation='softmax')
])
```

In [25]:

```
# Baseline model compilation
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
             )
```

In [26]:

```
# Baseline model fitting
history = model.fit(x_train, y_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
```

```
Epoch 1/100
469/469 - 2s - loss: 3.4813 - sparse_categorical_accuracy: 0.2235 - val_loss: 1.8703 - val_sparse_ca
tegorical_accuracy: 0.3016 - 2s/epoch - 4ms/step
Epoch 2/100
469/469 - 1s - loss: 1.7270 - sparse_categorical_accuracy: 0.3347 - val_loss: 1.6121 - val_sparse_ca
tegorical_accuracy: 0.3809 - 1s/epoch - 2ms/step
Epoch 3/100
469/469 - 1s - loss: 1.4502 - sparse_categorical_accuracy: 0.4292 - val_loss: 1.3154 - val_sparse_ca
tegorical_accuracy: 0.5176 - 1s/epoch - 2ms/step
Epoch 4/100
469/469 - 1s - loss: 1.1873 - sparse_categorical_accuracy: 0.5732 - val_loss: 1.0806 - val_sparse_ca
tegorical_accuracy: 0.6098 - 1s/epoch - 2ms/step
Epoch 5/100
469/469 - 1s - loss: 0.9974 - sparse_categorical_accuracy: 0.6550 - val_loss: 0.9226 - val_sparse_ca
tegorical_accuracy: 0.6843 - 1s/epoch - 2ms/step
Epoch 6/100
469/469 - 1s - loss: 0.8633 - sparse_categorical_accuracy: 0.7049 - val_loss: 0.7786 - val_sparse_ca
tegorical_accuracy: 0.7701 - 1s/epoch - 3ms/step
Epoch 7/100
469/469 - 1s - loss: 0.7000 - sparse_categorical_accuracy: 0.7954 - val_loss: 0.6394 - val_sparse_ca
tegorical_accuracy: 0.8129 - 1s/epoch - 3ms/step
Epoch 8/100
469/469 - 1s - loss: 0.6103 - sparse_categorical_accuracy: 0.8210 - val_loss: 0.6009 - val_sparse_ca
tegorical_accuracy: 0.8258 - 1s/epoch - 3ms/step
Epoch 9/100
469/469 - 1s - loss: 0.5686 - sparse_categorical_accuracy: 0.8319 - val_loss: 0.5832 - val_sparse_ca
tegorical_accuracy: 0.8263 - 1s/epoch - 2ms/step
Epoch 10/100
469/469 - 1s - loss: 0.5393 - sparse_categorical_accuracy: 0.8397 - val_loss: 0.5569 - val_sparse_ca
tegorical_accuracy: 0.8366 - 1s/epoch - 2ms/step
Epoch 11/100
469/469 - 1s - loss: 0.5224 - sparse_categorical_accuracy: 0.8460 - val_loss: 0.5913 - val_sparse_ca
tegorical_accuracy: 0.8305 - 1s/epoch - 3ms/step
Epoch 12/100
469/469 - 1s - loss: 0.5153 - sparse_categorical_accuracy: 0.8484 - val_loss: 0.5234 - val_sparse_ca
tegorical_accuracy: 0.8507 - 1s/epoch - 3ms/step
Epoch 13/100
469/469 - 1s - loss: 0.4947 - sparse_categorical_accuracy: 0.8549 - val_loss: 0.5228 - val_sparse_ca
```

```
tegorical_accuracy: 0.8520 - 1s/epoch - 2ms/step
Epoch 14/100
469/469 - 1s - loss: 0.4920 - sparse_categorical_accuracy: 0.8546 - val_loss: 0.4950 - val_sparse_ca
tegorical_accuracy: 0.8522 - 1s/epoch - 2ms/step
Epoch 15/100
469/469 - 1s - loss: 0.4808 - sparse_categorical_accuracy: 0.8581 - val_loss: 0.5023 - val_sparse_ca
tegorical_accuracy: 0.8591 - 1s/epoch - 2ms/step
Epoch 16/100
469/469 - 1s - loss: 0.4767 - sparse_categorical_accuracy: 0.8600 - val_loss: 0.5039 - val_sparse_ca
tegorical_accuracy: 0.8574 - 1s/epoch - 2ms/step
Epoch 17/100
469/469 - 1s - loss: 0.4617 - sparse_categorical_accuracy: 0.8652 - val_loss: 0.5059 - val_sparse_ca
tegorical_accuracy: 0.8514 - 1s/epoch - 2ms/step
Epoch 18/100
469/469 - 1s - loss: 0.4574 - sparse_categorical_accuracy: 0.8670 - val_loss: 0.4912 - val_sparse_ca
tegorical_accuracy: 0.8592 - 1s/epoch - 2ms/step
Epoch 19/100
469/469 - 1s - loss: 0.4452 - sparse_categorical_accuracy: 0.8695 - val_loss: 0.5115 - val_sparse_ca
tegorical_accuracy: 0.8507 - 1s/epoch - 2ms/step
Epoch 20/100
469/469 - 1s - loss: 0.4451 - sparse_categorical_accuracy: 0.8694 - val_loss: 0.4859 - val_sparse_ca
tegorical_accuracy: 0.8688 - 1s/epoch - 3ms/step
Epoch 21/100
469/469 - 1s - loss: 0.4351 - sparse_categorical_accuracy: 0.8719 - val_loss: 0.4707 - val_sparse_ca
tegorical_accuracy: 0.8691 - 1s/epoch - 3ms/step
Epoch 22/100
469/469 - 1s - loss: 0.4351 - sparse_categorical_accuracy: 0.8713 - val_loss: 0.4566 - val_sparse_ca
tegorical_accuracy: 0.8721 - 1s/epoch - 3ms/step
Epoch 23/100
469/469 - 1s - loss: 0.4251 - sparse_categorical_accuracy: 0.8758 - val_loss: 0.4583 - val_sparse_ca
tegorical_accuracy: 0.8715 - 1s/epoch - 3ms/step
Epoch 24/100
469/469 - 1s - loss: 0.4229 - sparse_categorical_accuracy: 0.8754 - val_loss: 0.4349 - val_sparse_ca
tegorical_accuracy: 0.8719 - 1s/epoch - 3ms/step
Epoch 25/100
469/469 - 1s - loss: 0.4197 - sparse_categorical_accuracy: 0.8760 - val_loss: 0.4526 - val_sparse_ca
tegorical_accuracy: 0.8702 - 1s/epoch - 3ms/step
Epoch 26/100
469/469 - 1s - loss: 0.4176 - sparse_categorical_accuracy: 0.8777 - val_loss: 0.4548 - val_sparse_ca
tegorical_accuracy: 0.8733 - 1s/epoch - 3ms/step
Epoch 27/100
469/469 - 1s - loss: 0.4124 - sparse_categorical_accuracy: 0.8798 - val_loss: 0.4366 - val_sparse_ca
tegorical_accuracy: 0.8775 - 1s/epoch - 2ms/step
Epoch 28/100
469/469 - 1s - loss: 0.4105 - sparse_categorical_accuracy: 0.8780 - val_loss: 0.4691 - val_sparse_ca
tegorical_accuracy: 0.8673 - 1s/epoch - 2ms/step
Epoch 29/100
469/469 - 1s - loss: 0.4032 - sparse_categorical_accuracy: 0.8813 - val_loss: 0.4517 - val_sparse_ca
tegorical_accuracy: 0.8752 - 1s/epoch - 3ms/step
Epoch 30/100
469/469 - 1s - loss: 0.4065 - sparse_categorical_accuracy: 0.8802 - val_loss: 0.4477 - val_sparse_ca
tegorical_accuracy: 0.8728 - 1s/epoch - 3ms/step
Epoch 31/100
469/469 - 1s - loss: 0.3960 - sparse_categorical_accuracy: 0.8827 - val_loss: 0.4577 - val_sparse_ca
tegorical_accuracy: 0.8727 - 1s/epoch - 3ms/step
Epoch 32/100
469/469 - 1s - loss: 0.3949 - sparse_categorical_accuracy: 0.8843 - val_loss: 0.4395 - val_sparse_ca
tegorical_accuracy: 0.8780 - 1s/epoch - 2ms/step
Epoch 33/100
469/469 - 1s - loss: 0.3929 - sparse_categorical_accuracy: 0.8846 - val_loss: 0.4188 - val_sparse_ca
tegorical_accuracy: 0.8838 - 1s/epoch - 2ms/step
Epoch 34/100
469/469 - 1s - loss: 0.3892 - sparse_categorical_accuracy: 0.8846 - val_loss: 0.4685 - val_sparse_ca
tegorical_accuracy: 0.8654 - 1s/epoch - 3ms/step
Epoch 35/100
469/469 - 1s - loss: 0.3862 - sparse_categorical_accuracy: 0.8859 - val_loss: 0.4143 - val_sparse_ca
tegorical_accuracy: 0.8813 - 1s/epoch - 2ms/step
Epoch 36/100
469/469 - 1s - loss: 0.3856 - sparse_categorical_accuracy: 0.8848 - val_loss: 0.3990 - val_sparse_ca
tegorical_accuracy: 0.8876 - 1s/epoch - 2ms/step
Epoch 37/100
469/469 - 1s - loss: 0.3844 - sparse_categorical_accuracy: 0.8857 - val_loss: 0.4032 - val_sparse_ca
tegorical_accuracy: 0.8867 - 1s/epoch - 3ms/step
Epoch 38/100
469/469 - 1s - loss: 0.3757 - sparse_categorical_accuracy: 0.8895 - val_loss: 0.3886 - val_sparse_ca
tegorical_accuracy: 0.8871 - 1s/epoch - 3ms/step
Epoch 39/100
469/469 - 1s - loss: 0.3747 - sparse_categorical_accuracy: 0.8879 - val_loss: 0.4156 - val_sparse_ca
tegorical_accuracy: 0.8842 - 1s/epoch - 3ms/step
Epoch 40/100
469/469 - 1s - loss: 0.3749 - sparse_categorical_accuracy: 0.8886 - val_loss: 0.3993 - val_sparse_ca
tegorical_accuracy: 0.8842 - 1s/epoch - 2ms/step
Epoch 41/100
```

```
469/469 - 1s - loss: 0.3708 - sparse_categorical_accuracy: 0.8893 - val_loss: 0.4245 - val_sparse_ca
tegorical_accuracy: 0.8791 - 1s/epoch - 2ms/step
Epoch 42/100
469/469 - 1s - loss: 0.3660 - sparse_categorical_accuracy: 0.8900 - val_loss: 0.3907 - val_sparse_ca
tegorical_accuracy: 0.8897 - 1s/epoch - 2ms/step
Epoch 43/100
469/469 - 1s - loss: 0.3693 - sparse_categorical_accuracy: 0.8893 - val_loss: 0.4119 - val_sparse_ca
tegorical_accuracy: 0.8806 - 1s/epoch - 2ms/step
Epoch 44/100
469/469 - 1s - loss: 0.3690 - sparse_categorical_accuracy: 0.8902 - val_loss: 0.4147 - val_sparse_ca
tegorical_accuracy: 0.8838 - 1s/epoch - 2ms/step
Epoch 45/100
469/469 - 1s - loss: 0.3651 - sparse_categorical_accuracy: 0.8906 - val_loss: 0.3861 - val_sparse_ca
tegorical_accuracy: 0.8928 - 1s/epoch - 2ms/step
Epoch 46/100
469/469 - 1s - loss: 0.3591 - sparse_categorical_accuracy: 0.8923 - val_loss: 0.3980 - val_sparse_ca
tegorical_accuracy: 0.8896 - 1s/epoch - 2ms/step
Epoch 47/100
469/469 - 1s - loss: 0.3584 - sparse_categorical_accuracy: 0.8914 - val_loss: 0.3905 - val_sparse_ca
tegorical_accuracy: 0.8889 - 1s/epoch - 2ms/step
Epoch 48/100
469/469 - 1s - loss: 0.3569 - sparse_categorical_accuracy: 0.8934 - val_loss: 0.3978 - val_sparse_ca
tegorical_accuracy: 0.8846 - 1s/epoch - 2ms/step
Epoch 49/100
469/469 - 1s - loss: 0.3511 - sparse_categorical_accuracy: 0.8942 - val_loss: 0.4017 - val_sparse_ca
tegorical_accuracy: 0.8850 - 1s/epoch - 3ms/step
Epoch 50/100
469/469 - 1s - loss: 0.3540 - sparse_categorical_accuracy: 0.8943 - val_loss: 0.3961 - val_sparse_ca
tegorical_accuracy: 0.8811 - 1s/epoch - 3ms/step
Epoch 51/100
469/469 - 1s - loss: 0.3517 - sparse_categorical_accuracy: 0.8948 - val_loss: 0.3783 - val_sparse_ca
tegorical_accuracy: 0.8935 - 1s/epoch - 2ms/step
Epoch 52/100
469/469 - 1s - loss: 0.3521 - sparse_categorical_accuracy: 0.8946 - val_loss: 0.3986 - val_sparse_ca
tegorical_accuracy: 0.8828 - 1s/epoch - 3ms/step
Epoch 53/100
469/469 - 1s - loss: 0.3458 - sparse_categorical_accuracy: 0.8964 - val_loss: 0.3811 - val_sparse_ca
tegorical_accuracy: 0.8916 - 1s/epoch - 2ms/step
Epoch 54/100
469/469 - 1s - loss: 0.3466 - sparse_categorical_accuracy: 0.8968 - val_loss: 0.4034 - val_sparse_ca
tegorical_accuracy: 0.8889 - 1s/epoch - 3ms/step
Epoch 55/100
469/469 - 1s - loss: 0.3480 - sparse_categorical_accuracy: 0.8969 - val_loss: 0.3984 - val_sparse_ca
tegorical_accuracy: 0.8856 - 1s/epoch - 2ms/step
Epoch 56/100
469/469 - 1s - loss: 0.3401 - sparse_categorical_accuracy: 0.8987 - val_loss: 0.3873 - val_sparse_ca
tegorical_accuracy: 0.8845 - 1s/epoch - 2ms/step
Epoch 57/100
469/469 - 1s - loss: 0.3367 - sparse_categorical_accuracy: 0.8992 - val_loss: 0.4113 - val_sparse_ca
tegorical_accuracy: 0.8845 - 1s/epoch - 2ms/step
Epoch 58/100
469/469 - 1s - loss: 0.3423 - sparse_categorical_accuracy: 0.8978 - val_loss: 0.4381 - val_sparse_ca
tegorical_accuracy: 0.8753 - 1s/epoch - 2ms/step
Epoch 59/100
469/469 - 1s - loss: 0.3386 - sparse_categorical_accuracy: 0.8989 - val_loss: 0.3560 - val_sparse_ca
tegorical_accuracy: 0.8973 - 1s/epoch - 2ms/step
Epoch 60/100
469/469 - 1s - loss: 0.3321 - sparse_categorical_accuracy: 0.9014 - val_loss: 0.3864 - val_sparse_ca
tegorical_accuracy: 0.8881 - 1s/epoch - 2ms/step
Epoch 61/100
469/469 - 1s - loss: 0.3357 - sparse_categorical_accuracy: 0.8984 - val_loss: 0.3714 - val_sparse_ca
tegorical_accuracy: 0.8959 - 1s/epoch - 2ms/step
Epoch 62/100
469/469 - 1s - loss: 0.3368 - sparse_categorical_accuracy: 0.8988 - val_loss: 0.3853 - val_sparse_ca
tegorical_accuracy: 0.8904 - 1s/epoch - 2ms/step
Epoch 63/100
469/469 - 1s - loss: 0.3313 - sparse_categorical_accuracy: 0.9010 - val_loss: 0.3544 - val_sparse_ca
tegorical_accuracy: 0.9008 - 1s/epoch - 2ms/step
Epoch 64/100
469/469 - 1s - loss: 0.3307 - sparse_categorical_accuracy: 0.9015 - val_loss: 0.4290 - val_sparse_ca
tegorical_accuracy: 0.8718 - 1s/epoch - 2ms/step
Epoch 65/100
469/469 - 1s - loss: 0.3268 - sparse_categorical_accuracy: 0.9021 - val_loss: 0.4166 - val_sparse_ca
tegorical_accuracy: 0.8829 - 1s/epoch - 2ms/step
Epoch 66/100
469/469 - 1s - loss: 0.3304 - sparse_categorical_accuracy: 0.9023 - val_loss: 0.3535 - val_sparse_ca
tegorical_accuracy: 0.8998 - 1s/epoch - 2ms/step
Epoch 67/100
469/469 - 1s - loss: 0.3253 - sparse_categorical_accuracy: 0.9040 - val_loss: 0.3681 - val_sparse_ca
tegorical_accuracy: 0.8957 - 1s/epoch - 2ms/step
Epoch 68/100
469/469 - 1s - loss: 0.3233 - sparse_categorical_accuracy: 0.9034 - val_loss: 0.3707 - val_sparse_ca
tegorical_accuracy: 0.8946 - 1s/epoch - 2ms/step
```

```
Epoch 69/100
469/469 - 1s - loss: 0.3250 - sparse_categorical_accuracy: 0.9031 - val_loss: 0.4041 - val_sparse_ca
tegorical_accuracy: 0.8870 - 1s/epoch - 2ms/step
Epoch 70/100
469/469 - 1s - loss: 0.3205 - sparse_categorical_accuracy: 0.9039 - val_loss: 0.3650 - val_sparse_ca
tegorical_accuracy: 0.8995 - 1s/epoch - 3ms/step
Epoch 71/100
469/469 - 1s - loss: 0.3221 - sparse_categorical_accuracy: 0.9032 - val_loss: 0.3664 - val_sparse_ca
tegorical_accuracy: 0.8941 - 1s/epoch - 2ms/step
Epoch 72/100
469/469 - 1s - loss: 0.3174 - sparse_categorical_accuracy: 0.9058 - val_loss: 0.3602 - val_sparse_ca
tegorical_accuracy: 0.8964 - 1s/epoch - 2ms/step
Epoch 73/100
469/469 - 1s - loss: 0.3165 - sparse_categorical_accuracy: 0.9063 - val_loss: 0.3613 - val_sparse_ca
tegorical_accuracy: 0.9001 - 1s/epoch - 2ms/step
Epoch 74/100
469/469 - 1s - loss: 0.3191 - sparse_categorical_accuracy: 0.9040 - val_loss: 0.3533 - val_sparse_ca
tegorical_accuracy: 0.8973 - 1s/epoch - 2ms/step
Epoch 75/100
469/469 - 1s - loss: 0.3136 - sparse_categorical_accuracy: 0.9068 - val_loss: 0.3734 - val_sparse_ca
tegorical_accuracy: 0.8911 - 1s/epoch - 2ms/step
Epoch 76/100
469/469 - 1s - loss: 0.3148 - sparse_categorical_accuracy: 0.9067 - val_loss: 0.3867 - val_sparse_ca
tegorical_accuracy: 0.8917 - 1s/epoch - 2ms/step
Epoch 77/100
469/469 - 1s - loss: 0.3101 - sparse_categorical_accuracy: 0.9079 - val_loss: 0.3768 - val_sparse_ca
tegorical_accuracy: 0.8966 - 1s/epoch - 2ms/step
Epoch 78/100
469/469 - 1s - loss: 0.3155 - sparse_categorical_accuracy: 0.9064 - val_loss: 0.3758 - val_sparse_ca
tegorical_accuracy: 0.8891 - 1s/epoch - 3ms/step
Epoch 79/100
469/469 - 1s - loss: 0.3092 - sparse_categorical_accuracy: 0.9081 - val_loss: 0.3602 - val_sparse_ca
tegorical_accuracy: 0.8963 - 1s/epoch - 3ms/step
Epoch 80/100
469/469 - 1s - loss: 0.3124 - sparse_categorical_accuracy: 0.9071 - val_loss: 0.3526 - val_sparse_ca
tegorical_accuracy: 0.9007 - 1s/epoch - 3ms/step
Epoch 81/100
469/469 - 1s - loss: 0.3055 - sparse_categorical_accuracy: 0.9089 - val_loss: 0.3790 - val_sparse_ca
tegorical_accuracy: 0.8929 - 1s/epoch - 3ms/step
Epoch 82/100
469/469 - 1s - loss: 0.3063 - sparse_categorical_accuracy: 0.9078 - val_loss: 0.3692 - val_sparse_ca
tegorical_accuracy: 0.8983 - 1s/epoch - 2ms/step
Epoch 83/100
469/469 - 1s - loss: 0.3063 - sparse_categorical_accuracy: 0.9085 - val_loss: 0.3728 - val_sparse_ca
tegorical_accuracy: 0.8973 - 1s/epoch - 2ms/step
Epoch 84/100
469/469 - 1s - loss: 0.3033 - sparse_categorical_accuracy: 0.9097 - val_loss: 0.3573 - val_sparse_ca
tegorical_accuracy: 0.8991 - 1s/epoch - 2ms/step
Epoch 85/100
469/469 - 1s - loss: 0.3103 - sparse_categorical_accuracy: 0.9074 - val_loss: 0.3759 - val_sparse_ca
tegorical_accuracy: 0.8908 - 1s/epoch - 2ms/step
Epoch 86/100
469/469 - 1s - loss: 0.3033 - sparse_categorical_accuracy: 0.9099 - val_loss: 0.3776 - val_sparse_ca
tegorical_accuracy: 0.8902 - 1s/epoch - 2ms/step
Epoch 87/100
469/469 - 1s - loss: 0.3033 - sparse_categorical_accuracy: 0.9096 - val_loss: 0.3568 - val_sparse_ca
tegorical_accuracy: 0.9008 - 1s/epoch - 2ms/step
Epoch 88/100
469/469 - 1s - loss: 0.3026 - sparse_categorical_accuracy: 0.9096 - val_loss: 0.3658 - val_sparse_ca
tegorical_accuracy: 0.8945 - 1s/epoch - 2ms/step
Epoch 89/100
469/469 - 1s - loss: 0.3045 - sparse_categorical_accuracy: 0.9079 - val_loss: 0.3824 - val_sparse_ca
tegorical_accuracy: 0.8905 - 1s/epoch - 2ms/step
Epoch 90/100
469/469 - 1s - loss: 0.3031 - sparse_categorical_accuracy: 0.9097 - val_loss: 0.3468 - val_sparse_ca
tegorical_accuracy: 0.9027 - 1s/epoch - 2ms/step
Epoch 91/100
469/469 - 1s - loss: 0.3011 - sparse_categorical_accuracy: 0.9102 - val_loss: 0.3838 - val_sparse_ca
tegorical_accuracy: 0.8971 - 1s/epoch - 2ms/step
Epoch 92/100
469/469 - 1s - loss: 0.2997 - sparse_categorical_accuracy: 0.9101 - val_loss: 0.3875 - val_sparse_ca
tegorical_accuracy: 0.8941 - 1s/epoch - 2ms/step
Epoch 93/100
469/469 - 1s - loss: 0.2985 - sparse_categorical_accuracy: 0.9107 - val_loss: 0.3629 - val_sparse_ca
tegorical_accuracy: 0.8986 - 1s/epoch - 2ms/step
Epoch 94/100
469/469 - 1s - loss: 0.2980 - sparse_categorical_accuracy: 0.9111 - val_loss: 0.3759 - val_sparse_ca
tegorical_accuracy: 0.8926 - 1s/epoch - 2ms/step
Epoch 95/100
469/469 - 1s - loss: 0.2951 - sparse_categorical_accuracy: 0.9109 - val_loss: 0.3586 - val_sparse_ca
tegorical_accuracy: 0.8960 - 1s/epoch - 2ms/step
Epoch 96/100
469/469 - 1s - loss: 0.2971 - sparse_categorical_accuracy: 0.9107 - val_loss: 0.3574 - val_sparse_ca
```

```
tegorical_accuracy: 0.8997 - 1s/epoch - 2ms/step
Epoch 97/100
469/469 - 1s - loss: 0.2968 - sparse_categorical_accuracy: 0.9109 - val_loss: 0.3556 - val_sparse_ca
tegorical_accuracy: 0.9000 - 1s/epoch - 2ms/step
Epoch 98/100
469/469 - 1s - loss: 0.2940 - sparse_categorical_accuracy: 0.9126 - val_loss: 0.3756 - val_sparse_ca
tegorical_accuracy: 0.8898 - 1s/epoch - 2ms/step
Epoch 99/100
469/469 - 1s - loss: 0.2929 - sparse_categorical_accuracy: 0.9113 - val_loss: 0.3642 - val_sparse_ca
tegorical_accuracy: 0.9015 - 1s/epoch - 3ms/step
Epoch 100/100
469/469 - 1s - loss: 0.2931 - sparse_categorical_accuracy: 0.9120 - val_loss: 0.3579 - val_sparse_ca
tegorical_accuracy: 0.8982 - 1s/epoch - 2ms/step
```

In [29]:

```
# Baseline model evaluation
model.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 1s - loss: 0.3579 - sparse_categorical_accuracy: 0.8982 - 651ms/epoch - 2ms/step
```

Out[29]:

```
[0.35786983370780945, 0.8981999754905701]
```

In [31]:

```
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
             )
# Baseline model fitting
history1_1 = model.fit(fX_train, fY_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(fX_test, fY_test),
                    verbose=2
                    )
model.evaluate(fX_test, fY_test, verbose=2)
```

```
Epoch 1/100
469/469 - 2s - loss: 2.5334 - sparse_categorical_accuracy: 0.4122 - val_loss: 1.3043 - val_sparse_ca
tegorical_accuracy: 0.5352 - 2s/epoch - 4ms/step
Epoch 2/100
469/469 - 1s - loss: 1.0943 - sparse_categorical_accuracy: 0.6061 - val_loss: 0.9917 - val_sparse_ca
tegorical_accuracy: 0.6490 - 1s/epoch - 3ms/step
Epoch 3/100
469/469 - 1s - loss: 0.8741 - sparse_categorical_accuracy: 0.6800 - val_loss: 0.9081 - val_sparse_ca
tegorical_accuracy: 0.6722 - 1s/epoch - 2ms/step
Epoch 4/100
469/469 - 2s - loss: 0.7782 - sparse_categorical_accuracy: 0.7096 - val_loss: 0.7141 - val_sparse_ca
tegorical_accuracy: 0.7215 - 2s/epoch - 3ms/step
Epoch 5/100
469/469 - 1s - loss: 0.7183 - sparse_categorical_accuracy: 0.7329 - val_loss: 0.7124 - val_sparse_ca
tegorical_accuracy: 0.7359 - 1s/epoch - 2ms/step
Epoch 6/100
469/469 - 1s - loss: 0.6715 - sparse_categorical_accuracy: 0.7534 - val_loss: 0.6500 - val_sparse_ca
tegorical_accuracy: 0.7667 - 1s/epoch - 2ms/step
Epoch 7/100
469/469 - 1s - loss: 0.6356 - sparse_categorical_accuracy: 0.7745 - val_loss: 0.6380 - val_sparse_ca
tegorical_accuracy: 0.7791 - 1s/epoch - 2ms/step
Epoch 8/100
469/469 - 1s - loss: 0.5994 - sparse_categorical_accuracy: 0.7911 - val_loss: 0.6095 - val_sparse_ca
tegorical_accuracy: 0.7940 - 1s/epoch - 3ms/step
Epoch 9/100
469/469 - 1s - loss: 0.5713 - sparse_categorical_accuracy: 0.8015 - val_loss: 0.6788 - val_sparse_ca
tegorical_accuracy: 0.7575 - 1s/epoch - 3ms/step
Epoch 10/100
469/469 - 1s - loss: 0.5518 - sparse_categorical_accuracy: 0.8073 - val_loss: 0.5621 - val_sparse_ca
tegorical_accuracy: 0.8046 - 1s/epoch - 2ms/step
Epoch 11/100
469/469 - 1s - loss: 0.5268 - sparse_categorical_accuracy: 0.8148 - val_loss: 0.5579 - val_sparse_ca
tegorical_accuracy: 0.8078 - 1s/epoch - 2ms/step
Epoch 12/100
469/469 - 2s - loss: 0.5176 - sparse_categorical_accuracy: 0.8179 - val_loss: 0.5335 - val_sparse_ca
tegorical_accuracy: 0.8151 - 2s/epoch - 3ms/step
Epoch 13/100
469/469 - 1s - loss: 0.5096 - sparse_categorical_accuracy: 0.8217 - val_loss: 0.5671 - val_sparse_ca
tegorical_accuracy: 0.8077 - 1s/epoch - 3ms/step
Epoch 14/100
469/469 - 1s - loss: 0.5019 - sparse_categorical_accuracy: 0.8222 - val_loss: 0.5400 - val_sparse_ca
tegorical_accuracy: 0.8110 - 1s/epoch - 3ms/step
Epoch 15/100
469/469 - 1s - loss: 0.4895 - sparse_categorical_accuracy: 0.8252 - val_loss: 0.5183 - val_sparse_ca
```

```
tegorical_accuracy: 0.8189 - 1s/epoch - 3ms/step
Epoch 16/100
469/469 - 1s - loss: 0.4828 - sparse_categorical_accuracy: 0.8275 - val_loss: 0.5250 - val_sparse_ca
tegorical_accuracy: 0.8148 - 1s/epoch - 2ms/step
Epoch 17/100
469/469 - 1s - loss: 0.4732 - sparse_categorical_accuracy: 0.8310 - val_loss: 0.5327 - val_sparse_ca
tegorical_accuracy: 0.8135 - 1s/epoch - 3ms/step
Epoch 18/100
469/469 - 1s - loss: 0.4666 - sparse_categorical_accuracy: 0.8324 - val_loss: 0.5491 - val_sparse_ca
tegorical_accuracy: 0.8111 - 1s/epoch - 3ms/step
Epoch 19/100
469/469 - 1s - loss: 0.4622 - sparse_categorical_accuracy: 0.8345 - val_loss: 0.5168 - val_sparse_ca
tegorical_accuracy: 0.8184 - 1s/epoch - 3ms/step
Epoch 20/100
469/469 - 1s - loss: 0.4594 - sparse_categorical_accuracy: 0.8343 - val_loss: 0.5163 - val_sparse_ca
tegorical_accuracy: 0.8222 - 1s/epoch - 2ms/step
Epoch 21/100
469/469 - 1s - loss: 0.4580 - sparse_categorical_accuracy: 0.8344 - val_loss: 0.5055 - val_sparse_ca
tegorical_accuracy: 0.8225 - 1s/epoch - 3ms/step
Epoch 22/100
469/469 - 1s - loss: 0.4508 - sparse_categorical_accuracy: 0.8376 - val_loss: 0.5191 - val_sparse_ca
tegorical_accuracy: 0.8181 - 1s/epoch - 3ms/step
Epoch 23/100
469/469 - 1s - loss: 0.4472 - sparse_categorical_accuracy: 0.8397 - val_loss: 0.5180 - val_sparse_ca
tegorical_accuracy: 0.8148 - 1s/epoch - 3ms/step
Epoch 24/100
469/469 - 1s - loss: 0.4416 - sparse_categorical_accuracy: 0.8402 - val_loss: 0.5219 - val_sparse_ca
tegorical_accuracy: 0.8232 - 1s/epoch - 2ms/step
Epoch 25/100
469/469 - 1s - loss: 0.4408 - sparse_categorical_accuracy: 0.8414 - val_loss: 0.5160 - val_sparse_ca
tegorical_accuracy: 0.8230 - 1s/epoch - 2ms/step
Epoch 26/100
469/469 - 1s - loss: 0.4390 - sparse_categorical_accuracy: 0.8414 - val_loss: 0.5002 - val_sparse_ca
tegorical_accuracy: 0.8275 - 1s/epoch - 3ms/step
Epoch 27/100
469/469 - 1s - loss: 0.4389 - sparse_categorical_accuracy: 0.8415 - val_loss: 0.4934 - val_sparse_ca
tegorical_accuracy: 0.8313 - 1s/epoch - 3ms/step
Epoch 28/100
469/469 - 1s - loss: 0.4353 - sparse_categorical_accuracy: 0.8428 - val_loss: 0.5034 - val_sparse_ca
tegorical_accuracy: 0.8259 - 1s/epoch - 2ms/step
Epoch 29/100
469/469 - 1s - loss: 0.4332 - sparse_categorical_accuracy: 0.8444 - val_loss: 0.5026 - val_sparse_ca
tegorical_accuracy: 0.8237 - 1s/epoch - 3ms/step
Epoch 30/100
469/469 - 1s - loss: 0.4239 - sparse_categorical_accuracy: 0.8473 - val_loss: 0.4919 - val_sparse_ca
tegorical_accuracy: 0.8275 - 1s/epoch - 3ms/step
Epoch 31/100
469/469 - 1s - loss: 0.4247 - sparse_categorical_accuracy: 0.8462 - val_loss: 0.4979 - val_sparse_ca
tegorical_accuracy: 0.8290 - 1s/epoch - 3ms/step
Epoch 32/100
469/469 - 1s - loss: 0.4273 - sparse_categorical_accuracy: 0.8450 - val_loss: 0.4919 - val_sparse_ca
tegorical_accuracy: 0.8310 - 1s/epoch - 2ms/step
Epoch 33/100
469/469 - 1s - loss: 0.4210 - sparse_categorical_accuracy: 0.8473 - val_loss: 0.4954 - val_sparse_ca
tegorical_accuracy: 0.8313 - 1s/epoch - 2ms/step
Epoch 34/100
469/469 - 1s - loss: 0.4187 - sparse_categorical_accuracy: 0.8483 - val_loss: 0.5019 - val_sparse_ca
tegorical_accuracy: 0.8261 - 1s/epoch - 2ms/step
Epoch 35/100
469/469 - 1s - loss: 0.4176 - sparse_categorical_accuracy: 0.8481 - val_loss: 0.4964 - val_sparse_ca
tegorical_accuracy: 0.8285 - 1s/epoch - 3ms/step
Epoch 36/100
469/469 - 1s - loss: 0.4196 - sparse_categorical_accuracy: 0.8473 - val_loss: 0.5024 - val_sparse_ca
tegorical_accuracy: 0.8233 - 1s/epoch - 2ms/step
Epoch 37/100
469/469 - 1s - loss: 0.4152 - sparse_categorical_accuracy: 0.8497 - val_loss: 0.5038 - val_sparse_ca
tegorical_accuracy: 0.8321 - 1s/epoch - 3ms/step
Epoch 38/100
469/469 - 2s - loss: 0.4111 - sparse_categorical_accuracy: 0.8513 - val_loss: 0.5071 - val_sparse_ca
tegorical_accuracy: 0.8274 - 2s/epoch - 5ms/step
Epoch 39/100
469/469 - 2s - loss: 0.4115 - sparse_categorical_accuracy: 0.8489 - val_loss: 0.5121 - val_sparse_ca
tegorical_accuracy: 0.8272 - 2s/epoch - 5ms/step
Epoch 40/100
469/469 - 2s - loss: 0.4122 - sparse_categorical_accuracy: 0.8497 - val_loss: 0.4967 - val_sparse_ca
tegorical_accuracy: 0.8275 - 2s/epoch - 3ms/step
Epoch 41/100
469/469 - 3s - loss: 0.4097 - sparse_categorical_accuracy: 0.8511 - val_loss: 0.5098 - val_sparse_ca
tegorical_accuracy: 0.8236 - 3s/epoch - 7ms/step
Epoch 42/100
469/469 - 5s - loss: 0.4083 - sparse_categorical_accuracy: 0.8507 - val_loss: 0.5019 - val_sparse_ca
tegorical_accuracy: 0.8315 - 5s/epoch - 11ms/step
Epoch 43/100
```

```
469/469 - 4s - loss: 0.4074 - sparse_categorical_accuracy: 0.8514 - val_loss: 0.5102 - val_sparse_ca
tegorical_accuracy: 0.8258 - 4s/epoch - 8ms/step
Epoch 44/100
469/469 - 3s - loss: 0.4063 - sparse_categorical_accuracy: 0.8508 - val_loss: 0.5050 - val_sparse_ca
tegorical_accuracy: 0.8290 - 3s/epoch - 6ms/step
Epoch 45/100
469/469 - 3s - loss: 0.4044 - sparse_categorical_accuracy: 0.8536 - val_loss: 0.5004 - val_sparse_ca
tegorical_accuracy: 0.8317 - 3s/epoch - 6ms/step
Epoch 46/100
469/469 - 3s - loss: 0.4067 - sparse_categorical_accuracy: 0.8518 - val_loss: 0.4990 - val_sparse_ca
tegorical_accuracy: 0.8302 - 3s/epoch - 6ms/step
Epoch 47/100
469/469 - 4s - loss: 0.4020 - sparse_categorical_accuracy: 0.8544 - val_loss: 0.5003 - val_sparse_ca
tegorical_accuracy: 0.8309 - 4s/epoch - 8ms/step
Epoch 48/100
469/469 - 5s - loss: 0.3987 - sparse_categorical_accuracy: 0.8549 - val_loss: 0.5034 - val_sparse_ca
tegorical_accuracy: 0.8292 - 5s/epoch - 10ms/step
Epoch 49/100
469/469 - 2s - loss: 0.3993 - sparse_categorical_accuracy: 0.8540 - val_loss: 0.4915 - val_sparse_ca
tegorical_accuracy: 0.8301 - 2s/epoch - 4ms/step
Epoch 50/100
469/469 - 1s - loss: 0.3981 - sparse_categorical_accuracy: 0.8547 - val_loss: 0.5236 - val_sparse_ca
tegorical_accuracy: 0.8279 - 1s/epoch - 3ms/step
Epoch 51/100
469/469 - 1s - loss: 0.4017 - sparse_categorical_accuracy: 0.8550 - val_loss: 0.4995 - val_sparse_ca
tegorical_accuracy: 0.8300 - 1s/epoch - 2ms/step
Epoch 52/100
469/469 - 1s - loss: 0.4057 - sparse_categorical_accuracy: 0.8539 - val_loss: 0.5124 - val_sparse_ca
tegorical_accuracy: 0.8233 - 1s/epoch - 3ms/step
Epoch 53/100
469/469 - 1s - loss: 0.4009 - sparse_categorical_accuracy: 0.8549 - val_loss: 0.5047 - val_sparse_ca
tegorical_accuracy: 0.8274 - 1s/epoch - 3ms/step
Epoch 54/100
469/469 - 1s - loss: 0.3958 - sparse_categorical_accuracy: 0.8569 - val_loss: 0.4869 - val_sparse_ca
tegorical_accuracy: 0.8320 - 1s/epoch - 2ms/step
Epoch 55/100
469/469 - 1s - loss: 0.3945 - sparse_categorical_accuracy: 0.8574 - val_loss: 0.5510 - val_sparse_ca
tegorical_accuracy: 0.8253 - 1s/epoch - 2ms/step
Epoch 56/100
469/469 - 1s - loss: 0.3927 - sparse_categorical_accuracy: 0.8576 - val_loss: 0.5077 - val_sparse_ca
tegorical_accuracy: 0.8272 - 1s/epoch - 2ms/step
Epoch 57/100
469/469 - 1s - loss: 0.3930 - sparse_categorical_accuracy: 0.8568 - val_loss: 0.5083 - val_sparse_ca
tegorical_accuracy: 0.8356 - 1s/epoch - 2ms/step
Epoch 58/100
469/469 - 1s - loss: 0.3905 - sparse_categorical_accuracy: 0.8575 - val_loss: 0.5002 - val_sparse_ca
tegorical_accuracy: 0.8323 - 1s/epoch - 3ms/step
Epoch 59/100
469/469 - 1s - loss: 0.3915 - sparse_categorical_accuracy: 0.8588 - val_loss: 0.4996 - val_sparse_ca
tegorical_accuracy: 0.8330 - 1s/epoch - 3ms/step
Epoch 60/100
469/469 - 1s - loss: 0.3941 - sparse_categorical_accuracy: 0.8569 - val_loss: 0.4979 - val_sparse_ca
tegorical_accuracy: 0.8335 - 1s/epoch - 3ms/step
Epoch 61/100
469/469 - 1s - loss: 0.3941 - sparse_categorical_accuracy: 0.8572 - val_loss: 0.5048 - val_sparse_ca
tegorical_accuracy: 0.8295 - 1s/epoch - 2ms/step
Epoch 62/100
469/469 - 1s - loss: 0.3892 - sparse_categorical_accuracy: 0.8590 - val_loss: 0.5065 - val_sparse_ca
tegorical_accuracy: 0.8309 - 1s/epoch - 3ms/step
Epoch 63/100
469/469 - 1s - loss: 0.3886 - sparse_categorical_accuracy: 0.8590 - val_loss: 0.5203 - val_sparse_ca
tegorical_accuracy: 0.8249 - 1s/epoch - 3ms/step
Epoch 64/100
469/469 - 1s - loss: 0.3915 - sparse_categorical_accuracy: 0.8578 - val_loss: 0.4969 - val_sparse_ca
tegorical_accuracy: 0.8332 - 1s/epoch - 2ms/step
Epoch 65/100
469/469 - 1s - loss: 0.3880 - sparse_categorical_accuracy: 0.8589 - val_loss: 0.4928 - val_sparse_ca
tegorical_accuracy: 0.8331 - 1s/epoch - 2ms/step
Epoch 66/100
469/469 - 1s - loss: 0.3860 - sparse_categorical_accuracy: 0.8594 - val_loss: 0.5126 - val_sparse_ca
tegorical_accuracy: 0.8342 - 1s/epoch - 2ms/step
Epoch 67/100
469/469 - 1s - loss: 0.3923 - sparse_categorical_accuracy: 0.8569 - val_loss: 0.5169 - val_sparse_ca
tegorical_accuracy: 0.8317 - 1s/epoch - 2ms/step
Epoch 68/100
469/469 - 1s - loss: 0.3875 - sparse_categorical_accuracy: 0.8605 - val_loss: 0.5169 - val_sparse_ca
tegorical_accuracy: 0.8303 - 1s/epoch - 2ms/step
Epoch 69/100
469/469 - 1s - loss: 0.3919 - sparse_categorical_accuracy: 0.8579 - val_loss: 0.5013 - val_sparse_ca
tegorical_accuracy: 0.8329 - 1s/epoch - 2ms/step
Epoch 70/100
469/469 - 1s - loss: 0.3934 - sparse_categorical_accuracy: 0.8573 - val_loss: 0.5051 - val_sparse_ca
tegorical_accuracy: 0.8328 - 1s/epoch - 2ms/step
```

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Epoch 71/100
469/469 - 1s - loss: 0.3829 - sparse_categorical_accuracy: 0.8597 - val_loss: 0.5041 - val_sparse_ca
tegorical_accuracy: 0.8337 - 1s/epoch - 2ms/step
Epoch 72/100
469/469 - 1s - loss: 0.3849 - sparse_categorical_accuracy: 0.8606 - val_loss: 0.5152 - val_sparse_ca
tegorical_accuracy: 0.8281 - 1s/epoch - 2ms/step
Epoch 73/100
469/469 - 1s - loss: 0.3836 - sparse_categorical_accuracy: 0.8604 - val_loss: 0.5022 - val_sparse_ca
tegorical_accuracy: 0.8330 - 1s/epoch - 2ms/step
Epoch 74/100
469/469 - 1s - loss: 0.3840 - sparse_categorical_accuracy: 0.8607 - val_loss: 0.5061 - val_sparse_ca
tegorical_accuracy: 0.8324 - 1s/epoch - 2ms/step
Epoch 75/100
469/469 - 1s - loss: 0.3903 - sparse_categorical_accuracy: 0.8586 - val_loss: 0.5112 - val_sparse_ca
tegorical_accuracy: 0.8282 - 1s/epoch - 3ms/step
Epoch 76/100
469/469 - 1s - loss: 0.3872 - sparse_categorical_accuracy: 0.8587 - val_loss: 0.5670 - val_sparse_ca
tegorical_accuracy: 0.8302 - 1s/epoch - 2ms/step
Epoch 77/100
469/469 - 1s - loss: 0.3840 - sparse_categorical_accuracy: 0.8609 - val_loss: 0.5816 - val_sparse_ca
tegorical_accuracy: 0.8286 - 1s/epoch - 2ms/step
Epoch 78/100
469/469 - 1s - loss: 0.3845 - sparse_categorical_accuracy: 0.8601 - val_loss: 0.5251 - val_sparse_ca
tegorical_accuracy: 0.8294 - 1s/epoch - 2ms/step
Epoch 79/100
469/469 - 1s - loss: 0.3878 - sparse_categorical_accuracy: 0.8594 - val_loss: 0.5233 - val_sparse_ca
tegorical_accuracy: 0.8297 - 1s/epoch - 2ms/step
Epoch 80/100
469/469 - 1s - loss: 0.3857 - sparse_categorical_accuracy: 0.8591 - val_loss: 0.5199 - val_sparse_ca
tegorical_accuracy: 0.8294 - 1s/epoch - 2ms/step
Epoch 81/100
469/469 - 1s - loss: 0.3827 - sparse_categorical_accuracy: 0.8610 - val_loss: 0.5283 - val_sparse_ca
tegorical_accuracy: 0.8349 - 1s/epoch - 2ms/step
Epoch 82/100
469/469 - 1s - loss: 0.3813 - sparse_categorical_accuracy: 0.8600 - val_loss: 0.5151 - val_sparse_ca
tegorical_accuracy: 0.8329 - 1s/epoch - 3ms/step
Epoch 83/100
469/469 - 2s - loss: 0.3827 - sparse_categorical_accuracy: 0.8609 - val_loss: 0.5120 - val_sparse_ca
tegorical_accuracy: 0.8251 - 2s/epoch - 3ms/step
Epoch 84/100
469/469 - 1s - loss: 0.3837 - sparse_categorical_accuracy: 0.8603 - val_loss: 0.5023 - val_sparse_ca
tegorical_accuracy: 0.8325 - 1s/epoch - 3ms/step
Epoch 85/100
469/469 - 1s - loss: 0.3791 - sparse_categorical_accuracy: 0.8623 - val_loss: 0.5095 - val_sparse_ca
tegorical_accuracy: 0.8338 - 1s/epoch - 2ms/step
Epoch 86/100
469/469 - 1s - loss: 0.3805 - sparse_categorical_accuracy: 0.8616 - val_loss: 0.4991 - val_sparse_ca
tegorical_accuracy: 0.8369 - 1s/epoch - 3ms/step
Epoch 87/100
469/469 - 1s - loss: 0.3824 - sparse_categorical_accuracy: 0.8621 - val_loss: 0.5156 - val_sparse_ca
tegorical_accuracy: 0.8307 - 1s/epoch - 2ms/step
Epoch 88/100
469/469 - 1s - loss: 0.3802 - sparse_categorical_accuracy: 0.8618 - val_loss: 0.5175 - val_sparse_ca
tegorical_accuracy: 0.8301 - 1s/epoch - 2ms/step
Epoch 89/100
469/469 - 1s - loss: 0.3813 - sparse_categorical_accuracy: 0.8613 - val_loss: 0.5155 - val_sparse_ca
tegorical_accuracy: 0.8277 - 1s/epoch - 2ms/step
Epoch 90/100
469/469 - 1s - loss: 0.3780 - sparse_categorical_accuracy: 0.8616 - val_loss: 0.5569 - val_sparse_ca
tegorical_accuracy: 0.8181 - 1s/epoch - 2ms/step
Epoch 91/100
469/469 - 1s - loss: 0.3811 - sparse_categorical_accuracy: 0.8622 - val_loss: 0.5071 - val_sparse_ca
tegorical_accuracy: 0.8323 - 1s/epoch - 2ms/step
Epoch 92/100
469/469 - 1s - loss: 0.3778 - sparse_categorical_accuracy: 0.8626 - val_loss: 0.5074 - val_sparse_ca
tegorical_accuracy: 0.8310 - 1s/epoch - 2ms/step
Epoch 93/100
469/469 - 1s - loss: 0.3800 - sparse_categorical_accuracy: 0.8619 - val_loss: 0.5058 - val_sparse_ca
tegorical_accuracy: 0.8321 - 1s/epoch - 2ms/step
Epoch 94/100
469/469 - 1s - loss: 0.3810 - sparse_categorical_accuracy: 0.8597 - val_loss: 0.5238 - val_sparse_ca
tegorical_accuracy: 0.8301 - 1s/epoch - 2ms/step
Epoch 95/100
469/469 - 1s - loss: 0.3829 - sparse_categorical_accuracy: 0.8606 - val_loss: 0.5006 - val_sparse_ca
tegorical_accuracy: 0.8331 - 1s/epoch - 3ms/step
Epoch 96/100
469/469 - 1s - loss: 0.3795 - sparse_categorical_accuracy: 0.8608 - val_loss: 0.5231 - val_sparse_ca
tegorical_accuracy: 0.8329 - 1s/epoch - 2ms/step
Epoch 97/100
469/469 - 1s - loss: 0.3764 - sparse_categorical_accuracy: 0.8627 - val_loss: 0.5333 - val_sparse_ca
tegorical_accuracy: 0.8335 - 1s/epoch - 2ms/step
Epoch 98/100
469/469 - 1s - loss: 0.3774 - sparse_categorical_accuracy: 0.8628 - val_loss: 0.5184 - val_sparse_ca
```

```
tegorical_accuracy: 0.8323 - 1s/epoch - 2ms/step
Epoch 99/100
469/469 - 1s - loss: 0.3757 - sparse_categorical_accuracy: 0.8627 - val_loss: 0.5336 - val_sparse_ca
tegorical_accuracy: 0.8328 - 1s/epoch - 2ms/step
Epoch 100/100
469/469 - 1s - loss: 0.3790 - sparse_categorical_accuracy: 0.8614 - val_loss: 0.5229 - val_sparse_ca
tegorical_accuracy: 0.8287 - 1s/epoch - 2ms/step
313/313 - 0s - loss: 0.5229 - sparse_categorical_accuracy: 0.8287 - 364ms/epoch - 1ms/step
```

Out[31]:

```
[0.5229210257530212, 0.8287000060081482]
```

In [5]:

```
# Architecture2
# Model with batch normalization and convolutional layers
model2 = tf.keras.models.Sequential([
  tf.keras.layers.Input(shape=(28, 28,1)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.Flatten(),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.Dense(10, activation='softmax')
])
model2.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
              )
model2.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 max_pooling2d (MaxPooling2D  (None, 14, 14, 1)        0
 )

 flatten (Flatten)           (None, 196)               0

 batch_normalization (BatchN  (None, 196)              784
 ormalization)

 dropout (Dropout)           (None, 196)               0

 dense (Dense)               (None, 16)                3152

 dense_1 (Dense)             (None, 16)                272

 dense_2 (Dense)             (None, 10)                170

=================================================================
Total params: 4,378
Trainable params: 3,986
Non-trainable params: 392
_________________________________________________________________
```

In [32]:

```
model2.fit(x_train, y_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
```

```
Epoch 1/100
469/469 - 3s - loss: 0.9015 - sparse_categorical_accuracy: 0.7099 - val_loss: 0.3489 - val_sparse_ca
tegorical_accuracy: 0.8992 - 3s/epoch - 7ms/step
Epoch 2/100
469/469 - 2s - loss: 0.3897 - sparse_categorical_accuracy: 0.8787 - val_loss: 0.2798 - val_sparse_ca
tegorical_accuracy: 0.9204 - 2s/epoch - 5ms/step
Epoch 3/100
469/469 - 2s - loss: 0.3408 - sparse_categorical_accuracy: 0.8937 - val_loss: 0.2599 - val_sparse_ca
tegorical_accuracy: 0.9259 - 2s/epoch - 5ms/step
Epoch 4/100
469/469 - 3s - loss: 0.3103 - sparse_categorical_accuracy: 0.9033 - val_loss: 0.2470 - val_sparse_ca
tegorical_accuracy: 0.9325 - 3s/epoch - 6ms/step
Epoch 5/100
469/469 - 2s - loss: 0.2869 - sparse_categorical_accuracy: 0.9103 - val_loss: 0.2253 - val_sparse_ca
tegorical_accuracy: 0.9363 - 2s/epoch - 5ms/step
Epoch 6/100
```

```
469/469 - 3s - loss: 0.2733 - sparse_categorical_accuracy: 0.9142 - val_loss: 0.2071 - val_sparse_ca
tegorical_accuracy: 0.9391 - 3s/epoch - 5ms/step
Epoch 7/100
469/469 - 3s - loss: 0.2638 - sparse_categorical_accuracy: 0.9163 - val_loss: 0.2080 - val_sparse_ca
tegorical_accuracy: 0.9423 - 3s/epoch - 6ms/step
Epoch 8/100
469/469 - 3s - loss: 0.2554 - sparse_categorical_accuracy: 0.9195 - val_loss: 0.2074 - val_sparse_ca
tegorical_accuracy: 0.9429 - 3s/epoch - 5ms/step
Epoch 9/100
469/469 - 3s - loss: 0.2506 - sparse_categorical_accuracy: 0.9210 - val_loss: 0.1977 - val_sparse_ca
tegorical_accuracy: 0.9448 - 3s/epoch - 5ms/step
Epoch 10/100
469/469 - 2s - loss: 0.2411 - sparse_categorical_accuracy: 0.9242 - val_loss: 0.1960 - val_sparse_ca
tegorical_accuracy: 0.9470 - 2s/epoch - 5ms/step
Epoch 11/100
469/469 - 3s - loss: 0.2404 - sparse_categorical_accuracy: 0.9249 - val_loss: 0.1814 - val_sparse_ca
tegorical_accuracy: 0.9488 - 3s/epoch - 6ms/step
Epoch 12/100
469/469 - 2s - loss: 0.2351 - sparse_categorical_accuracy: 0.9254 - val_loss: 0.1824 - val_sparse_ca
tegorical_accuracy: 0.9481 - 2s/epoch - 5ms/step
Epoch 13/100
469/469 - 2s - loss: 0.2287 - sparse_categorical_accuracy: 0.9281 - val_loss: 0.1814 - val_sparse_ca
tegorical_accuracy: 0.9474 - 2s/epoch - 5ms/step
Epoch 14/100
469/469 - 2s - loss: 0.2322 - sparse_categorical_accuracy: 0.9260 - val_loss: 0.1831 - val_sparse_ca
tegorical_accuracy: 0.9480 - 2s/epoch - 5ms/step
Epoch 15/100
469/469 - 2s - loss: 0.2276 - sparse_categorical_accuracy: 0.9268 - val_loss: 0.1784 - val_sparse_ca
tegorical_accuracy: 0.9492 - 2s/epoch - 5ms/step
Epoch 16/100
469/469 - 3s - loss: 0.2257 - sparse_categorical_accuracy: 0.9283 - val_loss: 0.1761 - val_sparse_ca
tegorical_accuracy: 0.9497 - 3s/epoch - 6ms/step
Epoch 17/100
469/469 - 3s - loss: 0.2225 - sparse_categorical_accuracy: 0.9298 - val_loss: 0.1820 - val_sparse_ca
tegorical_accuracy: 0.9498 - 3s/epoch - 6ms/step
Epoch 18/100
469/469 - 2s - loss: 0.2197 - sparse_categorical_accuracy: 0.9306 - val_loss: 0.1738 - val_sparse_ca
tegorical_accuracy: 0.9498 - 2s/epoch - 5ms/step
Epoch 19/100
469/469 - 2s - loss: 0.2204 - sparse_categorical_accuracy: 0.9304 - val_loss: 0.1749 - val_sparse_ca
tegorical_accuracy: 0.9496 - 2s/epoch - 5ms/step
Epoch 20/100
469/469 - 3s - loss: 0.2189 - sparse_categorical_accuracy: 0.9303 - val_loss: 0.1651 - val_sparse_ca
tegorical_accuracy: 0.9504 - 3s/epoch - 5ms/step
Epoch 21/100
469/469 - 3s - loss: 0.2190 - sparse_categorical_accuracy: 0.9303 - val_loss: 0.1685 - val_sparse_ca
tegorical_accuracy: 0.9504 - 3s/epoch - 6ms/step
Epoch 22/100
469/469 - 2s - loss: 0.2160 - sparse_categorical_accuracy: 0.9321 - val_loss: 0.1640 - val_sparse_ca
tegorical_accuracy: 0.9520 - 2s/epoch - 5ms/step
Epoch 23/100
469/469 - 2s - loss: 0.2148 - sparse_categorical_accuracy: 0.9308 - val_loss: 0.1683 - val_sparse_ca
tegorical_accuracy: 0.9498 - 2s/epoch - 5ms/step
Epoch 24/100
469/469 - 3s - loss: 0.2118 - sparse_categorical_accuracy: 0.9320 - val_loss: 0.1658 - val_sparse_ca
tegorical_accuracy: 0.9516 - 3s/epoch - 5ms/step
Epoch 25/100
469/469 - 2s - loss: 0.2135 - sparse_categorical_accuracy: 0.9316 - val_loss: 0.1739 - val_sparse_ca
tegorical_accuracy: 0.9508 - 2s/epoch - 5ms/step
Epoch 26/100
469/469 - 2s - loss: 0.2113 - sparse_categorical_accuracy: 0.9333 - val_loss: 0.1612 - val_sparse_ca
tegorical_accuracy: 0.9531 - 2s/epoch - 5ms/step
Epoch 27/100
469/469 - 2s - loss: 0.2115 - sparse_categorical_accuracy: 0.9319 - val_loss: 0.1658 - val_sparse_ca
tegorical_accuracy: 0.9522 - 2s/epoch - 5ms/step
Epoch 28/100
469/469 - 3s - loss: 0.2086 - sparse_categorical_accuracy: 0.9334 - val_loss: 0.1713 - val_sparse_ca
tegorical_accuracy: 0.9506 - 3s/epoch - 5ms/step
Epoch 29/100
469/469 - 2s - loss: 0.2084 - sparse_categorical_accuracy: 0.9345 - val_loss: 0.1680 - val_sparse_ca
tegorical_accuracy: 0.9531 - 2s/epoch - 5ms/step
Epoch 30/100
469/469 - 3s - loss: 0.2076 - sparse_categorical_accuracy: 0.9340 - val_loss: 0.1652 - val_sparse_ca
tegorical_accuracy: 0.9531 - 3s/epoch - 5ms/step
Epoch 31/100
469/469 - 2s - loss: 0.2075 - sparse_categorical_accuracy: 0.9338 - val_loss: 0.1630 - val_sparse_ca
tegorical_accuracy: 0.9529 - 2s/epoch - 5ms/step
Epoch 32/100
469/469 - 3s - loss: 0.2079 - sparse_categorical_accuracy: 0.9342 - val_loss: 0.1586 - val_sparse_ca
tegorical_accuracy: 0.9521 - 3s/epoch - 6ms/step
Epoch 33/100
469/469 - 3s - loss: 0.2084 - sparse_categorical_accuracy: 0.9333 - val_loss: 0.1679 - val_sparse_ca
tegorical_accuracy: 0.9526 - 3s/epoch - 6ms/step
```

```
Epoch 34/100
469/469 - 3s - loss: 0.2073 - sparse_categorical_accuracy: 0.9335 - val_loss: 0.1638 - val_sparse_ca
tegorical_accuracy: 0.9509 - 3s/epoch - 5ms/step
Epoch 35/100
469/469 - 3s - loss: 0.2019 - sparse_categorical_accuracy: 0.9357 - val_loss: 0.1638 - val_sparse_ca
tegorical_accuracy: 0.9513 - 3s/epoch - 5ms/step
Epoch 36/100
469/469 - 3s - loss: 0.2005 - sparse_categorical_accuracy: 0.9361 - val_loss: 0.1588 - val_sparse_ca
tegorical_accuracy: 0.9528 - 3s/epoch - 5ms/step
Epoch 37/100
469/469 - 2s - loss: 0.2026 - sparse_categorical_accuracy: 0.9354 - val_loss: 0.1582 - val_sparse_ca
tegorical_accuracy: 0.9540 - 2s/epoch - 5ms/step
Epoch 38/100
469/469 - 3s - loss: 0.1991 - sparse_categorical_accuracy: 0.9364 - val_loss: 0.1737 - val_sparse_ca
tegorical_accuracy: 0.9541 - 3s/epoch - 6ms/step
Epoch 39/100
469/469 - 3s - loss: 0.2061 - sparse_categorical_accuracy: 0.9337 - val_loss: 0.1661 - val_sparse_ca
tegorical_accuracy: 0.9542 - 3s/epoch - 6ms/step
Epoch 40/100
469/469 - 3s - loss: 0.2000 - sparse_categorical_accuracy: 0.9362 - val_loss: 0.1753 - val_sparse_ca
tegorical_accuracy: 0.9531 - 3s/epoch - 6ms/step
Epoch 41/100
469/469 - 3s - loss: 0.2011 - sparse_categorical_accuracy: 0.9373 - val_loss: 0.1685 - val_sparse_ca
tegorical_accuracy: 0.9533 - 3s/epoch - 6ms/step
Epoch 42/100
469/469 - 3s - loss: 0.1998 - sparse_categorical_accuracy: 0.9359 - val_loss: 0.1683 - val_sparse_ca
tegorical_accuracy: 0.9533 - 3s/epoch - 6ms/step
Epoch 43/100
469/469 - 3s - loss: 0.2002 - sparse_categorical_accuracy: 0.9366 - val_loss: 0.1566 - val_sparse_ca
tegorical_accuracy: 0.9543 - 3s/epoch - 5ms/step
Epoch 44/100
469/469 - 3s - loss: 0.1982 - sparse_categorical_accuracy: 0.9376 - val_loss: 0.1597 - val_sparse_ca
tegorical_accuracy: 0.9533 - 3s/epoch - 5ms/step
Epoch 45/100
469/469 - 2s - loss: 0.1987 - sparse_categorical_accuracy: 0.9365 - val_loss: 0.1618 - val_sparse_ca
tegorical_accuracy: 0.9534 - 2s/epoch - 5ms/step
Epoch 46/100
469/469 - 2s - loss: 0.1972 - sparse_categorical_accuracy: 0.9372 - val_loss: 0.1705 - val_sparse_ca
tegorical_accuracy: 0.9529 - 2s/epoch - 5ms/step
Epoch 47/100
469/469 - 3s - loss: 0.1956 - sparse_categorical_accuracy: 0.9371 - val_loss: 0.1602 - val_sparse_ca
tegorical_accuracy: 0.9557 - 3s/epoch - 5ms/step
Epoch 48/100
469/469 - 3s - loss: 0.1971 - sparse_categorical_accuracy: 0.9369 - val_loss: 0.1621 - val_sparse_ca
tegorical_accuracy: 0.9550 - 3s/epoch - 6ms/step
Epoch 49/100
469/469 - 3s - loss: 0.1942 - sparse_categorical_accuracy: 0.9386 - val_loss: 0.1613 - val_sparse_ca
tegorical_accuracy: 0.9550 - 3s/epoch - 6ms/step
Epoch 50/100
469/469 - 3s - loss: 0.1968 - sparse_categorical_accuracy: 0.9372 - val_loss: 0.1577 - val_sparse_ca
tegorical_accuracy: 0.9545 - 3s/epoch - 5ms/step
Epoch 51/100
469/469 - 2s - loss: 0.1994 - sparse_categorical_accuracy: 0.9366 - val_loss: 0.1714 - val_sparse_ca
tegorical_accuracy: 0.9538 - 2s/epoch - 5ms/step
Epoch 52/100
469/469 - 3s - loss: 0.1946 - sparse_categorical_accuracy: 0.9381 - val_loss: 0.1730 - val_sparse_ca
tegorical_accuracy: 0.9550 - 3s/epoch - 5ms/step
Epoch 53/100
469/469 - 2s - loss: 0.1961 - sparse_categorical_accuracy: 0.9377 - val_loss: 0.1577 - val_sparse_ca
tegorical_accuracy: 0.9553 - 2s/epoch - 5ms/step
Epoch 54/100
469/469 - 2s - loss: 0.1960 - sparse_categorical_accuracy: 0.9374 - val_loss: 0.1530 - val_sparse_ca
tegorical_accuracy: 0.9554 - 2s/epoch - 5ms/step
Epoch 55/100
469/469 - 3s - loss: 0.1941 - sparse_categorical_accuracy: 0.9384 - val_loss: 0.1609 - val_sparse_ca
tegorical_accuracy: 0.9559 - 3s/epoch - 6ms/step
Epoch 56/100
469/469 - 3s - loss: 0.1914 - sparse_categorical_accuracy: 0.9388 - val_loss: 0.1707 - val_sparse_ca
tegorical_accuracy: 0.9542 - 3s/epoch - 6ms/step
Epoch 57/100
469/469 - 3s - loss: 0.1918 - sparse_categorical_accuracy: 0.9379 - val_loss: 0.1658 - val_sparse_ca
tegorical_accuracy: 0.9538 - 3s/epoch - 6ms/step
Epoch 58/100
469/469 - 3s - loss: 0.1968 - sparse_categorical_accuracy: 0.9370 - val_loss: 0.1608 - val_sparse_ca
tegorical_accuracy: 0.9569 - 3s/epoch - 6ms/step
Epoch 59/100
469/469 - 3s - loss: 0.1919 - sparse_categorical_accuracy: 0.9385 - val_loss: 0.1564 - val_sparse_ca
tegorical_accuracy: 0.9558 - 3s/epoch - 6ms/step
Epoch 60/100
469/469 - 3s - loss: 0.1928 - sparse_categorical_accuracy: 0.9388 - val_loss: 0.1639 - val_sparse_ca
tegorical_accuracy: 0.9543 - 3s/epoch - 5ms/step
Epoch 61/100
469/469 - 3s - loss: 0.1910 - sparse_categorical_accuracy: 0.9385 - val_loss: 0.1585 - val_sparse_ca
```

```
tegorical_accuracy: 0.9543 - 3s/epoch - 6ms/step
Epoch 62/100
469/469 - 3s - loss: 0.1923 - sparse_categorical_accuracy: 0.9381 - val_loss: 0.1564 - val_sparse_ca
tegorical_accuracy: 0.9546 - 3s/epoch - 5ms/step
Epoch 63/100
469/469 - 3s - loss: 0.1921 - sparse_categorical_accuracy: 0.9392 - val_loss: 0.1564 - val_sparse_ca
tegorical_accuracy: 0.9560 - 3s/epoch - 6ms/step
Epoch 64/100
469/469 - 3s - loss: 0.1937 - sparse_categorical_accuracy: 0.9378 - val_loss: 0.1523 - val_sparse_ca
tegorical_accuracy: 0.9539 - 3s/epoch - 6ms/step
Epoch 65/100
469/469 - 3s - loss: 0.1920 - sparse_categorical_accuracy: 0.9386 - val_loss: 0.1533 - val_sparse_ca
tegorical_accuracy: 0.9543 - 3s/epoch - 5ms/step
Epoch 66/100
469/469 - 3s - loss: 0.1901 - sparse_categorical_accuracy: 0.9390 - val_loss: 0.1583 - val_sparse_ca
tegorical_accuracy: 0.9540 - 3s/epoch - 6ms/step
Epoch 67/100
469/469 - 3s - loss: 0.1909 - sparse_categorical_accuracy: 0.9385 - val_loss: 0.1596 - val_sparse_ca
tegorical_accuracy: 0.9552 - 3s/epoch - 6ms/step
Epoch 68/100
469/469 - 2s - loss: 0.1879 - sparse_categorical_accuracy: 0.9405 - val_loss: 0.1644 - val_sparse_ca
tegorical_accuracy: 0.9564 - 2s/epoch - 5ms/step
Epoch 69/100
469/469 - 3s - loss: 0.1887 - sparse_categorical_accuracy: 0.9389 - val_loss: 0.1481 - val_sparse_ca
tegorical_accuracy: 0.9578 - 3s/epoch - 6ms/step
Epoch 70/100
469/469 - 3s - loss: 0.1894 - sparse_categorical_accuracy: 0.9395 - val_loss: 0.1537 - val_sparse_ca
tegorical_accuracy: 0.9552 - 3s/epoch - 5ms/step
Epoch 71/100
469/469 - 3s - loss: 0.1894 - sparse_categorical_accuracy: 0.9397 - val_loss: 0.1542 - val_sparse_ca
tegorical_accuracy: 0.9566 - 3s/epoch - 6ms/step
Epoch 72/100
469/469 - 3s - loss: 0.1886 - sparse_categorical_accuracy: 0.9408 - val_loss: 0.1534 - val_sparse_ca
tegorical_accuracy: 0.9548 - 3s/epoch - 6ms/step
Epoch 73/100
469/469 - 2s - loss: 0.1873 - sparse_categorical_accuracy: 0.9404 - val_loss: 0.1490 - val_sparse_ca
tegorical_accuracy: 0.9575 - 2s/epoch - 5ms/step
Epoch 74/100
469/469 - 2s - loss: 0.1880 - sparse_categorical_accuracy: 0.9401 - val_loss: 0.1606 - val_sparse_ca
tegorical_accuracy: 0.9578 - 2s/epoch - 5ms/step
Epoch 75/100
469/469 - 2s - loss: 0.1912 - sparse_categorical_accuracy: 0.9385 - val_loss: 0.1515 - val_sparse_ca
tegorical_accuracy: 0.9552 - 2s/epoch - 5ms/step
Epoch 76/100
469/469 - 3s - loss: 0.1895 - sparse_categorical_accuracy: 0.9391 - val_loss: 0.1630 - val_sparse_ca
tegorical_accuracy: 0.9579 - 3s/epoch - 5ms/step
Epoch 77/100
469/469 - 2s - loss: 0.1883 - sparse_categorical_accuracy: 0.9397 - val_loss: 0.1510 - val_sparse_ca
tegorical_accuracy: 0.9567 - 2s/epoch - 5ms/step
Epoch 78/100
469/469 - 2s - loss: 0.1867 - sparse_categorical_accuracy: 0.9410 - val_loss: 0.1521 - val_sparse_ca
tegorical_accuracy: 0.9570 - 2s/epoch - 5ms/step
Epoch 79/100
469/469 - 3s - loss: 0.1855 - sparse_categorical_accuracy: 0.9397 - val_loss: 0.1517 - val_sparse_ca
tegorical_accuracy: 0.9581 - 3s/epoch - 5ms/step
Epoch 80/100
469/469 - 3s - loss: 0.1856 - sparse_categorical_accuracy: 0.9414 - val_loss: 0.1557 - val_sparse_ca
tegorical_accuracy: 0.9557 - 3s/epoch - 5ms/step
Epoch 81/100
469/469 - 3s - loss: 0.1847 - sparse_categorical_accuracy: 0.9408 - val_loss: 0.1525 - val_sparse_ca
tegorical_accuracy: 0.9563 - 3s/epoch - 6ms/step
Epoch 82/100
469/469 - 3s - loss: 0.1860 - sparse_categorical_accuracy: 0.9406 - val_loss: 0.1569 - val_sparse_ca
tegorical_accuracy: 0.9560 - 3s/epoch - 5ms/step
Epoch 83/100
469/469 - 2s - loss: 0.1876 - sparse_categorical_accuracy: 0.9399 - val_loss: 0.1548 - val_sparse_ca
tegorical_accuracy: 0.9555 - 2s/epoch - 5ms/step
Epoch 84/100
469/469 - 2s - loss: 0.1881 - sparse_categorical_accuracy: 0.9399 - val_loss: 0.1530 - val_sparse_ca
tegorical_accuracy: 0.9562 - 2s/epoch - 5ms/step
Epoch 85/100
469/469 - 3s - loss: 0.1835 - sparse_categorical_accuracy: 0.9409 - val_loss: 0.1605 - val_sparse_ca
tegorical_accuracy: 0.9557 - 3s/epoch - 6ms/step
Epoch 86/100
469/469 - 3s - loss: 0.1862 - sparse_categorical_accuracy: 0.9405 - val_loss: 0.1588 - val_sparse_ca
tegorical_accuracy: 0.9575 - 3s/epoch - 5ms/step
Epoch 87/100
469/469 - 3s - loss: 0.1861 - sparse_categorical_accuracy: 0.9395 - val_loss: 0.1566 - val_sparse_ca
tegorical_accuracy: 0.9562 - 3s/epoch - 6ms/step
Epoch 88/100
469/469 - 2s - loss: 0.1828 - sparse_categorical_accuracy: 0.9410 - val_loss: 0.1592 - val_sparse_ca
tegorical_accuracy: 0.9565 - 2s/epoch - 5ms/step
Epoch 89/100
```

```
469/469 - 3s - loss: 0.1854 - sparse_categorical_accuracy: 0.9405 - val_loss: 0.1554 - val_sparse_ca
tegorical_accuracy: 0.9556 - 3s/epoch - 6ms/step
Epoch 90/100
469/469 - 2s - loss: 0.1850 - sparse_categorical_accuracy: 0.9402 - val_loss: 0.1521 - val_sparse_ca
tegorical_accuracy: 0.9565 - 2s/epoch - 5ms/step
Epoch 91/100
469/469 - 3s - loss: 0.1847 - sparse_categorical_accuracy: 0.9406 - val_loss: 0.1534 - val_sparse_ca
tegorical_accuracy: 0.9587 - 3s/epoch - 6ms/step
Epoch 92/100
469/469 - 3s - loss: 0.1845 - sparse_categorical_accuracy: 0.9405 - val_loss: 0.1527 - val_sparse_ca
tegorical_accuracy: 0.9567 - 3s/epoch - 6ms/step
Epoch 93/100
469/469 - 3s - loss: 0.1843 - sparse_categorical_accuracy: 0.9412 - val_loss: 0.1613 - val_sparse_ca
tegorical_accuracy: 0.9566 - 3s/epoch - 5ms/step
Epoch 94/100
469/469 - 3s - loss: 0.1856 - sparse_categorical_accuracy: 0.9407 - val_loss: 0.1553 - val_sparse_ca
tegorical_accuracy: 0.9567 - 3s/epoch - 5ms/step
Epoch 95/100
469/469 - 3s - loss: 0.1847 - sparse_categorical_accuracy: 0.9412 - val_loss: 0.1509 - val_sparse_ca
tegorical_accuracy: 0.9573 - 3s/epoch - 5ms/step
Epoch 96/100
469/469 - 3s - loss: 0.1850 - sparse_categorical_accuracy: 0.9409 - val_loss: 0.1532 - val_sparse_ca
tegorical_accuracy: 0.9557 - 3s/epoch - 6ms/step
Epoch 97/100
469/469 - 3s - loss: 0.1855 - sparse_categorical_accuracy: 0.9406 - val_loss: 0.1607 - val_sparse_ca
tegorical_accuracy: 0.9561 - 3s/epoch - 6ms/step
Epoch 98/100
469/469 - 3s - loss: 0.1874 - sparse_categorical_accuracy: 0.9404 - val_loss: 0.1584 - val_sparse_ca
tegorical_accuracy: 0.9570 - 3s/epoch - 5ms/step
Epoch 99/100
469/469 - 3s - loss: 0.1844 - sparse_categorical_accuracy: 0.9403 - val_loss: 0.1538 - val_sparse_ca
tegorical_accuracy: 0.9553 - 3s/epoch - 6ms/step
Epoch 100/100
469/469 - 3s - loss: 0.1857 - sparse_categorical_accuracy: 0.9409 - val_loss: 0.1591 - val_sparse_ca
tegorical_accuracy: 0.9545 - 3s/epoch - 6ms/step
```

Out[32]:

```
<keras.callbacks.History at 0x7f82693e2ad0>
```

In [33]:

```
model2.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 1s - loss: 0.1591 - sparse_categorical_accuracy: 0.9545 - 959ms/epoch - 3ms/step
```

Out[33]:

```
[0.15907402336597443, 0.9545000195503235]
```

In [6]:

```
model2.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
h2 = model2.fit(fX_train, fY_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(fX_test, fY_test),
                    verbose=2
                    )
model2.evaluate(fX_test, fY_test, verbose=2)
```

```
Epoch 1/100
469/469 - 3s - loss: 0.9308 - sparse_categorical_accuracy: 0.6626 - val_loss: 0.6061 - val_sparse_ca
tegorical_accuracy: 0.7813 - 3s/epoch - 7ms/step
Epoch 2/100
469/469 - 3s - loss: 0.5989 - sparse_categorical_accuracy: 0.7795 - val_loss: 0.5474 - val_sparse_ca
tegorical_accuracy: 0.7984 - 3s/epoch - 5ms/step
Epoch 3/100
469/469 - 2s - loss: 0.5570 - sparse_categorical_accuracy: 0.7940 - val_loss: 0.5177 - val_sparse_ca
tegorical_accuracy: 0.8128 - 2s/epoch - 5ms/step
Epoch 4/100
469/469 - 3s - loss: 0.5378 - sparse_categorical_accuracy: 0.7998 - val_loss: 0.5018 - val_sparse_ca
tegorical_accuracy: 0.8196 - 3s/epoch - 6ms/step
Epoch 5/100
469/469 - 2s - loss: 0.5258 - sparse_categorical_accuracy: 0.8071 - val_loss: 0.4918 - val_sparse_ca
tegorical_accuracy: 0.8248 - 2s/epoch - 5ms/step
Epoch 6/100
469/469 - 3s - loss: 0.5146 - sparse_categorical_accuracy: 0.8082 - val_loss: 0.4874 - val_sparse_ca
tegorical_accuracy: 0.8237 - 3s/epoch - 6ms/step
Epoch 7/100
469/469 - 3s - loss: 0.5074 - sparse_categorical_accuracy: 0.8130 - val_loss: 0.4733 - val_sparse_ca
tegorical_accuracy: 0.8304 - 3s/epoch - 5ms/step
```

```
Epoch 8/100
469/469 - 2s - loss: 0.5000 - sparse_categorical_accuracy: 0.8154 - val_loss: 0.4697 - val_sparse_ca
tegorical_accuracy: 0.8316 - 2s/epoch - 5ms/step
Epoch 9/100
469/469 - 2s - loss: 0.4963 - sparse_categorical_accuracy: 0.8167 - val_loss: 0.4637 - val_sparse_ca
tegorical_accuracy: 0.8319 - 2s/epoch - 5ms/step
Epoch 10/100
469/469 - 2s - loss: 0.4909 - sparse_categorical_accuracy: 0.8178 - val_loss: 0.4612 - val_sparse_ca
tegorical_accuracy: 0.8308 - 2s/epoch - 5ms/step
Epoch 11/100
469/469 - 2s - loss: 0.4880 - sparse_categorical_accuracy: 0.8178 - val_loss: 0.4721 - val_sparse_ca
tegorical_accuracy: 0.8272 - 2s/epoch - 5ms/step
Epoch 12/100
469/469 - 3s - loss: 0.4844 - sparse_categorical_accuracy: 0.8185 - val_loss: 0.4561 - val_sparse_ca
tegorical_accuracy: 0.8329 - 3s/epoch - 6ms/step
Epoch 13/100
469/469 - 3s - loss: 0.4847 - sparse_categorical_accuracy: 0.8187 - val_loss: 0.4539 - val_sparse_ca
tegorical_accuracy: 0.8362 - 3s/epoch - 6ms/step
Epoch 14/100
469/469 - 3s - loss: 0.4795 - sparse_categorical_accuracy: 0.8216 - val_loss: 0.4513 - val_sparse_ca
tegorical_accuracy: 0.8355 - 3s/epoch - 7ms/step
Epoch 15/100
469/469 - 3s - loss: 0.4780 - sparse_categorical_accuracy: 0.8217 - val_loss: 0.4476 - val_sparse_ca
tegorical_accuracy: 0.8371 - 3s/epoch - 6ms/step
Epoch 16/100
469/469 - 2s - loss: 0.4732 - sparse_categorical_accuracy: 0.8245 - val_loss: 0.4493 - val_sparse_ca
tegorical_accuracy: 0.8350 - 2s/epoch - 5ms/step
Epoch 17/100
469/469 - 3s - loss: 0.4738 - sparse_categorical_accuracy: 0.8228 - val_loss: 0.4429 - val_sparse_ca
tegorical_accuracy: 0.8373 - 3s/epoch - 7ms/step
Epoch 18/100
469/469 - 3s - loss: 0.4698 - sparse_categorical_accuracy: 0.8251 - val_loss: 0.4476 - val_sparse_ca
tegorical_accuracy: 0.8332 - 3s/epoch - 5ms/step
Epoch 19/100
469/469 - 2s - loss: 0.4679 - sparse_categorical_accuracy: 0.8244 - val_loss: 0.4393 - val_sparse_ca
tegorical_accuracy: 0.8403 - 2s/epoch - 5ms/step
Epoch 20/100
469/469 - 3s - loss: 0.4683 - sparse_categorical_accuracy: 0.8254 - val_loss: 0.4396 - val_sparse_ca
tegorical_accuracy: 0.8370 - 3s/epoch - 5ms/step
Epoch 21/100
469/469 - 2s - loss: 0.4690 - sparse_categorical_accuracy: 0.8252 - val_loss: 0.4363 - val_sparse_ca
tegorical_accuracy: 0.8384 - 2s/epoch - 5ms/step
Epoch 22/100
469/469 - 2s - loss: 0.4648 - sparse_categorical_accuracy: 0.8274 - val_loss: 0.4414 - val_sparse_ca
tegorical_accuracy: 0.8384 - 2s/epoch - 5ms/step
Epoch 23/100
469/469 - 3s - loss: 0.4645 - sparse_categorical_accuracy: 0.8278 - val_loss: 0.4369 - val_sparse_ca
tegorical_accuracy: 0.8396 - 3s/epoch - 6ms/step
Epoch 24/100
469/469 - 3s - loss: 0.4629 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.4371 - val_sparse_ca
tegorical_accuracy: 0.8402 - 3s/epoch - 5ms/step
Epoch 25/100
469/469 - 2s - loss: 0.4635 - sparse_categorical_accuracy: 0.8279 - val_loss: 0.4394 - val_sparse_ca
tegorical_accuracy: 0.8376 - 2s/epoch - 5ms/step
Epoch 26/100
469/469 - 3s - loss: 0.4632 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.4355 - val_sparse_ca
tegorical_accuracy: 0.8393 - 3s/epoch - 5ms/step
Epoch 27/100
469/469 - 3s - loss: 0.4599 - sparse_categorical_accuracy: 0.8274 - val_loss: 0.4313 - val_sparse_ca
tegorical_accuracy: 0.8431 - 3s/epoch - 6ms/step
Epoch 28/100
469/469 - 3s - loss: 0.4575 - sparse_categorical_accuracy: 0.8278 - val_loss: 0.4312 - val_sparse_ca
tegorical_accuracy: 0.8406 - 3s/epoch - 5ms/step
Epoch 29/100
469/469 - 3s - loss: 0.4575 - sparse_categorical_accuracy: 0.8295 - val_loss: 0.4326 - val_sparse_ca
tegorical_accuracy: 0.8408 - 3s/epoch - 6ms/step
Epoch 30/100
469/469 - 3s - loss: 0.4592 - sparse_categorical_accuracy: 0.8291 - val_loss: 0.4331 - val_sparse_ca
tegorical_accuracy: 0.8394 - 3s/epoch - 5ms/step
Epoch 31/100
469/469 - 2s - loss: 0.4576 - sparse_categorical_accuracy: 0.8306 - val_loss: 0.4302 - val_sparse_ca
tegorical_accuracy: 0.8402 - 2s/epoch - 5ms/step
Epoch 32/100
469/469 - 3s - loss: 0.4567 - sparse_categorical_accuracy: 0.8293 - val_loss: 0.4306 - val_sparse_ca
tegorical_accuracy: 0.8393 - 3s/epoch - 6ms/step
Epoch 33/100
469/469 - 3s - loss: 0.4560 - sparse_categorical_accuracy: 0.8298 - val_loss: 0.4309 - val_sparse_ca
tegorical_accuracy: 0.8403 - 3s/epoch - 5ms/step
Epoch 34/100
469/469 - 3s - loss: 0.4533 - sparse_categorical_accuracy: 0.8322 - val_loss: 0.4341 - val_sparse_ca
tegorical_accuracy: 0.8378 - 3s/epoch - 7ms/step
Epoch 35/100
469/469 - 3s - loss: 0.4559 - sparse_categorical_accuracy: 0.8300 - val_loss: 0.4296 - val_sparse_ca
```

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tegorical_accuracy: 0.8389 - 3s/epoch - 6ms/step
Epoch 36/100
469/469 - 3s - loss: 0.4553 - sparse_categorical_accuracy: 0.8293 - val_loss: 0.4287 - val_sparse_ca
tegorical_accuracy: 0.8428 - 3s/epoch - 5ms/step
Epoch 37/100
469/469 - 2s - loss: 0.4570 - sparse_categorical_accuracy: 0.8296 - val_loss: 0.4400 - val_sparse_ca
tegorical_accuracy: 0.8388 - 2s/epoch - 5ms/step
Epoch 38/100
469/469 - 3s - loss: 0.4512 - sparse_categorical_accuracy: 0.8319 - val_loss: 0.4309 - val_sparse_ca
tegorical_accuracy: 0.8371 - 3s/epoch - 5ms/step
Epoch 39/100
469/469 - 3s - loss: 0.4524 - sparse_categorical_accuracy: 0.8310 - val_loss: 0.4346 - val_sparse_ca
tegorical_accuracy: 0.8361 - 3s/epoch - 5ms/step
Epoch 40/100
469/469 - 3s - loss: 0.4522 - sparse_categorical_accuracy: 0.8307 - val_loss: 0.4252 - val_sparse_ca
tegorical_accuracy: 0.8432 - 3s/epoch - 5ms/step
Epoch 41/100
469/469 - 3s - loss: 0.4507 - sparse_categorical_accuracy: 0.8323 - val_loss: 0.4262 - val_sparse_ca
tegorical_accuracy: 0.8421 - 3s/epoch - 6ms/step
Epoch 42/100
469/469 - 3s - loss: 0.4523 - sparse_categorical_accuracy: 0.8301 - val_loss: 0.4252 - val_sparse_ca
tegorical_accuracy: 0.8444 - 3s/epoch - 5ms/step
Epoch 43/100
469/469 - 2s - loss: 0.4505 - sparse_categorical_accuracy: 0.8311 - val_loss: 0.4218 - val_sparse_ca
tegorical_accuracy: 0.8451 - 2s/epoch - 5ms/step
Epoch 44/100
469/469 - 3s - loss: 0.4496 - sparse_categorical_accuracy: 0.8323 - val_loss: 0.4239 - val_sparse_ca
tegorical_accuracy: 0.8415 - 3s/epoch - 6ms/step
Epoch 45/100
469/469 - 3s - loss: 0.4459 - sparse_categorical_accuracy: 0.8326 - val_loss: 0.4298 - val_sparse_ca
tegorical_accuracy: 0.8395 - 3s/epoch - 6ms/step
Epoch 46/100
469/469 - 3s - loss: 0.4490 - sparse_categorical_accuracy: 0.8336 - val_loss: 0.4289 - val_sparse_ca
tegorical_accuracy: 0.8394 - 3s/epoch - 5ms/step
Epoch 47/100
469/469 - 2s - loss: 0.4502 - sparse_categorical_accuracy: 0.8311 - val_loss: 0.4218 - val_sparse_ca
tegorical_accuracy: 0.8416 - 2s/epoch - 5ms/step
Epoch 48/100
469/469 - 2s - loss: 0.4458 - sparse_categorical_accuracy: 0.8327 - val_loss: 0.4264 - val_sparse_ca
tegorical_accuracy: 0.8374 - 2s/epoch - 5ms/step
Epoch 49/100
469/469 - 3s - loss: 0.4499 - sparse_categorical_accuracy: 0.8312 - val_loss: 0.4266 - val_sparse_ca
tegorical_accuracy: 0.8397 - 3s/epoch - 5ms/step
Epoch 50/100
469/469 - 3s - loss: 0.4466 - sparse_categorical_accuracy: 0.8342 - val_loss: 0.4275 - val_sparse_ca
tegorical_accuracy: 0.8401 - 3s/epoch - 6ms/step
Epoch 51/100
469/469 - 3s - loss: 0.4501 - sparse_categorical_accuracy: 0.8325 - val_loss: 0.4268 - val_sparse_ca
tegorical_accuracy: 0.8415 - 3s/epoch - 6ms/step
Epoch 52/100
469/469 - 2s - loss: 0.4497 - sparse_categorical_accuracy: 0.8322 - val_loss: 0.4261 - val_sparse_ca
tegorical_accuracy: 0.8413 - 2s/epoch - 5ms/step
Epoch 53/100
469/469 - 3s - loss: 0.4498 - sparse_categorical_accuracy: 0.8316 - val_loss: 0.4238 - val_sparse_ca
tegorical_accuracy: 0.8415 - 3s/epoch - 5ms/step
Epoch 54/100
469/469 - 2s - loss: 0.4478 - sparse_categorical_accuracy: 0.8317 - val_loss: 0.4244 - val_sparse_ca
tegorical_accuracy: 0.8413 - 2s/epoch - 5ms/step
Epoch 55/100
469/469 - 2s - loss: 0.4471 - sparse_categorical_accuracy: 0.8328 - val_loss: 0.4174 - val_sparse_ca
tegorical_accuracy: 0.8434 - 2s/epoch - 5ms/step
Epoch 56/100
469/469 - 3s - loss: 0.4465 - sparse_categorical_accuracy: 0.8333 - val_loss: 0.4224 - val_sparse_ca
tegorical_accuracy: 0.8432 - 3s/epoch - 5ms/step
Epoch 57/100
469/469 - 3s - loss: 0.4474 - sparse_categorical_accuracy: 0.8339 - val_loss: 0.4246 - val_sparse_ca
tegorical_accuracy: 0.8403 - 3s/epoch - 5ms/step
Epoch 58/100
469/469 - 3s - loss: 0.4443 - sparse_categorical_accuracy: 0.8335 - val_loss: 0.4176 - val_sparse_ca
tegorical_accuracy: 0.8409 - 3s/epoch - 5ms/step
Epoch 59/100
469/469 - 2s - loss: 0.4484 - sparse_categorical_accuracy: 0.8334 - val_loss: 0.4261 - val_sparse_ca
tegorical_accuracy: 0.8401 - 2s/epoch - 5ms/step
Epoch 60/100
469/469 - 2s - loss: 0.4445 - sparse_categorical_accuracy: 0.8346 - val_loss: 0.4206 - val_sparse_ca
tegorical_accuracy: 0.8425 - 2s/epoch - 5ms/step
Epoch 61/100
469/469 - 2s - loss: 0.4445 - sparse_categorical_accuracy: 0.8345 - val_loss: 0.4226 - val_sparse_ca
tegorical_accuracy: 0.8386 - 2s/epoch - 5ms/step
Epoch 62/100
469/469 - 2s - loss: 0.4447 - sparse_categorical_accuracy: 0.8342 - val_loss: 0.4301 - val_sparse_ca
tegorical_accuracy: 0.8376 - 2s/epoch - 5ms/step
Epoch 63/100
```

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469/469 - 2s - loss: 0.4443 - sparse_categorical_accuracy: 0.8335 - val_loss: 0.4236 - val_sparse_ca
tegorical_accuracy: 0.8412 - 2s/epoch - 5ms/step
Epoch 64/100
469/469 - 3s - loss: 0.4453 - sparse_categorical_accuracy: 0.8346 - val_loss: 0.4267 - val_sparse_ca
tegorical_accuracy: 0.8395 - 3s/epoch - 5ms/step
Epoch 65/100
469/469 - 3s - loss: 0.4420 - sparse_categorical_accuracy: 0.8358 - val_loss: 0.4183 - val_sparse_ca
tegorical_accuracy: 0.8411 - 3s/epoch - 5ms/step
Epoch 66/100
469/469 - 2s - loss: 0.4447 - sparse_categorical_accuracy: 0.8347 - val_loss: 0.4180 - val_sparse_ca
tegorical_accuracy: 0.8436 - 2s/epoch - 5ms/step
Epoch 67/100
469/469 - 3s - loss: 0.4424 - sparse_categorical_accuracy: 0.8324 - val_loss: 0.4252 - val_sparse_ca
tegorical_accuracy: 0.8400 - 3s/epoch - 6ms/step
Epoch 68/100
469/469 - 2s - loss: 0.4436 - sparse_categorical_accuracy: 0.8317 - val_loss: 0.4207 - val_sparse_ca
tegorical_accuracy: 0.8416 - 2s/epoch - 5ms/step
Epoch 69/100
469/469 - 2s - loss: 0.4429 - sparse_categorical_accuracy: 0.8342 - val_loss: 0.4173 - val_sparse_ca
tegorical_accuracy: 0.8433 - 2s/epoch - 5ms/step
Epoch 70/100
469/469 - 2s - loss: 0.4430 - sparse_categorical_accuracy: 0.8343 - val_loss: 0.4210 - val_sparse_ca
tegorical_accuracy: 0.8403 - 2s/epoch - 5ms/step
Epoch 71/100
469/469 - 2s - loss: 0.4423 - sparse_categorical_accuracy: 0.8331 - val_loss: 0.4265 - val_sparse_ca
tegorical_accuracy: 0.8398 - 2s/epoch - 5ms/step
Epoch 72/100
469/469 - 2s - loss: 0.4417 - sparse_categorical_accuracy: 0.8358 - val_loss: 0.4175 - val_sparse_ca
tegorical_accuracy: 0.8427 - 2s/epoch - 5ms/step
Epoch 73/100
469/469 - 2s - loss: 0.4423 - sparse_categorical_accuracy: 0.8328 - val_loss: 0.4232 - val_sparse_ca
tegorical_accuracy: 0.8427 - 2s/epoch - 5ms/step
Epoch 74/100
469/469 - 2s - loss: 0.4404 - sparse_categorical_accuracy: 0.8366 - val_loss: 0.4211 - val_sparse_ca
tegorical_accuracy: 0.8407 - 2s/epoch - 5ms/step
Epoch 75/100
469/469 - 2s - loss: 0.4422 - sparse_categorical_accuracy: 0.8346 - val_loss: 0.4245 - val_sparse_ca
tegorical_accuracy: 0.8412 - 2s/epoch - 5ms/step
Epoch 76/100
469/469 - 3s - loss: 0.4421 - sparse_categorical_accuracy: 0.8349 - val_loss: 0.4205 - val_sparse_ca
tegorical_accuracy: 0.8411 - 3s/epoch - 5ms/step
Epoch 77/100
469/469 - 3s - loss: 0.4392 - sparse_categorical_accuracy: 0.8376 - val_loss: 0.4238 - val_sparse_ca
tegorical_accuracy: 0.8409 - 3s/epoch - 5ms/step
Epoch 78/100
469/469 - 3s - loss: 0.4404 - sparse_categorical_accuracy: 0.8352 - val_loss: 0.4227 - val_sparse_ca
tegorical_accuracy: 0.8405 - 3s/epoch - 6ms/step
Epoch 79/100
469/469 - 2s - loss: 0.4417 - sparse_categorical_accuracy: 0.8348 - val_loss: 0.4167 - val_sparse_ca
tegorical_accuracy: 0.8430 - 2s/epoch - 5ms/step
Epoch 80/100
469/469 - 2s - loss: 0.4391 - sparse_categorical_accuracy: 0.8374 - val_loss: 0.4192 - val_sparse_ca
tegorical_accuracy: 0.8429 - 2s/epoch - 5ms/step
Epoch 81/100
469/469 - 3s - loss: 0.4427 - sparse_categorical_accuracy: 0.8353 - val_loss: 0.4179 - val_sparse_ca
tegorical_accuracy: 0.8428 - 3s/epoch - 6ms/step
Epoch 82/100
469/469 - 3s - loss: 0.4423 - sparse_categorical_accuracy: 0.8347 - val_loss: 0.4162 - val_sparse_ca
tegorical_accuracy: 0.8441 - 3s/epoch - 6ms/step
Epoch 83/100
469/469 - 3s - loss: 0.4403 - sparse_categorical_accuracy: 0.8364 - val_loss: 0.4165 - val_sparse_ca
tegorical_accuracy: 0.8412 - 3s/epoch - 5ms/step
Epoch 84/100
469/469 - 3s - loss: 0.4408 - sparse_categorical_accuracy: 0.8339 - val_loss: 0.4238 - val_sparse_ca
tegorical_accuracy: 0.8415 - 3s/epoch - 5ms/step
Epoch 85/100
469/469 - 2s - loss: 0.4398 - sparse_categorical_accuracy: 0.8359 - val_loss: 0.4237 - val_sparse_ca
tegorical_accuracy: 0.8380 - 2s/epoch - 5ms/step
Epoch 86/100
469/469 - 2s - loss: 0.4386 - sparse_categorical_accuracy: 0.8359 - val_loss: 0.4259 - val_sparse_ca
tegorical_accuracy: 0.8382 - 2s/epoch - 5ms/step
Epoch 87/100
469/469 - 2s - loss: 0.4379 - sparse_categorical_accuracy: 0.8353 - val_loss: 0.4218 - val_sparse_ca
tegorical_accuracy: 0.8426 - 2s/epoch - 5ms/step
Epoch 88/100
469/469 - 2s - loss: 0.4370 - sparse_categorical_accuracy: 0.8367 - val_loss: 0.4178 - val_sparse_ca
tegorical_accuracy: 0.8412 - 2s/epoch - 5ms/step
Epoch 89/100
469/469 - 2s - loss: 0.4376 - sparse_categorical_accuracy: 0.8360 - val_loss: 0.4182 - val_sparse_ca
tegorical_accuracy: 0.8415 - 2s/epoch - 5ms/step
Epoch 90/100
469/469 - 2s - loss: 0.4391 - sparse_categorical_accuracy: 0.8355 - val_loss: 0.4188 - val_sparse_ca
tegorical_accuracy: 0.8419 - 2s/epoch - 5ms/step
```

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Epoch 91/100
469/469 - 3s - loss: 0.4398 - sparse_categorical_accuracy: 0.8350 - val_loss: 0.4245 - val_sparse_ca
tegorical_accuracy: 0.8407 - 3s/epoch - 5ms/step
Epoch 92/100
469/469 - 2s - loss: 0.4393 - sparse_categorical_accuracy: 0.8352 - val_loss: 0.4258 - val_sparse_ca
tegorical_accuracy: 0.8397 - 2s/epoch - 5ms/step
Epoch 93/100
469/469 - 3s - loss: 0.4378 - sparse_categorical_accuracy: 0.8376 - val_loss: 0.4267 - val_sparse_ca
tegorical_accuracy: 0.8387 - 3s/epoch - 6ms/step
Epoch 94/100
469/469 - 2s - loss: 0.4413 - sparse_categorical_accuracy: 0.8353 - val_loss: 0.4191 - val_sparse_ca
tegorical_accuracy: 0.8409 - 2s/epoch - 5ms/step
Epoch 95/100
469/469 - 3s - loss: 0.4395 - sparse_categorical_accuracy: 0.8352 - val_loss: 0.4173 - val_sparse_ca
tegorical_accuracy: 0.8440 - 3s/epoch - 6ms/step
Epoch 96/100
469/469 - 2s - loss: 0.4358 - sparse_categorical_accuracy: 0.8374 - val_loss: 0.4213 - val_sparse_ca
tegorical_accuracy: 0.8393 - 2s/epoch - 5ms/step
Epoch 97/100
469/469 - 2s - loss: 0.4378 - sparse_categorical_accuracy: 0.8364 - val_loss: 0.4154 - val_sparse_ca
tegorical_accuracy: 0.8414 - 2s/epoch - 5ms/step
Epoch 98/100
469/469 - 2s - loss: 0.4375 - sparse_categorical_accuracy: 0.8376 - val_loss: 0.4147 - val_sparse_ca
tegorical_accuracy: 0.8431 - 2s/epoch - 5ms/step
Epoch 99/100
469/469 - 2s - loss: 0.4362 - sparse_categorical_accuracy: 0.8364 - val_loss: 0.4161 - val_sparse_ca
tegorical_accuracy: 0.8427 - 2s/epoch - 5ms/step
Epoch 100/100
469/469 - 2s - loss: 0.4354 - sparse_categorical_accuracy: 0.8371 - val_loss: 0.4174 - val_sparse_ca
tegorical_accuracy: 0.8426 - 2s/epoch - 5ms/step
313/313 - 1s - loss: 0.4174 - sparse_categorical_accuracy: 0.8426 - 522ms/epoch - 2ms/step
```

Out[6]:

```
[0.4173944890499115, 0.8425999879837036]
```

In [16]:

```
# build inception module function
import keras
from tensorflow.keras.layers import Layer
import keras.backend as K
import tensorflow as tf
from keras.datasets import cifar10
from keras.models import Model
from keras.layers import Conv2D, MaxPool2D,  \
    Dropout, Dense, Input, concatenate,      \
    GlobalAveragePooling2D, AveragePooling2D,\
    Flatten

import cv2
import numpy as np
from keras.datasets import cifar10
from keras import backend as K
#from keras.utils import np_utils
kernel_init = keras.initializers.glorot_uniform()
bias_init = keras.initializers.Constant(value=0.2)

def inception_module(x,
                     filters_1x1,
                     filters_3x3_reduce,
                     filters_3x3,
                     filters_5x5_reduce,
                     filters_5x5,
                     filters_pool_proj,
                     name=None):

    conv_1x1 = Conv2D(filters_1x1, (1, 1), padding='same', activation='relu', kernel_initializer=kernel_init, bia
s_initializer=bias_init)(x)

    conv_3x3 = Conv2D(filters_3x3_reduce, (1, 1), padding='same', activation='relu', kernel_initializer=kernel_in
it, bias_initializer=bias_init)(x)
    conv_3x3 = Conv2D(filters_3x3, (3, 3), padding='same', activation='relu', kernel_initializer=kernel_init, bia
s_initializer=bias_init)(conv_3x3)

    conv_5x5 = Conv2D(filters_5x5_reduce, (1, 1), padding='same', activation='relu', kernel_initializer=kernel_in
it, bias_initializer=bias_init)(x)
    conv_5x5 = Conv2D(filters_5x5, (5, 5), padding='same', activation='relu', kernel_initializer=kernel_init, bia
s_initializer=bias_init)(conv_5x5)

    pool_proj = MaxPool2D((3, 3), strides=(1, 1), padding='same')(x)
    pool_proj = Conv2D(filters_pool_proj, (1, 1), padding='same', activation='relu', kernel_initializer=kernel_in
it, bias_initializer=bias_init)(pool_proj)

    output = concatenate([conv_1x1, conv_3x3, conv_5x5, pool_proj], axis=1, name=name)

    return output
```

In [17]:

```
# Architecture3 with inception
input_layer = Input(shape=(28, 28,1))
x = inception_module(input_layer,
                     filters_1x1=1,
                     filters_3x3_reduce=1,
                     filters_3x3=1,
                     filters_5x5_reduce=1,
                     filters_5x5=1,
                     filters_pool_proj=1,
                     name='inception_3a')
x = tf.keras.layers.BatchNormalization()(x)
x = MaxPool2D((3, 3))(x)
x = tf.keras.layers.Flatten()(x)
x = Dropout(0.3)(x)
x = tf.keras.layers.Dense(16, activation='relu')(x)
x = tf.keras.layers.Dense(16, activation='relu')(x)
x = Dense(10, activation='softmax')(x)
model3 = Model(input_layer, x, name='inception_v1')
model3.summary()
```

```
Model: "inception_v1"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_6 (InputLayer)           [(None, 28, 28, 1)]  0           []

 conv2d_10 (Conv2D)             (None, 28, 28, 1)    2           ['input_6[0][0]']

 conv2d_12 (Conv2D)             (None, 28, 28, 1)    2           ['input_6[0][0]']

 max_pooling2d_10 (MaxPooling2D  (None, 28, 28, 1)   0           ['input_6[0][0]']
 )

 conv2d_9 (Conv2D)              (None, 28, 28, 1)    2           ['input_6[0][0]']

 conv2d_11 (Conv2D)             (None, 28, 28, 1)    10          ['conv2d_10[0][0]']

 conv2d_13 (Conv2D)             (None, 28, 28, 1)    26          ['conv2d_12[0][0]']

 conv2d_14 (Conv2D)             (None, 28, 28, 1)    2           ['max_pooling2d_10[0][0]']

 inception_3a (Concatenate)     (None, 112, 28, 1)   0           ['conv2d_9[0][0]',
                                                                  'conv2d_11[0][0]',
                                                                  'conv2d_13[0][0]',
                                                                  'conv2d_14[0][0]']

 batch_normalization_5 (BatchNo  (None, 112, 28, 1)  4           ['inception_3a[0][0]']
 rmalization)

 max_pooling2d_11 (MaxPooling2D  (None, 37, 9, 1)    0           ['batch_normalization_5[0][0]']
 )

 flatten_6 (Flatten)            (None, 333)          0           ['max_pooling2d_11[0][0]']

 dropout_5 (Dropout)            (None, 333)          0           ['flatten_6[0][0]']

 dense_18 (Dense)               (None, 16)           5344        ['dropout_5[0][0]']

 dense_19 (Dense)               (None, 16)           272         ['dense_18[0][0]']

 dense_20 (Dense)               (None, 10)           170         ['dense_19[0][0]']

==================================================================================================
Total params: 5,834
Trainable params: 5,832
Non-trainable params: 2
__________________________________________________________________________________________________
```

In [ ]:

```
model3.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model3.fit(x_train, y_train,
                    batch_size=128,
                    epochs=10,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
```

```
Epoch 1/10
469/469 - 58s - loss: 0.2915 - sparse_categorical_accuracy: 0.9067 - val_loss: 0.1847 - val_sparse_c
ategorical_accuracy: 0.9431 - 58s/epoch - 123ms/step
Epoch 2/10
469/469 - 56s - loss: 0.2810 - sparse_categorical_accuracy: 0.9104 - val_loss: 0.1711 - val_sparse_c
ategorical_accuracy: 0.9466 - 56s/epoch - 120ms/step
Epoch 3/10
469/469 - 56s - loss: 0.2693 - sparse_categorical_accuracy: 0.9140 - val_loss: 0.1713 - val_sparse_c
ategorical_accuracy: 0.9463 - 56s/epoch - 120ms/step
Epoch 4/10
469/469 - 56s - loss: 0.2636 - sparse_categorical_accuracy: 0.9166 - val_loss: 0.1597 - val_sparse_c
ategorical_accuracy: 0.9501 - 56s/epoch - 120ms/step
Epoch 5/10
469/469 - 56s - loss: 0.2550 - sparse_categorical_accuracy: 0.9189 - val_loss: 0.1529 - val_sparse_c
ategorical_accuracy: 0.9527 - 56s/epoch - 119ms/step
Epoch 6/10
469/469 - 56s - loss: 0.2490 - sparse_categorical_accuracy: 0.9196 - val_loss: 0.1550 - val_sparse_c
ategorical_accuracy: 0.9508 - 56s/epoch - 119ms/step
Epoch 7/10
469/469 - 56s - loss: 0.2447 - sparse_categorical_accuracy: 0.9216 - val_loss: 0.1480 - val_sparse_c
ategorical_accuracy: 0.9515 - 56s/epoch - 119ms/step
Epoch 8/10
469/469 - 56s - loss: 0.2409 - sparse_categorical_accuracy: 0.9229 - val_loss: 0.1446 - val_sparse_c
ategorical_accuracy: 0.9536 - 56s/epoch - 119ms/step
Epoch 9/10
469/469 - 56s - loss: 0.2381 - sparse_categorical_accuracy: 0.9246 - val_loss: 0.1449 - val_sparse_c
ategorical_accuracy: 0.9552 - 56s/epoch - 119ms/step
Epoch 10/10
469/469 - 56s - loss: 0.2356 - sparse_categorical_accuracy: 0.9234 - val_loss: 0.1416 - val_sparse_c
ategorical_accuracy: 0.9557 - 56s/epoch - 119ms/step
```

Out[ ]:

```
<keras.callbacks.History at 0x7fdbba7f1710>
```

In [ ]:

```
model3.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 5s - loss: 0.1416 - sparse_categorical_accuracy: 0.9557 - 5s/epoch - 15ms/step
```

Out[ ]:

```
[0.14159709215164185, 0.9556999802589417]
```

In [ ]:

```
# model compared with AlexNet
model4 = tf.keras.models.Sequential([
  tf.keras.layers.Input(shape=(28, 28, 1)),
  tf.keras.layers.GaussianNoise(0.1),
  tf.keras.layers.Conv2D(20, (5, 5)),
  tf.keras.layers.MaxPooling2D((3, 3)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.Flatten(),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Dense(10, activation='softmax')
])
model4.summary()
```

```
Model: "sequential_11"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gaussian_noise_9 (GaussianN  (None, 28, 28, 1)        0
 oise)

 conv2d_76 (Conv2D)          (None, 24, 24, 20)        520

 max_pooling2d_34 (MaxPoolin  (None, 8, 8, 20)         0
 g2D)

 max_pooling2d_35 (MaxPoolin  (None, 4, 4, 20)         0
 g2D)

 flatten_17 (Flatten)        (None, 320)               0

 dropout_16 (Dropout)        (None, 320)               0

 dense_47 (Dense)            (None, 16)                5136

 dense_48 (Dense)            (None, 16)                272

 batch_normalization_12 (Bat  (None, 16)               64
 chNormalization)

 dense_49 (Dense)            (None, 10)                170

=================================================================
Total params: 6,162
Trainable params: 6,130
Non-trainable params: 32
_________________________________________________________________
```

In [ ]:

```
model4.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model4.fit(x_train, y_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
```

```
Epoch 1/100
469/469 - 22s - loss: 0.9006 - sparse_categorical_accuracy: 0.7258 - val_loss: 0.2103 - val_sparse_c
ategorical_accuracy: 0.9491 - 22s/epoch - 47ms/step
Epoch 2/100
469/469 - 21s - loss: 0.2307 - sparse_categorical_accuracy: 0.9354 - val_loss: 0.1068 - val_sparse_c
ategorical_accuracy: 0.9696 - 21s/epoch - 45ms/step
Epoch 3/100
469/469 - 21s - loss: 0.1557 - sparse_categorical_accuracy: 0.9537 - val_loss: 0.0762 - val_sparse_c
ategorical_accuracy: 0.9769 - 21s/epoch - 45ms/step
Epoch 4/100
469/469 - 21s - loss: 0.1275 - sparse_categorical_accuracy: 0.9618 - val_loss: 0.0696 - val_sparse_c
ategorical_accuracy: 0.9790 - 21s/epoch - 45ms/step
Epoch 5/100
469/469 - 21s - loss: 0.1117 - sparse_categorical_accuracy: 0.9662 - val_loss: 0.0616 - val_sparse_c
ategorical_accuracy: 0.9805 - 21s/epoch - 45ms/step
Epoch 6/100
469/469 - 21s - loss: 0.1022 - sparse_categorical_accuracy: 0.9681 - val_loss: 0.0553 - val_sparse_c
ategorical_accuracy: 0.9822 - 21s/epoch - 45ms/step
```

```
Epoch 7/100
469/469 - 21s - loss: 0.0956 - sparse_categorical_accuracy: 0.9707 - val_loss: 0.0561 - val_sparse_c
ategorical_accuracy: 0.9808 - 21s/epoch - 45ms/step
Epoch 8/100
469/469 - 21s - loss: 0.0894 - sparse_categorical_accuracy: 0.9728 - val_loss: 0.0525 - val_sparse_c
ategorical_accuracy: 0.9825 - 21s/epoch - 46ms/step
Epoch 9/100
469/469 - 21s - loss: 0.0831 - sparse_categorical_accuracy: 0.9737 - val_loss: 0.0507 - val_sparse_c
ategorical_accuracy: 0.9839 - 21s/epoch - 45ms/step
Epoch 10/100
469/469 - 21s - loss: 0.0803 - sparse_categorical_accuracy: 0.9752 - val_loss: 0.0482 - val_sparse_c
ategorical_accuracy: 0.9826 - 21s/epoch - 44ms/step
Epoch 11/100
469/469 - 21s - loss: 0.0780 - sparse_categorical_accuracy: 0.9755 - val_loss: 0.0485 - val_sparse_c
ategorical_accuracy: 0.9850 - 21s/epoch - 44ms/step
Epoch 12/100
469/469 - 21s - loss: 0.0764 - sparse_categorical_accuracy: 0.9758 - val_loss: 0.0511 - val_sparse_c
ategorical_accuracy: 0.9830 - 21s/epoch - 45ms/step
Epoch 13/100
469/469 - 21s - loss: 0.0752 - sparse_categorical_accuracy: 0.9765 - val_loss: 0.0509 - val_sparse_c
ategorical_accuracy: 0.9832 - 21s/epoch - 45ms/step
Epoch 14/100
469/469 - 21s - loss: 0.0714 - sparse_categorical_accuracy: 0.9786 - val_loss: 0.0426 - val_sparse_c
ategorical_accuracy: 0.9862 - 21s/epoch - 44ms/step
Epoch 15/100
469/469 - 21s - loss: 0.0712 - sparse_categorical_accuracy: 0.9774 - val_loss: 0.0434 - val_sparse_c
ategorical_accuracy: 0.9855 - 21s/epoch - 44ms/step
Epoch 16/100
469/469 - 21s - loss: 0.0684 - sparse_categorical_accuracy: 0.9779 - val_loss: 0.0412 - val_sparse_c
ategorical_accuracy: 0.9864 - 21s/epoch - 44ms/step
Epoch 17/100
469/469 - 21s - loss: 0.0680 - sparse_categorical_accuracy: 0.9784 - val_loss: 0.0434 - val_sparse_c
ategorical_accuracy: 0.9849 - 21s/epoch - 44ms/step
Epoch 18/100
469/469 - 20s - loss: 0.0653 - sparse_categorical_accuracy: 0.9794 - val_loss: 0.0500 - val_sparse_c
ategorical_accuracy: 0.9843 - 20s/epoch - 44ms/step
Epoch 19/100
469/469 - 20s - loss: 0.0644 - sparse_categorical_accuracy: 0.9796 - val_loss: 0.0580 - val_sparse_c
ategorical_accuracy: 0.9819 - 20s/epoch - 44ms/step
Epoch 20/100
469/469 - 21s - loss: 0.0614 - sparse_categorical_accuracy: 0.9804 - val_loss: 0.0441 - val_sparse_c
ategorical_accuracy: 0.9856 - 21s/epoch - 44ms/step
Epoch 21/100
469/469 - 21s - loss: 0.0617 - sparse_categorical_accuracy: 0.9810 - val_loss: 0.0449 - val_sparse_c
ategorical_accuracy: 0.9861 - 21s/epoch - 44ms/step
Epoch 22/100
469/469 - 21s - loss: 0.0610 - sparse_categorical_accuracy: 0.9808 - val_loss: 0.0418 - val_sparse_c
ategorical_accuracy: 0.9867 - 21s/epoch - 44ms/step
Epoch 23/100
469/469 - 21s - loss: 0.0599 - sparse_categorical_accuracy: 0.9809 - val_loss: 0.0448 - val_sparse_c
ategorical_accuracy: 0.9856 - 21s/epoch - 44ms/step
Epoch 24/100
469/469 - 21s - loss: 0.0569 - sparse_categorical_accuracy: 0.9821 - val_loss: 0.0372 - val_sparse_c
ategorical_accuracy: 0.9874 - 21s/epoch - 44ms/step
Epoch 25/100
469/469 - 21s - loss: 0.0560 - sparse_categorical_accuracy: 0.9827 - val_loss: 0.0425 - val_sparse_c
ategorical_accuracy: 0.9867 - 21s/epoch - 44ms/step
Epoch 26/100
469/469 - 20s - loss: 0.0555 - sparse_categorical_accuracy: 0.9826 - val_loss: 0.0404 - val_sparse_c
ategorical_accuracy: 0.9878 - 20s/epoch - 44ms/step
Epoch 27/100
469/469 - 21s - loss: 0.0545 - sparse_categorical_accuracy: 0.9822 - val_loss: 0.0431 - val_sparse_c
ategorical_accuracy: 0.9861 - 21s/epoch - 44ms/step
Epoch 28/100
469/469 - 21s - loss: 0.0552 - sparse_categorical_accuracy: 0.9817 - val_loss: 0.0447 - val_sparse_c
ategorical_accuracy: 0.9864 - 21s/epoch - 44ms/step
Epoch 29/100
469/469 - 20s - loss: 0.0545 - sparse_categorical_accuracy: 0.9828 - val_loss: 0.0409 - val_sparse_c
ategorical_accuracy: 0.9867 - 20s/epoch - 44ms/step
Epoch 30/100
469/469 - 20s - loss: 0.0546 - sparse_categorical_accuracy: 0.9824 - val_loss: 0.0365 - val_sparse_c
ategorical_accuracy: 0.9886 - 20s/epoch - 44ms/step
Epoch 31/100
469/469 - 20s - loss: 0.0521 - sparse_categorical_accuracy: 0.9833 - val_loss: 0.0438 - val_sparse_c
ategorical_accuracy: 0.9846 - 20s/epoch - 44ms/step
Epoch 32/100
469/469 - 20s - loss: 0.0535 - sparse_categorical_accuracy: 0.9831 - val_loss: 0.0391 - val_sparse_c
ategorical_accuracy: 0.9872 - 20s/epoch - 44ms/step
Epoch 33/100
469/469 - 20s - loss: 0.0499 - sparse_categorical_accuracy: 0.9837 - val_loss: 0.0398 - val_sparse_c
ategorical_accuracy: 0.9866 - 20s/epoch - 44ms/step
Epoch 34/100
469/469 - 20s - loss: 0.0525 - sparse_categorical_accuracy: 0.9833 - val_loss: 0.0380 - val_sparse_c
```

```
ategorical_accuracy: 0.9886 - 20s/epoch - 44ms/step
Epoch 35/100
469/469 - 20s - loss: 0.0516 - sparse_categorical_accuracy: 0.9835 - val_loss: 0.0383 - val_sparse_c
ategorical_accuracy: 0.9876 - 20s/epoch - 44ms/step
Epoch 36/100
469/469 - 20s - loss: 0.0497 - sparse_categorical_accuracy: 0.9842 - val_loss: 0.0357 - val_sparse_c
ategorical_accuracy: 0.9891 - 20s/epoch - 44ms/step
Epoch 37/100
469/469 - 20s - loss: 0.0500 - sparse_categorical_accuracy: 0.9843 - val_loss: 0.0367 - val_sparse_c
ategorical_accuracy: 0.9883 - 20s/epoch - 44ms/step
Epoch 38/100
469/469 - 20s - loss: 0.0497 - sparse_categorical_accuracy: 0.9841 - val_loss: 0.0383 - val_sparse_c
ategorical_accuracy: 0.9878 - 20s/epoch - 44ms/step
Epoch 39/100
469/469 - 20s - loss: 0.0490 - sparse_categorical_accuracy: 0.9842 - val_loss: 0.0355 - val_sparse_c
ategorical_accuracy: 0.9885 - 20s/epoch - 44ms/step
Epoch 40/100
469/469 - 20s - loss: 0.0482 - sparse_categorical_accuracy: 0.9844 - val_loss: 0.0385 - val_sparse_c
ategorical_accuracy: 0.9873 - 20s/epoch - 44ms/step
Epoch 41/100
469/469 - 21s - loss: 0.0488 - sparse_categorical_accuracy: 0.9842 - val_loss: 0.0359 - val_sparse_c
ategorical_accuracy: 0.9882 - 21s/epoch - 44ms/step
Epoch 42/100
469/469 - 20s - loss: 0.0500 - sparse_categorical_accuracy: 0.9842 - val_loss: 0.0412 - val_sparse_c
ategorical_accuracy: 0.9863 - 20s/epoch - 43ms/step
Epoch 43/100
469/469 - 20s - loss: 0.0488 - sparse_categorical_accuracy: 0.9843 - val_loss: 0.0351 - val_sparse_c
ategorical_accuracy: 0.9885 - 20s/epoch - 43ms/step
Epoch 44/100
469/469 - 21s - loss: 0.0466 - sparse_categorical_accuracy: 0.9851 - val_loss: 0.0384 - val_sparse_c
ategorical_accuracy: 0.9874 - 21s/epoch - 44ms/step
Epoch 45/100
469/469 - 20s - loss: 0.0482 - sparse_categorical_accuracy: 0.9849 - val_loss: 0.0362 - val_sparse_c
ategorical_accuracy: 0.9884 - 20s/epoch - 44ms/step
Epoch 46/100
469/469 - 20s - loss: 0.0447 - sparse_categorical_accuracy: 0.9856 - val_loss: 0.0402 - val_sparse_c
ategorical_accuracy: 0.9877 - 20s/epoch - 44ms/step
Epoch 47/100
469/469 - 20s - loss: 0.0463 - sparse_categorical_accuracy: 0.9851 - val_loss: 0.0365 - val_sparse_c
ategorical_accuracy: 0.9880 - 20s/epoch - 44ms/step
Epoch 48/100
469/469 - 20s - loss: 0.0451 - sparse_categorical_accuracy: 0.9860 - val_loss: 0.0402 - val_sparse_c
ategorical_accuracy: 0.9875 - 20s/epoch - 44ms/step
Epoch 49/100
469/469 - 20s - loss: 0.0456 - sparse_categorical_accuracy: 0.9851 - val_loss: 0.0388 - val_sparse_c
ategorical_accuracy: 0.9884 - 20s/epoch - 43ms/step
Epoch 50/100
469/469 - 20s - loss: 0.0450 - sparse_categorical_accuracy: 0.9855 - val_loss: 0.0385 - val_sparse_c
ategorical_accuracy: 0.9880 - 20s/epoch - 44ms/step
Epoch 51/100
469/469 - 20s - loss: 0.0451 - sparse_categorical_accuracy: 0.9854 - val_loss: 0.0366 - val_sparse_c
ategorical_accuracy: 0.9879 - 20s/epoch - 44ms/step
Epoch 52/100
469/469 - 20s - loss: 0.0457 - sparse_categorical_accuracy: 0.9851 - val_loss: 0.0373 - val_sparse_c
ategorical_accuracy: 0.9885 - 20s/epoch - 44ms/step
Epoch 53/100
469/469 - 20s - loss: 0.0457 - sparse_categorical_accuracy: 0.9850 - val_loss: 0.0414 - val_sparse_c
ategorical_accuracy: 0.9869 - 20s/epoch - 44ms/step
Epoch 54/100
469/469 - 20s - loss: 0.0448 - sparse_categorical_accuracy: 0.9852 - val_loss: 0.0367 - val_sparse_c
ategorical_accuracy: 0.9877 - 20s/epoch - 44ms/step
Epoch 55/100
469/469 - 20s - loss: 0.0438 - sparse_categorical_accuracy: 0.9855 - val_loss: 0.0403 - val_sparse_c
ategorical_accuracy: 0.9876 - 20s/epoch - 44ms/step
Epoch 56/100
469/469 - 21s - loss: 0.0455 - sparse_categorical_accuracy: 0.9851 - val_loss: 0.0370 - val_sparse_c
ategorical_accuracy: 0.9893 - 21s/epoch - 44ms/step
Epoch 57/100
469/469 - 20s - loss: 0.0437 - sparse_categorical_accuracy: 0.9861 - val_loss: 0.0371 - val_sparse_c
ategorical_accuracy: 0.9879 - 20s/epoch - 44ms/step
Epoch 58/100
469/469 - 20s - loss: 0.0468 - sparse_categorical_accuracy: 0.9847 - val_loss: 0.0386 - val_sparse_c
ategorical_accuracy: 0.9876 - 20s/epoch - 44ms/step
Epoch 59/100
469/469 - 20s - loss: 0.0446 - sparse_categorical_accuracy: 0.9857 - val_loss: 0.0359 - val_sparse_c
ategorical_accuracy: 0.9882 - 20s/epoch - 44ms/step
Epoch 60/100
469/469 - 20s - loss: 0.0443 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0421 - val_sparse_c
ategorical_accuracy: 0.9864 - 20s/epoch - 43ms/step
Epoch 61/100
469/469 - 20s - loss: 0.0434 - sparse_categorical_accuracy: 0.9857 - val_loss: 0.0372 - val_sparse_c
ategorical_accuracy: 0.9888 - 20s/epoch - 43ms/step
Epoch 62/100
```

```
469/469 - 20s - loss: 0.0437 - sparse_categorical_accuracy: 0.9857 - val_loss: 0.0355 - val_sparse_c
ategorical_accuracy: 0.9884 - 20s/epoch - 43ms/step
Epoch 63/100
469/469 - 20s - loss: 0.0420 - sparse_categorical_accuracy: 0.9865 - val_loss: 0.0362 - val_sparse_c
ategorical_accuracy: 0.9890 - 20s/epoch - 43ms/step
Epoch 64/100
469/469 - 20s - loss: 0.0438 - sparse_categorical_accuracy: 0.9852 - val_loss: 0.0369 - val_sparse_c
ategorical_accuracy: 0.9884 - 20s/epoch - 44ms/step
Epoch 65/100
469/469 - 20s - loss: 0.0430 - sparse_categorical_accuracy: 0.9861 - val_loss: 0.0407 - val_sparse_c
ategorical_accuracy: 0.9878 - 20s/epoch - 44ms/step
Epoch 66/100
469/469 - 20s - loss: 0.0428 - sparse_categorical_accuracy: 0.9863 - val_loss: 0.0391 - val_sparse_c
ategorical_accuracy: 0.9882 - 20s/epoch - 44ms/step
Epoch 67/100
469/469 - 21s - loss: 0.0425 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0442 - val_sparse_c
ategorical_accuracy: 0.9860 - 21s/epoch - 44ms/step
Epoch 68/100
469/469 - 21s - loss: 0.0423 - sparse_categorical_accuracy: 0.9863 - val_loss: 0.0386 - val_sparse_c
ategorical_accuracy: 0.9877 - 21s/epoch - 44ms/step
Epoch 69/100
469/469 - 21s - loss: 0.0423 - sparse_categorical_accuracy: 0.9859 - val_loss: 0.0388 - val_sparse_c
ategorical_accuracy: 0.9879 - 21s/epoch - 44ms/step
Epoch 70/100
469/469 - 21s - loss: 0.0409 - sparse_categorical_accuracy: 0.9873 - val_loss: 0.0376 - val_sparse_c
ategorical_accuracy: 0.9881 - 21s/epoch - 44ms/step
Epoch 71/100
469/469 - 21s - loss: 0.0430 - sparse_categorical_accuracy: 0.9854 - val_loss: 0.0357 - val_sparse_c
ategorical_accuracy: 0.9902 - 21s/epoch - 44ms/step
Epoch 72/100
469/469 - 20s - loss: 0.0417 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0356 - val_sparse_c
ategorical_accuracy: 0.9897 - 20s/epoch - 44ms/step
Epoch 73/100
469/469 - 20s - loss: 0.0435 - sparse_categorical_accuracy: 0.9860 - val_loss: 0.0388 - val_sparse_c
ategorical_accuracy: 0.9874 - 20s/epoch - 44ms/step
Epoch 74/100
469/469 - 21s - loss: 0.0440 - sparse_categorical_accuracy: 0.9857 - val_loss: 0.0371 - val_sparse_c
ategorical_accuracy: 0.9884 - 21s/epoch - 44ms/step
Epoch 75/100
469/469 - 21s - loss: 0.0426 - sparse_categorical_accuracy: 0.9864 - val_loss: 0.0379 - val_sparse_c
ategorical_accuracy: 0.9885 - 21s/epoch - 44ms/step
Epoch 76/100
469/469 - 21s - loss: 0.0420 - sparse_categorical_accuracy: 0.9866 - val_loss: 0.0394 - val_sparse_c
ategorical_accuracy: 0.9883 - 21s/epoch - 44ms/step
Epoch 77/100
469/469 - 21s - loss: 0.0404 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0373 - val_sparse_c
ategorical_accuracy: 0.9888 - 21s/epoch - 44ms/step
Epoch 78/100
469/469 - 21s - loss: 0.0416 - sparse_categorical_accuracy: 0.9864 - val_loss: 0.0380 - val_sparse_c
ategorical_accuracy: 0.9888 - 21s/epoch - 44ms/step
Epoch 79/100
469/469 - 20s - loss: 0.0411 - sparse_categorical_accuracy: 0.9864 - val_loss: 0.0391 - val_sparse_c
ategorical_accuracy: 0.9883 - 20s/epoch - 43ms/step
Epoch 80/100
469/469 - 20s - loss: 0.0421 - sparse_categorical_accuracy: 0.9864 - val_loss: 0.0420 - val_sparse_c
ategorical_accuracy: 0.9873 - 20s/epoch - 44ms/step
Epoch 81/100
469/469 - 20s - loss: 0.0394 - sparse_categorical_accuracy: 0.9871 - val_loss: 0.0387 - val_sparse_c
ategorical_accuracy: 0.9881 - 20s/epoch - 44ms/step
Epoch 82/100
469/469 - 20s - loss: 0.0407 - sparse_categorical_accuracy: 0.9870 - val_loss: 0.0382 - val_sparse_c
ategorical_accuracy: 0.9890 - 20s/epoch - 44ms/step
Epoch 83/100
469/469 - 20s - loss: 0.0425 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0392 - val_sparse_c
ategorical_accuracy: 0.9880 - 20s/epoch - 44ms/step
Epoch 84/100
469/469 - 20s - loss: 0.0408 - sparse_categorical_accuracy: 0.9865 - val_loss: 0.0377 - val_sparse_c
ategorical_accuracy: 0.9883 - 20s/epoch - 44ms/step
Epoch 85/100
469/469 - 21s - loss: 0.0399 - sparse_categorical_accuracy: 0.9871 - val_loss: 0.0376 - val_sparse_c
ategorical_accuracy: 0.9889 - 21s/epoch - 44ms/step
Epoch 86/100
469/469 - 20s - loss: 0.0403 - sparse_categorical_accuracy: 0.9865 - val_loss: 0.0358 - val_sparse_c
ategorical_accuracy: 0.9892 - 20s/epoch - 44ms/step
Epoch 87/100
469/469 - 20s - loss: 0.0409 - sparse_categorical_accuracy: 0.9867 - val_loss: 0.0391 - val_sparse_c
ategorical_accuracy: 0.9875 - 20s/epoch - 44ms/step
Epoch 88/100
469/469 - 21s - loss: 0.0404 - sparse_categorical_accuracy: 0.9868 - val_loss: 0.0387 - val_sparse_c
ategorical_accuracy: 0.9877 - 21s/epoch - 44ms/step
Epoch 89/100
469/469 - 20s - loss: 0.0407 - sparse_categorical_accuracy: 0.9863 - val_loss: 0.0390 - val_sparse_c
ategorical_accuracy: 0.9879 - 20s/epoch - 44ms/step
```

```
Epoch 90/100
469/469 - 21s - loss: 0.0409 - sparse_categorical_accuracy: 0.9867 - val_loss: 0.0412 - val_sparse_c
ategorical_accuracy: 0.9882 - 21s/epoch - 44ms/step
Epoch 91/100
469/469 - 20s - loss: 0.0403 - sparse_categorical_accuracy: 0.9870 - val_loss: 0.0354 - val_sparse_c
ategorical_accuracy: 0.9890 - 20s/epoch - 44ms/step
Epoch 92/100
469/469 - 20s - loss: 0.0397 - sparse_categorical_accuracy: 0.9874 - val_loss: 0.0390 - val_sparse_c
ategorical_accuracy: 0.9885 - 20s/epoch - 44ms/step
Epoch 93/100
469/469 - 20s - loss: 0.0399 - sparse_categorical_accuracy: 0.9866 - val_loss: 0.0433 - val_sparse_c
ategorical_accuracy: 0.9868 - 20s/epoch - 44ms/step
Epoch 94/100
469/469 - 20s - loss: 0.0426 - sparse_categorical_accuracy: 0.9862 - val_loss: 0.0388 - val_sparse_c
ategorical_accuracy: 0.9880 - 20s/epoch - 44ms/step
Epoch 95/100
469/469 - 20s - loss: 0.0400 - sparse_categorical_accuracy: 0.9867 - val_loss: 0.0364 - val_sparse_c
ategorical_accuracy: 0.9894 - 20s/epoch - 44ms/step
Epoch 96/100
469/469 - 20s - loss: 0.0388 - sparse_categorical_accuracy: 0.9871 - val_loss: 0.0368 - val_sparse_c
ategorical_accuracy: 0.9889 - 20s/epoch - 44ms/step
Epoch 97/100
469/469 - 20s - loss: 0.0393 - sparse_categorical_accuracy: 0.9865 - val_loss: 0.0401 - val_sparse_c
ategorical_accuracy: 0.9873 - 20s/epoch - 44ms/step
Epoch 98/100
469/469 - 20s - loss: 0.0390 - sparse_categorical_accuracy: 0.9873 - val_loss: 0.0385 - val_sparse_c
ategorical_accuracy: 0.9883 - 20s/epoch - 44ms/step
Epoch 99/100
469/469 - 20s - loss: 0.0396 - sparse_categorical_accuracy: 0.9870 - val_loss: 0.0388 - val_sparse_c
ategorical_accuracy: 0.9880 - 20s/epoch - 43ms/step
Epoch 100/100
469/469 - 20s - loss: 0.0403 - sparse_categorical_accuracy: 0.9865 - val_loss: 0.0395 - val_sparse_c
ategorical_accuracy: 0.9884 - 20s/epoch - 44ms/step
```

Out[ ]:

```
<keras.callbacks.History at 0x7fdbbabd9f90>
```

In [ ]:

```
model4.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 2s - loss: 0.0395 - sparse_categorical_accuracy: 0.9884 - 2s/epoch - 5ms/step
```

Out[ ]:

```
[0.03949155658483505, 0.9883999824523926]
```

In [29]:

```

```

In [ ]:

```
model4.fit(fX_train, fY_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(fX_test, fY_test),
                    verbose=2
                    )
```

```
Epoch 1/100
469/469 - 20s - loss: 0.5184 - sparse_categorical_accuracy: 0.8169 - val_loss: 0.4610 - val_sparse_c
ategorical_accuracy: 0.8409 - 20s/epoch - 43ms/step
Epoch 2/100
469/469 - 20s - loss: 0.4838 - sparse_categorical_accuracy: 0.8287 - val_loss: 0.4361 - val_sparse_c
ategorical_accuracy: 0.8464 - 20s/epoch - 43ms/step
Epoch 3/100
469/469 - 20s - loss: 0.4565 - sparse_categorical_accuracy: 0.8365 - val_loss: 0.4158 - val_sparse_c
ategorical_accuracy: 0.8549 - 20s/epoch - 42ms/step
Epoch 4/100
469/469 - 20s - loss: 0.4305 - sparse_categorical_accuracy: 0.8463 - val_loss: 0.4075 - val_sparse_c
ategorical_accuracy: 0.8576 - 20s/epoch - 43ms/step
Epoch 5/100
469/469 - 20s - loss: 0.4183 - sparse_categorical_accuracy: 0.8492 - val_loss: 0.3949 - val_sparse_c
ategorical_accuracy: 0.8577 - 20s/epoch - 43ms/step
Epoch 6/100
469/469 - 20s - loss: 0.4025 - sparse_categorical_accuracy: 0.8554 - val_loss: 0.3862 - val_sparse_c
ategorical_accuracy: 0.8611 - 20s/epoch - 43ms/step
Epoch 7/100
469/469 - 20s - loss: 0.3985 - sparse_categorical_accuracy: 0.8576 - val_loss: 0.3727 - val_sparse_c
ategorical_accuracy: 0.8679 - 20s/epoch - 43ms/step
Epoch 8/100
469/469 - 20s - loss: 0.3864 - sparse_categorical_accuracy: 0.8599 - val_loss: 0.3701 - val_sparse_c
```

```
ategorical_accuracy: 0.8681 - 20s/epoch - 43ms/step
Epoch 9/100
469/469 - 20s - loss: 0.3822 - sparse_categorical_accuracy: 0.8624 - val_loss: 0.3582 - val_sparse_c
ategorical_accuracy: 0.8737 - 20s/epoch - 43ms/step
Epoch 10/100
469/469 - 20s - loss: 0.3747 - sparse_categorical_accuracy: 0.8637 - val_loss: 0.3555 - val_sparse_c
ategorical_accuracy: 0.8748 - 20s/epoch - 43ms/step
Epoch 11/100
469/469 - 20s - loss: 0.3692 - sparse_categorical_accuracy: 0.8667 - val_loss: 0.3509 - val_sparse_c
ategorical_accuracy: 0.8763 - 20s/epoch - 43ms/step
Epoch 12/100
469/469 - 20s - loss: 0.3652 - sparse_categorical_accuracy: 0.8679 - val_loss: 0.3552 - val_sparse_c
ategorical_accuracy: 0.8746 - 20s/epoch - 43ms/step
Epoch 13/100
469/469 - 20s - loss: 0.3626 - sparse_categorical_accuracy: 0.8687 - val_loss: 0.3524 - val_sparse_c
ategorical_accuracy: 0.8747 - 20s/epoch - 43ms/step
Epoch 14/100
469/469 - 20s - loss: 0.3548 - sparse_categorical_accuracy: 0.8722 - val_loss: 0.3438 - val_sparse_c
ategorical_accuracy: 0.8781 - 20s/epoch - 44ms/step
Epoch 15/100
469/469 - 20s - loss: 0.3535 - sparse_categorical_accuracy: 0.8715 - val_loss: 0.3411 - val_sparse_c
ategorical_accuracy: 0.8786 - 20s/epoch - 43ms/step
Epoch 16/100
469/469 - 20s - loss: 0.3491 - sparse_categorical_accuracy: 0.8733 - val_loss: 0.3346 - val_sparse_c
ategorical_accuracy: 0.8805 - 20s/epoch - 43ms/step
Epoch 17/100
469/469 - 20s - loss: 0.3478 - sparse_categorical_accuracy: 0.8723 - val_loss: 0.3316 - val_sparse_c
ategorical_accuracy: 0.8823 - 20s/epoch - 43ms/step
Epoch 18/100
469/469 - 20s - loss: 0.3451 - sparse_categorical_accuracy: 0.8749 - val_loss: 0.3406 - val_sparse_c
ategorical_accuracy: 0.8801 - 20s/epoch - 43ms/step
Epoch 19/100
469/469 - 20s - loss: 0.3398 - sparse_categorical_accuracy: 0.8770 - val_loss: 0.3411 - val_sparse_c
ategorical_accuracy: 0.8767 - 20s/epoch - 43ms/step
Epoch 20/100
469/469 - 20s - loss: 0.3386 - sparse_categorical_accuracy: 0.8781 - val_loss: 0.3299 - val_sparse_c
ategorical_accuracy: 0.8829 - 20s/epoch - 43ms/step
Epoch 21/100
469/469 - 20s - loss: 0.3356 - sparse_categorical_accuracy: 0.8769 - val_loss: 0.3299 - val_sparse_c
ategorical_accuracy: 0.8832 - 20s/epoch - 43ms/step
Epoch 22/100
469/469 - 20s - loss: 0.3356 - sparse_categorical_accuracy: 0.8763 - val_loss: 0.3310 - val_sparse_c
ategorical_accuracy: 0.8811 - 20s/epoch - 43ms/step
Epoch 23/100
469/469 - 20s - loss: 0.3307 - sparse_categorical_accuracy: 0.8796 - val_loss: 0.3271 - val_sparse_c
ategorical_accuracy: 0.8837 - 20s/epoch - 43ms/step
Epoch 24/100
469/469 - 20s - loss: 0.3293 - sparse_categorical_accuracy: 0.8781 - val_loss: 0.3231 - val_sparse_c
ategorical_accuracy: 0.8841 - 20s/epoch - 43ms/step
Epoch 25/100
469/469 - 20s - loss: 0.3281 - sparse_categorical_accuracy: 0.8791 - val_loss: 0.3201 - val_sparse_c
ategorical_accuracy: 0.8841 - 20s/epoch - 43ms/step
Epoch 26/100
469/469 - 20s - loss: 0.3277 - sparse_categorical_accuracy: 0.8802 - val_loss: 0.3194 - val_sparse_c
ategorical_accuracy: 0.8838 - 20s/epoch - 43ms/step
Epoch 27/100
469/469 - 20s - loss: 0.3260 - sparse_categorical_accuracy: 0.8793 - val_loss: 0.3183 - val_sparse_c
ategorical_accuracy: 0.8854 - 20s/epoch - 44ms/step
Epoch 28/100
469/469 - 20s - loss: 0.3232 - sparse_categorical_accuracy: 0.8812 - val_loss: 0.3164 - val_sparse_c
ategorical_accuracy: 0.8869 - 20s/epoch - 43ms/step
Epoch 29/100
469/469 - 20s - loss: 0.3209 - sparse_categorical_accuracy: 0.8813 - val_loss: 0.3193 - val_sparse_c
ategorical_accuracy: 0.8832 - 20s/epoch - 43ms/step
Epoch 30/100
469/469 - 20s - loss: 0.3215 - sparse_categorical_accuracy: 0.8825 - val_loss: 0.3176 - val_sparse_c
ategorical_accuracy: 0.8850 - 20s/epoch - 43ms/step
Epoch 31/100
469/469 - 20s - loss: 0.3179 - sparse_categorical_accuracy: 0.8831 - val_loss: 0.3203 - val_sparse_c
ategorical_accuracy: 0.8835 - 20s/epoch - 43ms/step
Epoch 32/100
469/469 - 20s - loss: 0.3168 - sparse_categorical_accuracy: 0.8835 - val_loss: 0.3129 - val_sparse_c
ategorical_accuracy: 0.8863 - 20s/epoch - 43ms/step
Epoch 33/100
469/469 - 20s - loss: 0.3166 - sparse_categorical_accuracy: 0.8841 - val_loss: 0.3120 - val_sparse_c
ategorical_accuracy: 0.8879 - 20s/epoch - 43ms/step
Epoch 34/100
469/469 - 20s - loss: 0.3152 - sparse_categorical_accuracy: 0.8858 - val_loss: 0.3086 - val_sparse_c
ategorical_accuracy: 0.8887 - 20s/epoch - 43ms/step
Epoch 35/100
469/469 - 20s - loss: 0.3157 - sparse_categorical_accuracy: 0.8837 - val_loss: 0.3077 - val_sparse_c
ategorical_accuracy: 0.8870 - 20s/epoch - 43ms/step
Epoch 36/100
```

```
469/469 - 20s - loss: 0.3126 - sparse_categorical_accuracy: 0.8837 - val_loss: 0.3132 - val_sparse_c
ategorical_accuracy: 0.8859 - 20s/epoch - 43ms/step
Epoch 37/100
469/469 - 20s - loss: 0.3132 - sparse_categorical_accuracy: 0.8847 - val_loss: 0.3103 - val_sparse_c
ategorical_accuracy: 0.8877 - 20s/epoch - 43ms/step
Epoch 38/100
469/469 - 20s - loss: 0.3083 - sparse_categorical_accuracy: 0.8873 - val_loss: 0.3141 - val_sparse_c
ategorical_accuracy: 0.8839 - 20s/epoch - 43ms/step
Epoch 39/100
469/469 - 20s - loss: 0.3091 - sparse_categorical_accuracy: 0.8856 - val_loss: 0.3100 - val_sparse_c
ategorical_accuracy: 0.8856 - 20s/epoch - 43ms/step
Epoch 40/100
469/469 - 20s - loss: 0.3109 - sparse_categorical_accuracy: 0.8848 - val_loss: 0.3126 - val_sparse_c
ategorical_accuracy: 0.8857 - 20s/epoch - 43ms/step
Epoch 41/100
469/469 - 20s - loss: 0.3079 - sparse_categorical_accuracy: 0.8864 - val_loss: 0.3077 - val_sparse_c
ategorical_accuracy: 0.8892 - 20s/epoch - 43ms/step
Epoch 42/100
469/469 - 20s - loss: 0.3051 - sparse_categorical_accuracy: 0.8875 - val_loss: 0.3024 - val_sparse_c
ategorical_accuracy: 0.8896 - 20s/epoch - 43ms/step
Epoch 43/100
469/469 - 20s - loss: 0.3074 - sparse_categorical_accuracy: 0.8862 - val_loss: 0.3033 - val_sparse_c
ategorical_accuracy: 0.8901 - 20s/epoch - 43ms/step
Epoch 44/100
469/469 - 20s - loss: 0.3043 - sparse_categorical_accuracy: 0.8882 - val_loss: 0.3055 - val_sparse_c
ategorical_accuracy: 0.8882 - 20s/epoch - 43ms/step
Epoch 45/100
469/469 - 20s - loss: 0.3057 - sparse_categorical_accuracy: 0.8862 - val_loss: 0.3030 - val_sparse_c
ategorical_accuracy: 0.8895 - 20s/epoch - 43ms/step
Epoch 46/100
469/469 - 20s - loss: 0.3021 - sparse_categorical_accuracy: 0.8888 - val_loss: 0.3020 - val_sparse_c
ategorical_accuracy: 0.8914 - 20s/epoch - 43ms/step
Epoch 47/100
469/469 - 20s - loss: 0.3020 - sparse_categorical_accuracy: 0.8885 - val_loss: 0.3031 - val_sparse_c
ategorical_accuracy: 0.8904 - 20s/epoch - 43ms/step
Epoch 48/100
469/469 - 20s - loss: 0.3018 - sparse_categorical_accuracy: 0.8889 - val_loss: 0.3100 - val_sparse_c
ategorical_accuracy: 0.8880 - 20s/epoch - 43ms/step
Epoch 49/100
469/469 - 20s - loss: 0.3023 - sparse_categorical_accuracy: 0.8877 - val_loss: 0.3002 - val_sparse_c
ategorical_accuracy: 0.8916 - 20s/epoch - 43ms/step
Epoch 50/100
469/469 - 20s - loss: 0.2991 - sparse_categorical_accuracy: 0.8895 - val_loss: 0.2997 - val_sparse_c
ategorical_accuracy: 0.8905 - 20s/epoch - 43ms/step
Epoch 51/100
469/469 - 20s - loss: 0.3001 - sparse_categorical_accuracy: 0.8899 - val_loss: 0.3022 - val_sparse_c
ategorical_accuracy: 0.8927 - 20s/epoch - 43ms/step
Epoch 52/100
469/469 - 20s - loss: 0.2968 - sparse_categorical_accuracy: 0.8906 - val_loss: 0.3046 - val_sparse_c
ategorical_accuracy: 0.8893 - 20s/epoch - 43ms/step
Epoch 53/100
469/469 - 20s - loss: 0.2959 - sparse_categorical_accuracy: 0.8901 - val_loss: 0.2983 - val_sparse_c
ategorical_accuracy: 0.8906 - 20s/epoch - 43ms/step
Epoch 54/100
469/469 - 20s - loss: 0.2989 - sparse_categorical_accuracy: 0.8894 - val_loss: 0.3038 - val_sparse_c
ategorical_accuracy: 0.8884 - 20s/epoch - 43ms/step
Epoch 55/100
469/469 - 20s - loss: 0.2973 - sparse_categorical_accuracy: 0.8895 - val_loss: 0.2991 - val_sparse_c
ategorical_accuracy: 0.8925 - 20s/epoch - 43ms/step
Epoch 56/100
469/469 - 20s - loss: 0.2974 - sparse_categorical_accuracy: 0.8896 - val_loss: 0.2977 - val_sparse_c
ategorical_accuracy: 0.8926 - 20s/epoch - 43ms/step
Epoch 57/100
469/469 - 20s - loss: 0.2943 - sparse_categorical_accuracy: 0.8909 - val_loss: 0.3008 - val_sparse_c
ategorical_accuracy: 0.8900 - 20s/epoch - 43ms/step
Epoch 58/100
469/469 - 20s - loss: 0.2954 - sparse_categorical_accuracy: 0.8898 - val_loss: 0.3030 - val_sparse_c
ategorical_accuracy: 0.8880 - 20s/epoch - 43ms/step
Epoch 59/100
469/469 - 20s - loss: 0.2952 - sparse_categorical_accuracy: 0.8909 - val_loss: 0.2939 - val_sparse_c
ategorical_accuracy: 0.8925 - 20s/epoch - 43ms/step
Epoch 60/100
469/469 - 20s - loss: 0.2934 - sparse_categorical_accuracy: 0.8906 - val_loss: 0.2953 - val_sparse_c
ategorical_accuracy: 0.8933 - 20s/epoch - 43ms/step
Epoch 61/100
469/469 - 20s - loss: 0.2937 - sparse_categorical_accuracy: 0.8922 - val_loss: 0.3009 - val_sparse_c
ategorical_accuracy: 0.8902 - 20s/epoch - 43ms/step
Epoch 62/100
469/469 - 20s - loss: 0.2939 - sparse_categorical_accuracy: 0.8901 - val_loss: 0.2947 - val_sparse_c
ategorical_accuracy: 0.8936 - 20s/epoch - 43ms/step
Epoch 63/100
469/469 - 20s - loss: 0.2941 - sparse_categorical_accuracy: 0.8908 - val_loss: 0.3052 - val_sparse_c
ategorical_accuracy: 0.8881 - 20s/epoch - 43ms/step
```

```
Epoch 64/100
469/469 - 20s - loss: 0.2923 - sparse_categorical_accuracy: 0.8919 - val_loss: 0.2955 - val_sparse_c
ategorical_accuracy: 0.8921 - 20s/epoch - 43ms/step
Epoch 65/100
469/469 - 20s - loss: 0.2913 - sparse_categorical_accuracy: 0.8921 - val_loss: 0.2914 - val_sparse_c
ategorical_accuracy: 0.8931 - 20s/epoch - 43ms/step
Epoch 66/100
469/469 - 20s - loss: 0.2907 - sparse_categorical_accuracy: 0.8924 - val_loss: 0.2998 - val_sparse_c
ategorical_accuracy: 0.8921 - 20s/epoch - 43ms/step
Epoch 67/100
469/469 - 20s - loss: 0.2913 - sparse_categorical_accuracy: 0.8931 - val_loss: 0.2961 - val_sparse_c
ategorical_accuracy: 0.8918 - 20s/epoch - 43ms/step
Epoch 68/100
469/469 - 20s - loss: 0.2917 - sparse_categorical_accuracy: 0.8919 - val_loss: 0.2917 - val_sparse_c
ategorical_accuracy: 0.8947 - 20s/epoch - 43ms/step
Epoch 69/100
469/469 - 20s - loss: 0.2919 - sparse_categorical_accuracy: 0.8912 - val_loss: 0.2929 - val_sparse_c
ategorical_accuracy: 0.8927 - 20s/epoch - 43ms/step
Epoch 70/100
469/469 - 20s - loss: 0.2891 - sparse_categorical_accuracy: 0.8933 - val_loss: 0.2914 - val_sparse_c
ategorical_accuracy: 0.8950 - 20s/epoch - 43ms/step
Epoch 71/100
469/469 - 20s - loss: 0.2889 - sparse_categorical_accuracy: 0.8945 - val_loss: 0.2937 - val_sparse_c
ategorical_accuracy: 0.8944 - 20s/epoch - 43ms/step
Epoch 72/100
469/469 - 20s - loss: 0.2894 - sparse_categorical_accuracy: 0.8944 - val_loss: 0.2914 - val_sparse_c
ategorical_accuracy: 0.8938 - 20s/epoch - 43ms/step
Epoch 73/100
469/469 - 20s - loss: 0.2907 - sparse_categorical_accuracy: 0.8912 - val_loss: 0.2955 - val_sparse_c
ategorical_accuracy: 0.8934 - 20s/epoch - 43ms/step
Epoch 74/100
469/469 - 20s - loss: 0.2898 - sparse_categorical_accuracy: 0.8937 - val_loss: 0.2908 - val_sparse_c
ategorical_accuracy: 0.8919 - 20s/epoch - 43ms/step
Epoch 75/100
469/469 - 20s - loss: 0.2886 - sparse_categorical_accuracy: 0.8931 - val_loss: 0.2964 - val_sparse_c
ategorical_accuracy: 0.8906 - 20s/epoch - 43ms/step
Epoch 76/100
469/469 - 20s - loss: 0.2867 - sparse_categorical_accuracy: 0.8938 - val_loss: 0.2961 - val_sparse_c
ategorical_accuracy: 0.8916 - 20s/epoch - 43ms/step
Epoch 77/100
469/469 - 20s - loss: 0.2872 - sparse_categorical_accuracy: 0.8929 - val_loss: 0.2899 - val_sparse_c
ategorical_accuracy: 0.8970 - 20s/epoch - 43ms/step
Epoch 78/100
469/469 - 20s - loss: 0.2886 - sparse_categorical_accuracy: 0.8939 - val_loss: 0.2909 - val_sparse_c
ategorical_accuracy: 0.8931 - 20s/epoch - 43ms/step
Epoch 79/100
469/469 - 20s - loss: 0.2841 - sparse_categorical_accuracy: 0.8950 - val_loss: 0.2911 - val_sparse_c
ategorical_accuracy: 0.8941 - 20s/epoch - 43ms/step
Epoch 80/100
469/469 - 20s - loss: 0.2875 - sparse_categorical_accuracy: 0.8939 - val_loss: 0.2936 - val_sparse_c
ategorical_accuracy: 0.8937 - 20s/epoch - 43ms/step
Epoch 81/100
469/469 - 20s - loss: 0.2852 - sparse_categorical_accuracy: 0.8941 - val_loss: 0.2920 - val_sparse_c
ategorical_accuracy: 0.8938 - 20s/epoch - 43ms/step
Epoch 82/100
469/469 - 20s - loss: 0.2867 - sparse_categorical_accuracy: 0.8940 - val_loss: 0.2868 - val_sparse_c
ategorical_accuracy: 0.8939 - 20s/epoch - 43ms/step
Epoch 83/100
469/469 - 20s - loss: 0.2846 - sparse_categorical_accuracy: 0.8942 - val_loss: 0.2886 - val_sparse_c
ategorical_accuracy: 0.8957 - 20s/epoch - 43ms/step
Epoch 84/100
469/469 - 20s - loss: 0.2878 - sparse_categorical_accuracy: 0.8931 - val_loss: 0.2878 - val_sparse_c
ategorical_accuracy: 0.8963 - 20s/epoch - 43ms/step
Epoch 85/100
469/469 - 20s - loss: 0.2853 - sparse_categorical_accuracy: 0.8950 - val_loss: 0.2924 - val_sparse_c
ategorical_accuracy: 0.8945 - 20s/epoch - 43ms/step
Epoch 86/100
469/469 - 20s - loss: 0.2849 - sparse_categorical_accuracy: 0.8947 - val_loss: 0.2886 - val_sparse_c
ategorical_accuracy: 0.8957 - 20s/epoch - 43ms/step
Epoch 87/100
469/469 - 21s - loss: 0.2876 - sparse_categorical_accuracy: 0.8932 - val_loss: 0.2934 - val_sparse_c
ategorical_accuracy: 0.8909 - 21s/epoch - 44ms/step
Epoch 88/100
469/469 - 21s - loss: 0.2855 - sparse_categorical_accuracy: 0.8940 - val_loss: 0.2904 - val_sparse_c
ategorical_accuracy: 0.8948 - 21s/epoch - 44ms/step
Epoch 89/100
469/469 - 20s - loss: 0.2843 - sparse_categorical_accuracy: 0.8947 - val_loss: 0.2897 - val_sparse_c
ategorical_accuracy: 0.8934 - 20s/epoch - 44ms/step
Epoch 90/100
469/469 - 20s - loss: 0.2835 - sparse_categorical_accuracy: 0.8951 - val_loss: 0.2873 - val_sparse_c
ategorical_accuracy: 0.8951 - 20s/epoch - 43ms/step
Epoch 91/100
469/469 - 20s - loss: 0.2841 - sparse_categorical_accuracy: 0.8958 - val_loss: 0.2862 - val_sparse_c
```

```
ategorical_accuracy: 0.8953 - 20s/epoch - 43ms/step
Epoch 92/100
469/469 - 20s - loss: 0.2827 - sparse_categorical_accuracy: 0.8953 - val_loss: 0.2890 - val_sparse_c
ategorical_accuracy: 0.8930 - 20s/epoch - 44ms/step
Epoch 93/100
469/469 - 21s - loss: 0.2840 - sparse_categorical_accuracy: 0.8943 - val_loss: 0.2878 - val_sparse_c
ategorical_accuracy: 0.8931 - 21s/epoch - 44ms/step
Epoch 94/100
469/469 - 21s - loss: 0.2860 - sparse_categorical_accuracy: 0.8932 - val_loss: 0.2865 - val_sparse_c
ategorical_accuracy: 0.8959 - 21s/epoch - 45ms/step
Epoch 95/100
469/469 - 21s - loss: 0.2827 - sparse_categorical_accuracy: 0.8943 - val_loss: 0.2935 - val_sparse_c
ategorical_accuracy: 0.8920 - 21s/epoch - 44ms/step
Epoch 96/100
469/469 - 21s - loss: 0.2840 - sparse_categorical_accuracy: 0.8952 - val_loss: 0.2866 - val_sparse_c
ategorical_accuracy: 0.8940 - 21s/epoch - 44ms/step
Epoch 97/100
469/469 - 20s - loss: 0.2833 - sparse_categorical_accuracy: 0.8963 - val_loss: 0.2855 - val_sparse_c
ategorical_accuracy: 0.8952 - 20s/epoch - 44ms/step
Epoch 98/100
469/469 - 20s - loss: 0.2819 - sparse_categorical_accuracy: 0.8955 - val_loss: 0.2915 - val_sparse_c
ategorical_accuracy: 0.8924 - 20s/epoch - 43ms/step
Epoch 99/100
469/469 - 20s - loss: 0.2845 - sparse_categorical_accuracy: 0.8953 - val_loss: 0.2882 - val_sparse_c
ategorical_accuracy: 0.8957 - 20s/epoch - 43ms/step
Epoch 100/100
469/469 - 20s - loss: 0.2825 - sparse_categorical_accuracy: 0.8945 - val_loss: 0.2872 - val_sparse_c
ategorical_accuracy: 0.8946 - 20s/epoch - 43ms/step
```

Out[ ]:

```
<keras.callbacks.History at 0x7fdbae173d10>
```

In [ ]:

```
model4.evaluate(fX_test, fY_test, verbose=2)
```

```
313/313 - 1s - loss: 0.2872 - sparse_categorical_accuracy: 0.8946 - 1s/epoch - 5ms/step
```

Out[ ]:

```
[0.28716278076171875, 0.894599974155426]
```

In [ ]:

```
# Baseline model on the fashion-MNIST dataset
model.fit(fX_train, fY_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(fX_test, fY_test),
                    verbose=2
                    )
```

```
Epoch 1/100
469/469 - 1s - loss: 1.8499 - sparse_categorical_accuracy: 0.4328 - val_loss: 1.0754 - val_sparse_ca
tegorical_accuracy: 0.5513 - 1s/epoch - 3ms/step
Epoch 2/100
469/469 - 1s - loss: 1.0193 - sparse_categorical_accuracy: 0.5770 - val_loss: 0.9641 - val_sparse_ca
tegorical_accuracy: 0.6292 - 1s/epoch - 2ms/step
Epoch 3/100
469/469 - 1s - loss: 0.8854 - sparse_categorical_accuracy: 0.6426 - val_loss: 0.8783 - val_sparse_ca
tegorical_accuracy: 0.6497 - 1s/epoch - 3ms/step
Epoch 4/100
469/469 - 1s - loss: 0.8123 - sparse_categorical_accuracy: 0.6738 - val_loss: 0.8451 - val_sparse_ca
tegorical_accuracy: 0.6735 - 1s/epoch - 2ms/step
Epoch 5/100
469/469 - 1s - loss: 0.7706 - sparse_categorical_accuracy: 0.6904 - val_loss: 0.7684 - val_sparse_ca
tegorical_accuracy: 0.6999 - 1s/epoch - 2ms/step
Epoch 6/100
469/469 - 1s - loss: 0.7424 - sparse_categorical_accuracy: 0.6999 - val_loss: 0.7578 - val_sparse_ca
tegorical_accuracy: 0.6978 - 1s/epoch - 2ms/step
Epoch 7/100
469/469 - 1s - loss: 0.7227 - sparse_categorical_accuracy: 0.7078 - val_loss: 0.7380 - val_sparse_ca
tegorical_accuracy: 0.7091 - 1s/epoch - 3ms/step
Epoch 8/100
469/469 - 1s - loss: 0.7048 - sparse_categorical_accuracy: 0.7144 - val_loss: 0.7255 - val_sparse_ca
tegorical_accuracy: 0.7097 - 1s/epoch - 2ms/step
Epoch 9/100
469/469 - 1s - loss: 0.6928 - sparse_categorical_accuracy: 0.7178 - val_loss: 0.7122 - val_sparse_ca
tegorical_accuracy: 0.7132 - 1s/epoch - 3ms/step
Epoch 10/100
469/469 - 1s - loss: 0.6832 - sparse_categorical_accuracy: 0.7186 - val_loss: 0.7159 - val_sparse_ca
tegorical_accuracy: 0.7119 - 1s/epoch - 3ms/step
Epoch 11/100
469/469 - 1s - loss: 0.6749 - sparse_categorical_accuracy: 0.7239 - val_loss: 0.7048 - val_sparse_ca
```

```
tegorical_accuracy: 0.7153 - 1s/epoch - 3ms/step
Epoch 12/100
469/469 - 1s - loss: 0.6701 - sparse_categorical_accuracy: 0.7249 - val_loss: 0.7161 - val_sparse_ca
tegorical_accuracy: 0.7178 - 1s/epoch - 3ms/step
Epoch 13/100
469/469 - 1s - loss: 0.6586 - sparse_categorical_accuracy: 0.7270 - val_loss: 0.6732 - val_sparse_ca
tegorical_accuracy: 0.7245 - 1s/epoch - 3ms/step
Epoch 14/100
469/469 - 1s - loss: 0.6416 - sparse_categorical_accuracy: 0.7322 - val_loss: 0.6809 - val_sparse_ca
tegorical_accuracy: 0.7255 - 1s/epoch - 3ms/step
Epoch 15/100
469/469 - 1s - loss: 0.6123 - sparse_categorical_accuracy: 0.7459 - val_loss: 0.6315 - val_sparse_ca
tegorical_accuracy: 0.7446 - 1s/epoch - 3ms/step
Epoch 16/100
469/469 - 1s - loss: 0.5882 - sparse_categorical_accuracy: 0.7559 - val_loss: 0.6005 - val_sparse_ca
tegorical_accuracy: 0.7580 - 1s/epoch - 2ms/step
Epoch 17/100
469/469 - 1s - loss: 0.5730 - sparse_categorical_accuracy: 0.7640 - val_loss: 0.5980 - val_sparse_ca
tegorical_accuracy: 0.7607 - 1s/epoch - 2ms/step
Epoch 18/100
469/469 - 1s - loss: 0.5651 - sparse_categorical_accuracy: 0.7678 - val_loss: 0.5876 - val_sparse_ca
tegorical_accuracy: 0.7641 - 1s/epoch - 3ms/step
Epoch 19/100
469/469 - 1s - loss: 0.5594 - sparse_categorical_accuracy: 0.7739 - val_loss: 0.5804 - val_sparse_ca
tegorical_accuracy: 0.7610 - 1s/epoch - 3ms/step
Epoch 20/100
469/469 - 1s - loss: 0.5497 - sparse_categorical_accuracy: 0.7784 - val_loss: 0.5865 - val_sparse_ca
tegorical_accuracy: 0.7643 - 1s/epoch - 3ms/step
Epoch 21/100
469/469 - 1s - loss: 0.5407 - sparse_categorical_accuracy: 0.7821 - val_loss: 0.5755 - val_sparse_ca
tegorical_accuracy: 0.7661 - 1s/epoch - 2ms/step
Epoch 22/100
469/469 - 1s - loss: 0.5308 - sparse_categorical_accuracy: 0.7870 - val_loss: 0.5625 - val_sparse_ca
tegorical_accuracy: 0.7771 - 1s/epoch - 2ms/step
Epoch 23/100
469/469 - 1s - loss: 0.5226 - sparse_categorical_accuracy: 0.7929 - val_loss: 0.5668 - val_sparse_ca
tegorical_accuracy: 0.7775 - 1s/epoch - 3ms/step
Epoch 24/100
469/469 - 1s - loss: 0.5145 - sparse_categorical_accuracy: 0.7996 - val_loss: 0.5586 - val_sparse_ca
tegorical_accuracy: 0.7880 - 1s/epoch - 3ms/step
Epoch 25/100
469/469 - 1s - loss: 0.5099 - sparse_categorical_accuracy: 0.8020 - val_loss: 0.5626 - val_sparse_ca
tegorical_accuracy: 0.7907 - 1s/epoch - 3ms/step
Epoch 26/100
469/469 - 1s - loss: 0.4996 - sparse_categorical_accuracy: 0.8058 - val_loss: 0.5489 - val_sparse_ca
tegorical_accuracy: 0.7933 - 1s/epoch - 3ms/step
Epoch 27/100
469/469 - 1s - loss: 0.5003 - sparse_categorical_accuracy: 0.8073 - val_loss: 0.5445 - val_sparse_ca
tegorical_accuracy: 0.7925 - 1s/epoch - 3ms/step
Epoch 28/100
469/469 - 1s - loss: 0.4901 - sparse_categorical_accuracy: 0.8079 - val_loss: 0.5384 - val_sparse_ca
tegorical_accuracy: 0.7958 - 1s/epoch - 3ms/step
Epoch 29/100
469/469 - 1s - loss: 0.4855 - sparse_categorical_accuracy: 0.8109 - val_loss: 0.5441 - val_sparse_ca
tegorical_accuracy: 0.7939 - 1s/epoch - 3ms/step
Epoch 30/100
469/469 - 1s - loss: 0.4807 - sparse_categorical_accuracy: 0.8107 - val_loss: 0.5336 - val_sparse_ca
tegorical_accuracy: 0.7951 - 1s/epoch - 3ms/step
Epoch 31/100
469/469 - 1s - loss: 0.4793 - sparse_categorical_accuracy: 0.8113 - val_loss: 0.5440 - val_sparse_ca
tegorical_accuracy: 0.7920 - 1s/epoch - 2ms/step
Epoch 32/100
469/469 - 1s - loss: 0.4816 - sparse_categorical_accuracy: 0.8124 - val_loss: 0.5277 - val_sparse_ca
tegorical_accuracy: 0.8033 - 1s/epoch - 2ms/step
Epoch 33/100
469/469 - 1s - loss: 0.4667 - sparse_categorical_accuracy: 0.8180 - val_loss: 0.5205 - val_sparse_ca
tegorical_accuracy: 0.8033 - 1s/epoch - 3ms/step
Epoch 34/100
469/469 - 1s - loss: 0.4615 - sparse_categorical_accuracy: 0.8226 - val_loss: 0.5184 - val_sparse_ca
tegorical_accuracy: 0.8059 - 1s/epoch - 3ms/step
Epoch 35/100
469/469 - 1s - loss: 0.4574 - sparse_categorical_accuracy: 0.8239 - val_loss: 0.5207 - val_sparse_ca
tegorical_accuracy: 0.8049 - 1s/epoch - 3ms/step
Epoch 36/100
469/469 - 1s - loss: 0.4571 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.5276 - val_sparse_ca
tegorical_accuracy: 0.8036 - 1s/epoch - 3ms/step
Epoch 37/100
469/469 - 1s - loss: 0.4528 - sparse_categorical_accuracy: 0.8299 - val_loss: 0.5194 - val_sparse_ca
tegorical_accuracy: 0.8062 - 1s/epoch - 3ms/step
Epoch 38/100
469/469 - 1s - loss: 0.4514 - sparse_categorical_accuracy: 0.8320 - val_loss: 0.5104 - val_sparse_ca
tegorical_accuracy: 0.8171 - 1s/epoch - 3ms/step
Epoch 39/100
```

```
469/469 - 1s - loss: 0.4466 - sparse_categorical_accuracy: 0.8344 - val_loss: 0.5150 - val_sparse_ca
tegorical_accuracy: 0.8134 - 1s/epoch - 3ms/step
Epoch 40/100
469/469 - 1s - loss: 0.4438 - sparse_categorical_accuracy: 0.8361 - val_loss: 0.5055 - val_sparse_ca
tegorical_accuracy: 0.8168 - 1s/epoch - 3ms/step
Epoch 41/100
469/469 - 1s - loss: 0.4364 - sparse_categorical_accuracy: 0.8396 - val_loss: 0.5029 - val_sparse_ca
tegorical_accuracy: 0.8179 - 1s/epoch - 3ms/step
Epoch 42/100
469/469 - 1s - loss: 0.4338 - sparse_categorical_accuracy: 0.8398 - val_loss: 0.5151 - val_sparse_ca
tegorical_accuracy: 0.8167 - 1s/epoch - 3ms/step
Epoch 43/100
469/469 - 1s - loss: 0.4363 - sparse_categorical_accuracy: 0.8386 - val_loss: 0.5086 - val_sparse_ca
tegorical_accuracy: 0.8160 - 1s/epoch - 2ms/step
Epoch 44/100
469/469 - 1s - loss: 0.4340 - sparse_categorical_accuracy: 0.8409 - val_loss: 0.5270 - val_sparse_ca
tegorical_accuracy: 0.8141 - 1s/epoch - 2ms/step
Epoch 45/100
469/469 - 1s - loss: 0.4284 - sparse_categorical_accuracy: 0.8422 - val_loss: 0.5106 - val_sparse_ca
tegorical_accuracy: 0.8165 - 1s/epoch - 3ms/step
Epoch 46/100
469/469 - 1s - loss: 0.4310 - sparse_categorical_accuracy: 0.8406 - val_loss: 0.5037 - val_sparse_ca
tegorical_accuracy: 0.8211 - 1s/epoch - 3ms/step
Epoch 47/100
469/469 - 1s - loss: 0.4263 - sparse_categorical_accuracy: 0.8434 - val_loss: 0.4985 - val_sparse_ca
tegorical_accuracy: 0.8209 - 1s/epoch - 3ms/step
Epoch 48/100
469/469 - 1s - loss: 0.4217 - sparse_categorical_accuracy: 0.8448 - val_loss: 0.5028 - val_sparse_ca
tegorical_accuracy: 0.8260 - 1s/epoch - 3ms/step
Epoch 49/100
469/469 - 1s - loss: 0.4213 - sparse_categorical_accuracy: 0.8461 - val_loss: 0.4961 - val_sparse_ca
tegorical_accuracy: 0.8246 - 1s/epoch - 3ms/step
Epoch 50/100
469/469 - 1s - loss: 0.4188 - sparse_categorical_accuracy: 0.8457 - val_loss: 0.4952 - val_sparse_ca
tegorical_accuracy: 0.8211 - 1s/epoch - 3ms/step
Epoch 51/100
469/469 - 1s - loss: 0.4131 - sparse_categorical_accuracy: 0.8481 - val_loss: 0.5261 - val_sparse_ca
tegorical_accuracy: 0.8135 - 1s/epoch - 3ms/step
Epoch 52/100
469/469 - 1s - loss: 0.4142 - sparse_categorical_accuracy: 0.8490 - val_loss: 0.5010 - val_sparse_ca
tegorical_accuracy: 0.8241 - 1s/epoch - 3ms/step
Epoch 53/100
469/469 - 1s - loss: 0.4122 - sparse_categorical_accuracy: 0.8495 - val_loss: 0.5018 - val_sparse_ca
tegorical_accuracy: 0.8213 - 1s/epoch - 2ms/step
Epoch 54/100
469/469 - 1s - loss: 0.4149 - sparse_categorical_accuracy: 0.8477 - val_loss: 0.4850 - val_sparse_ca
tegorical_accuracy: 0.8303 - 1s/epoch - 2ms/step
Epoch 55/100
469/469 - 1s - loss: 0.4097 - sparse_categorical_accuracy: 0.8509 - val_loss: 0.4851 - val_sparse_ca
tegorical_accuracy: 0.8306 - 1s/epoch - 2ms/step
Epoch 56/100
469/469 - 1s - loss: 0.4083 - sparse_categorical_accuracy: 0.8503 - val_loss: 0.5109 - val_sparse_ca
tegorical_accuracy: 0.8219 - 1s/epoch - 2ms/step
Epoch 57/100
469/469 - 1s - loss: 0.4052 - sparse_categorical_accuracy: 0.8533 - val_loss: 0.4819 - val_sparse_ca
tegorical_accuracy: 0.8302 - 1s/epoch - 2ms/step
Epoch 58/100
469/469 - 1s - loss: 0.4043 - sparse_categorical_accuracy: 0.8532 - val_loss: 0.4942 - val_sparse_ca
tegorical_accuracy: 0.8214 - 1s/epoch - 2ms/step
Epoch 59/100
469/469 - 1s - loss: 0.3998 - sparse_categorical_accuracy: 0.8535 - val_loss: 0.4862 - val_sparse_ca
tegorical_accuracy: 0.8306 - 1s/epoch - 2ms/step
Epoch 60/100
469/469 - 1s - loss: 0.4018 - sparse_categorical_accuracy: 0.8536 - val_loss: 0.4898 - val_sparse_ca
tegorical_accuracy: 0.8303 - 1s/epoch - 2ms/step
Epoch 61/100
469/469 - 1s - loss: 0.4018 - sparse_categorical_accuracy: 0.8551 - val_loss: 0.4935 - val_sparse_ca
tegorical_accuracy: 0.8307 - 1s/epoch - 2ms/step
Epoch 62/100
469/469 - 1s - loss: 0.4015 - sparse_categorical_accuracy: 0.8543 - val_loss: 0.4910 - val_sparse_ca
tegorical_accuracy: 0.8342 - 1s/epoch - 2ms/step
Epoch 63/100
469/469 - 1s - loss: 0.3984 - sparse_categorical_accuracy: 0.8558 - val_loss: 0.4880 - val_sparse_ca
tegorical_accuracy: 0.8324 - 1s/epoch - 2ms/step
Epoch 64/100
469/469 - 1s - loss: 0.3954 - sparse_categorical_accuracy: 0.8563 - val_loss: 0.4945 - val_sparse_ca
tegorical_accuracy: 0.8268 - 1s/epoch - 2ms/step
Epoch 65/100
469/469 - 1s - loss: 0.3905 - sparse_categorical_accuracy: 0.8597 - val_loss: 0.4978 - val_sparse_ca
tegorical_accuracy: 0.8326 - 1s/epoch - 2ms/step
Epoch 66/100
469/469 - 1s - loss: 0.3955 - sparse_categorical_accuracy: 0.8580 - val_loss: 0.4937 - val_sparse_ca
tegorical_accuracy: 0.8298 - 1s/epoch - 2ms/step
```

```
Epoch 67/100
469/469 - 1s - loss: 0.3937 - sparse_categorical_accuracy: 0.8594 - val_loss: 0.4938 - val_sparse_ca
tegorical_accuracy: 0.8308 - 1s/epoch - 2ms/step
Epoch 68/100
469/469 - 1s - loss: 0.3909 - sparse_categorical_accuracy: 0.8586 - val_loss: 0.4811 - val_sparse_ca
tegorical_accuracy: 0.8357 - 1s/epoch - 2ms/step
Epoch 69/100
469/469 - 1s - loss: 0.3900 - sparse_categorical_accuracy: 0.8586 - val_loss: 0.5024 - val_sparse_ca
tegorical_accuracy: 0.8284 - 1s/epoch - 2ms/step
Epoch 70/100
469/469 - 1s - loss: 0.3873 - sparse_categorical_accuracy: 0.8594 - val_loss: 0.4890 - val_sparse_ca
tegorical_accuracy: 0.8302 - 1s/epoch - 2ms/step
Epoch 71/100
469/469 - 1s - loss: 0.3885 - sparse_categorical_accuracy: 0.8600 - val_loss: 0.4863 - val_sparse_ca
tegorical_accuracy: 0.8333 - 1s/epoch - 2ms/step
Epoch 72/100
469/469 - 1s - loss: 0.3843 - sparse_categorical_accuracy: 0.8607 - val_loss: 0.4839 - val_sparse_ca
tegorical_accuracy: 0.8358 - 1s/epoch - 2ms/step
Epoch 73/100
469/469 - 1s - loss: 0.3844 - sparse_categorical_accuracy: 0.8625 - val_loss: 0.4923 - val_sparse_ca
tegorical_accuracy: 0.8320 - 1s/epoch - 2ms/step
Epoch 74/100
469/469 - 1s - loss: 0.3828 - sparse_categorical_accuracy: 0.8620 - val_loss: 0.4854 - val_sparse_ca
tegorical_accuracy: 0.8334 - 1s/epoch - 2ms/step
Epoch 75/100
469/469 - 1s - loss: 0.3844 - sparse_categorical_accuracy: 0.8619 - val_loss: 0.4887 - val_sparse_ca
tegorical_accuracy: 0.8322 - 1s/epoch - 2ms/step
Epoch 76/100
469/469 - 1s - loss: 0.3836 - sparse_categorical_accuracy: 0.8615 - val_loss: 0.4967 - val_sparse_ca
tegorical_accuracy: 0.8353 - 1s/epoch - 3ms/step
Epoch 77/100
469/469 - 1s - loss: 0.3801 - sparse_categorical_accuracy: 0.8629 - val_loss: 0.4978 - val_sparse_ca
tegorical_accuracy: 0.8317 - 1s/epoch - 2ms/step
Epoch 78/100
469/469 - 1s - loss: 0.3783 - sparse_categorical_accuracy: 0.8635 - val_loss: 0.4863 - val_sparse_ca
tegorical_accuracy: 0.8369 - 1s/epoch - 2ms/step
Epoch 79/100
469/469 - 1s - loss: 0.3842 - sparse_categorical_accuracy: 0.8622 - val_loss: 0.4828 - val_sparse_ca
tegorical_accuracy: 0.8345 - 1s/epoch - 2ms/step
Epoch 80/100
469/469 - 1s - loss: 0.3780 - sparse_categorical_accuracy: 0.8643 - val_loss: 0.4827 - val_sparse_ca
tegorical_accuracy: 0.8360 - 1s/epoch - 2ms/step
Epoch 81/100
469/469 - 1s - loss: 0.3768 - sparse_categorical_accuracy: 0.8650 - val_loss: 0.4761 - val_sparse_ca
tegorical_accuracy: 0.8375 - 1s/epoch - 2ms/step
Epoch 82/100
469/469 - 1s - loss: 0.3761 - sparse_categorical_accuracy: 0.8649 - val_loss: 0.4777 - val_sparse_ca
tegorical_accuracy: 0.8394 - 1s/epoch - 2ms/step
Epoch 83/100
469/469 - 1s - loss: 0.3769 - sparse_categorical_accuracy: 0.8631 - val_loss: 0.4934 - val_sparse_ca
tegorical_accuracy: 0.8364 - 1s/epoch - 2ms/step
Epoch 84/100
469/469 - 1s - loss: 0.3783 - sparse_categorical_accuracy: 0.8639 - val_loss: 0.4828 - val_sparse_ca
tegorical_accuracy: 0.8304 - 1s/epoch - 2ms/step
Epoch 85/100
469/469 - 1s - loss: 0.3762 - sparse_categorical_accuracy: 0.8645 - val_loss: 0.4968 - val_sparse_ca
tegorical_accuracy: 0.8335 - 1s/epoch - 3ms/step
Epoch 86/100
469/469 - 1s - loss: 0.3744 - sparse_categorical_accuracy: 0.8658 - val_loss: 0.4965 - val_sparse_ca
tegorical_accuracy: 0.8357 - 1s/epoch - 2ms/step
Epoch 87/100
469/469 - 1s - loss: 0.3794 - sparse_categorical_accuracy: 0.8626 - val_loss: 0.4940 - val_sparse_ca
tegorical_accuracy: 0.8353 - 1s/epoch - 3ms/step
Epoch 88/100
469/469 - 1s - loss: 0.3712 - sparse_categorical_accuracy: 0.8666 - val_loss: 0.5005 - val_sparse_ca
tegorical_accuracy: 0.8376 - 1s/epoch - 2ms/step
Epoch 89/100
469/469 - 1s - loss: 0.3692 - sparse_categorical_accuracy: 0.8671 - val_loss: 0.4921 - val_sparse_ca
tegorical_accuracy: 0.8356 - 1s/epoch - 2ms/step
Epoch 90/100
469/469 - 1s - loss: 0.3726 - sparse_categorical_accuracy: 0.8658 - val_loss: 0.4866 - val_sparse_ca
tegorical_accuracy: 0.8343 - 1s/epoch - 2ms/step
Epoch 91/100
469/469 - 1s - loss: 0.3682 - sparse_categorical_accuracy: 0.8661 - val_loss: 0.4917 - val_sparse_ca
tegorical_accuracy: 0.8387 - 1s/epoch - 2ms/step
Epoch 92/100
469/469 - 1s - loss: 0.3697 - sparse_categorical_accuracy: 0.8666 - val_loss: 0.4842 - val_sparse_ca
tegorical_accuracy: 0.8357 - 1s/epoch - 2ms/step
Epoch 93/100
469/469 - 1s - loss: 0.3692 - sparse_categorical_accuracy: 0.8668 - val_loss: 0.4853 - val_sparse_ca
tegorical_accuracy: 0.8376 - 1s/epoch - 2ms/step
Epoch 94/100
469/469 - 1s - loss: 0.3687 - sparse_categorical_accuracy: 0.8661 - val_loss: 0.4877 - val_sparse_ca
```

```
tegorical_accuracy: 0.8370 - 1s/epoch - 3ms/step
Epoch 95/100
469/469 - 1s - loss: 0.3679 - sparse_categorical_accuracy: 0.8667 - val_loss: 0.5021 - val_sparse_ca
tegorical_accuracy: 0.8342 - 1s/epoch - 3ms/step
Epoch 96/100
469/469 - 1s - loss: 0.3716 - sparse_categorical_accuracy: 0.8650 - val_loss: 0.5196 - val_sparse_ca
tegorical_accuracy: 0.8306 - 1s/epoch - 3ms/step
Epoch 97/100
469/469 - 1s - loss: 0.3670 - sparse_categorical_accuracy: 0.8677 - val_loss: 0.4865 - val_sparse_ca
tegorical_accuracy: 0.8367 - 1s/epoch - 3ms/step
Epoch 98/100
469/469 - 1s - loss: 0.3640 - sparse_categorical_accuracy: 0.8679 - val_loss: 0.4895 - val_sparse_ca
tegorical_accuracy: 0.8368 - 1s/epoch - 2ms/step
Epoch 99/100
469/469 - 1s - loss: 0.3651 - sparse_categorical_accuracy: 0.8670 - val_loss: 0.4997 - val_sparse_ca
tegorical_accuracy: 0.8367 - 1s/epoch - 2ms/step
Epoch 100/100
469/469 - 1s - loss: 0.3661 - sparse_categorical_accuracy: 0.8677 - val_loss: 0.4916 - val_sparse_ca
tegorical_accuracy: 0.8388 - 1s/epoch - 2ms/step
```

Out[ ]:

```
<keras.callbacks.History at 0x7fdbae1cde10>
```

In [ ]:

```
model.evaluate(fX_test, fY_test, verbose=2)
```

```
313/313 - 0s - loss: 0.4916 - sparse_categorical_accuracy: 0.8388 - 373ms/epoch - 1ms/step
```

Out[ ]:

```
[0.49162164330482483, 0.8388000130653381]
```

In [ ]:

```

```

In [8]:

```
# model with 3 maxpooling layers
model5 = tf.keras.models.Sequential([
  tf.keras.layers.Input(shape=(28, 28, 1)),
  tf.keras.layers.GaussianNoise(0.1),
  tf.keras.layers.Conv2D(32, (3, 3)),
  tf.keras.layers.MaxPooling2D((3, 3)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.Flatten(),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Dense(10, activation='softmax')
])
model5.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 gaussian_noise_1 (GaussianN  (None, 28, 28, 1)        0
 oise)

 conv2d_1 (Conv2D)           (None, 26, 26, 32)        320

 max_pooling2d_4 (MaxPooling  (None, 8, 8, 32)         0
 2D)

 max_pooling2d_5 (MaxPooling  (None, 4, 4, 32)         0
 2D)

 max_pooling2d_6 (MaxPooling  (None, 2, 2, 32)         0
 2D)

 flatten_2 (Flatten)         (None, 128)               0

 dropout_2 (Dropout)         (None, 128)               0

 dense_6 (Dense)             (None, 16)                2064

 dense_7 (Dense)             (None, 16)                272

 batch_normalization_2 (Batc  (None, 16)               64
 hNormalization)

 dense_8 (Dense)             (None, 10)                170

=================================================================
Total params: 2,890
Trainable params: 2,858
Non-trainable params: 32
_________________________________________________________________
```

In [9]:

```
model5.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model5.fit(x_train, y_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
model5.evaluate(x_test, y_test, verbose=2)
```

```
Epoch 1/100
469/469 - 20s - loss: 1.4075 - sparse_categorical_accuracy: 0.5246 - val_loss: 0.5979 - val_sparse_c
ategorical_accuracy: 0.8493 - 20s/epoch - 42ms/step
Epoch 2/100
469/469 - 19s - loss: 0.6205 - sparse_categorical_accuracy: 0.8005 - val_loss: 0.3332 - val_sparse_c
ategorical_accuracy: 0.9079 - 19s/epoch - 40ms/step
Epoch 3/100
469/469 - 19s - loss: 0.4634 - sparse_categorical_accuracy: 0.8507 - val_loss: 0.2555 - val_sparse_c
ategorical_accuracy: 0.9223 - 19s/epoch - 40ms/step
Epoch 4/100
469/469 - 19s - loss: 0.4075 - sparse_categorical_accuracy: 0.8690 - val_loss: 0.2481 - val_sparse_c
ategorical_accuracy: 0.9211 - 19s/epoch - 40ms/step
Epoch 5/100
469/469 - 19s - loss: 0.3684 - sparse_categorical_accuracy: 0.8798 - val_loss: 0.2329 - val_sparse_c
ategorical_accuracy: 0.9287 - 19s/epoch - 41ms/step
Epoch 6/100
469/469 - 19s - loss: 0.3432 - sparse_categorical_accuracy: 0.8882 - val_loss: 0.2032 - val_sparse_c
ategorical_accuracy: 0.9386 - 19s/epoch - 40ms/step
Epoch 7/100
469/469 - 19s - loss: 0.3248 - sparse_categorical_accuracy: 0.8955 - val_loss: 0.1975 - val_sparse_c
ategorical_accuracy: 0.9363 - 19s/epoch - 40ms/step
Epoch 8/100
469/469 - 19s - loss: 0.3075 - sparse_categorical_accuracy: 0.9003 - val_loss: 0.1851 - val_sparse_c
ategorical_accuracy: 0.9429 - 19s/epoch - 40ms/step
Epoch 9/100
469/469 - 19s - loss: 0.2959 - sparse_categorical_accuracy: 0.9051 - val_loss: 0.1740 - val_sparse_c
ategorical_accuracy: 0.9458 - 19s/epoch - 40ms/step
Epoch 10/100
469/469 - 19s - loss: 0.2857 - sparse_categorical_accuracy: 0.9075 - val_loss: 0.1597 - val_sparse_c
ategorical_accuracy: 0.9505 - 19s/epoch - 40ms/step
Epoch 11/100
469/469 - 19s - loss: 0.2741 - sparse_categorical_accuracy: 0.9122 - val_loss: 0.1683 - val_sparse_c
```

```
ategorical_accuracy: 0.9465 - 19s/epoch - 40ms/step
Epoch 12/100
469/469 - 19s - loss: 0.2642 - sparse_categorical_accuracy: 0.9143 - val_loss: 0.1495 - val_sparse_c
ategorical_accuracy: 0.9539 - 19s/epoch - 40ms/step
Epoch 13/100
469/469 - 19s - loss: 0.2558 - sparse_categorical_accuracy: 0.9182 - val_loss: 0.2360 - val_sparse_c
ategorical_accuracy: 0.9243 - 19s/epoch - 40ms/step
Epoch 14/100
469/469 - 19s - loss: 0.2440 - sparse_categorical_accuracy: 0.9211 - val_loss: 0.1502 - val_sparse_c
ategorical_accuracy: 0.9514 - 19s/epoch - 40ms/step
Epoch 15/100
469/469 - 19s - loss: 0.2300 - sparse_categorical_accuracy: 0.9272 - val_loss: 0.1682 - val_sparse_c
ategorical_accuracy: 0.9462 - 19s/epoch - 40ms/step
Epoch 16/100
469/469 - 19s - loss: 0.2191 - sparse_categorical_accuracy: 0.9291 - val_loss: 0.1309 - val_sparse_c
ategorical_accuracy: 0.9575 - 19s/epoch - 40ms/step
Epoch 17/100
469/469 - 19s - loss: 0.2177 - sparse_categorical_accuracy: 0.9305 - val_loss: 0.1434 - val_sparse_c
ategorical_accuracy: 0.9548 - 19s/epoch - 41ms/step
Epoch 18/100
469/469 - 19s - loss: 0.2077 - sparse_categorical_accuracy: 0.9330 - val_loss: 0.1410 - val_sparse_c
ategorical_accuracy: 0.9546 - 19s/epoch - 41ms/step
Epoch 19/100
469/469 - 19s - loss: 0.2015 - sparse_categorical_accuracy: 0.9344 - val_loss: 0.1243 - val_sparse_c
ategorical_accuracy: 0.9603 - 19s/epoch - 41ms/step
Epoch 20/100
469/469 - 19s - loss: 0.1985 - sparse_categorical_accuracy: 0.9351 - val_loss: 0.1167 - val_sparse_c
ategorical_accuracy: 0.9624 - 19s/epoch - 41ms/step
Epoch 21/100
469/469 - 19s - loss: 0.1926 - sparse_categorical_accuracy: 0.9376 - val_loss: 0.1803 - val_sparse_c
ategorical_accuracy: 0.9406 - 19s/epoch - 41ms/step
Epoch 22/100
469/469 - 19s - loss: 0.1940 - sparse_categorical_accuracy: 0.9368 - val_loss: 0.1195 - val_sparse_c
ategorical_accuracy: 0.9621 - 19s/epoch - 40ms/step
Epoch 23/100
469/469 - 19s - loss: 0.1900 - sparse_categorical_accuracy: 0.9388 - val_loss: 0.1534 - val_sparse_c
ategorical_accuracy: 0.9507 - 19s/epoch - 40ms/step
Epoch 24/100
469/469 - 19s - loss: 0.1884 - sparse_categorical_accuracy: 0.9392 - val_loss: 0.1568 - val_sparse_c
ategorical_accuracy: 0.9478 - 19s/epoch - 41ms/step
Epoch 25/100
469/469 - 19s - loss: 0.1840 - sparse_categorical_accuracy: 0.9406 - val_loss: 0.1353 - val_sparse_c
ategorical_accuracy: 0.9563 - 19s/epoch - 41ms/step
Epoch 26/100
469/469 - 19s - loss: 0.1790 - sparse_categorical_accuracy: 0.9418 - val_loss: 0.1183 - val_sparse_c
ategorical_accuracy: 0.9626 - 19s/epoch - 41ms/step
Epoch 27/100
469/469 - 19s - loss: 0.1787 - sparse_categorical_accuracy: 0.9424 - val_loss: 0.1094 - val_sparse_c
ategorical_accuracy: 0.9658 - 19s/epoch - 41ms/step
Epoch 28/100
469/469 - 19s - loss: 0.1756 - sparse_categorical_accuracy: 0.9434 - val_loss: 0.1164 - val_sparse_c
ategorical_accuracy: 0.9618 - 19s/epoch - 41ms/step
Epoch 29/100
469/469 - 19s - loss: 0.1718 - sparse_categorical_accuracy: 0.9446 - val_loss: 0.1269 - val_sparse_c
ategorical_accuracy: 0.9597 - 19s/epoch - 40ms/step
Epoch 30/100
469/469 - 19s - loss: 0.1695 - sparse_categorical_accuracy: 0.9456 - val_loss: 0.1039 - val_sparse_c
ategorical_accuracy: 0.9662 - 19s/epoch - 40ms/step
Epoch 31/100
469/469 - 19s - loss: 0.1704 - sparse_categorical_accuracy: 0.9448 - val_loss: 0.1040 - val_sparse_c
ategorical_accuracy: 0.9649 - 19s/epoch - 40ms/step
Epoch 32/100
469/469 - 19s - loss: 0.1679 - sparse_categorical_accuracy: 0.9445 - val_loss: 0.1699 - val_sparse_c
ategorical_accuracy: 0.9420 - 19s/epoch - 41ms/step
Epoch 33/100
469/469 - 19s - loss: 0.1673 - sparse_categorical_accuracy: 0.9459 - val_loss: 0.1096 - val_sparse_c
ategorical_accuracy: 0.9658 - 19s/epoch - 40ms/step
Epoch 34/100
469/469 - 19s - loss: 0.1656 - sparse_categorical_accuracy: 0.9467 - val_loss: 0.1439 - val_sparse_c
ategorical_accuracy: 0.9514 - 19s/epoch - 41ms/step
Epoch 35/100
469/469 - 19s - loss: 0.1638 - sparse_categorical_accuracy: 0.9476 - val_loss: 0.1201 - val_sparse_c
ategorical_accuracy: 0.9616 - 19s/epoch - 40ms/step
Epoch 36/100
469/469 - 19s - loss: 0.1644 - sparse_categorical_accuracy: 0.9468 - val_loss: 0.1140 - val_sparse_c
ategorical_accuracy: 0.9627 - 19s/epoch - 41ms/step
Epoch 37/100
469/469 - 19s - loss: 0.1606 - sparse_categorical_accuracy: 0.9481 - val_loss: 0.1278 - val_sparse_c
ategorical_accuracy: 0.9604 - 19s/epoch - 40ms/step
Epoch 38/100
469/469 - 19s - loss: 0.1603 - sparse_categorical_accuracy: 0.9480 - val_loss: 0.1176 - val_sparse_c
ategorical_accuracy: 0.9638 - 19s/epoch - 40ms/step
Epoch 39/100
```

```
469/469 - 19s - loss: 0.1570 - sparse_categorical_accuracy: 0.9493 - val_loss: 0.0997 - val_sparse_c
ategorical_accuracy: 0.9677 - 19s/epoch - 40ms/step
Epoch 40/100
469/469 - 19s - loss: 0.1598 - sparse_categorical_accuracy: 0.9488 - val_loss: 0.0945 - val_sparse_c
ategorical_accuracy: 0.9698 - 19s/epoch - 41ms/step
Epoch 41/100
469/469 - 19s - loss: 0.1602 - sparse_categorical_accuracy: 0.9487 - val_loss: 0.0998 - val_sparse_c
ategorical_accuracy: 0.9682 - 19s/epoch - 41ms/step
Epoch 42/100
469/469 - 19s - loss: 0.1580 - sparse_categorical_accuracy: 0.9491 - val_loss: 0.0996 - val_sparse_c
ategorical_accuracy: 0.9695 - 19s/epoch - 40ms/step
Epoch 43/100
469/469 - 19s - loss: 0.1564 - sparse_categorical_accuracy: 0.9497 - val_loss: 0.1076 - val_sparse_c
ategorical_accuracy: 0.9659 - 19s/epoch - 41ms/step
Epoch 44/100
469/469 - 19s - loss: 0.1549 - sparse_categorical_accuracy: 0.9495 - val_loss: 0.1111 - val_sparse_c
ategorical_accuracy: 0.9653 - 19s/epoch - 40ms/step
Epoch 45/100
469/469 - 19s - loss: 0.1525 - sparse_categorical_accuracy: 0.9502 - val_loss: 0.0948 - val_sparse_c
ategorical_accuracy: 0.9692 - 19s/epoch - 40ms/step
Epoch 46/100
469/469 - 19s - loss: 0.1530 - sparse_categorical_accuracy: 0.9511 - val_loss: 0.1067 - val_sparse_c
ategorical_accuracy: 0.9650 - 19s/epoch - 40ms/step
Epoch 47/100
469/469 - 19s - loss: 0.1525 - sparse_categorical_accuracy: 0.9512 - val_loss: 0.1100 - val_sparse_c
ategorical_accuracy: 0.9648 - 19s/epoch - 40ms/step
Epoch 48/100
469/469 - 19s - loss: 0.1482 - sparse_categorical_accuracy: 0.9520 - val_loss: 0.1000 - val_sparse_c
ategorical_accuracy: 0.9664 - 19s/epoch - 40ms/step
Epoch 49/100
469/469 - 19s - loss: 0.1487 - sparse_categorical_accuracy: 0.9517 - val_loss: 0.1036 - val_sparse_c
ategorical_accuracy: 0.9648 - 19s/epoch - 40ms/step
Epoch 50/100
469/469 - 19s - loss: 0.1531 - sparse_categorical_accuracy: 0.9494 - val_loss: 0.1024 - val_sparse_c
ategorical_accuracy: 0.9671 - 19s/epoch - 40ms/step
Epoch 51/100
469/469 - 19s - loss: 0.1530 - sparse_categorical_accuracy: 0.9502 - val_loss: 0.1277 - val_sparse_c
ategorical_accuracy: 0.9586 - 19s/epoch - 40ms/step
Epoch 52/100
469/469 - 19s - loss: 0.1493 - sparse_categorical_accuracy: 0.9524 - val_loss: 0.1010 - val_sparse_c
ategorical_accuracy: 0.9680 - 19s/epoch - 40ms/step
Epoch 53/100
469/469 - 19s - loss: 0.1465 - sparse_categorical_accuracy: 0.9527 - val_loss: 0.1066 - val_sparse_c
ategorical_accuracy: 0.9656 - 19s/epoch - 40ms/step
Epoch 54/100
469/469 - 19s - loss: 0.1451 - sparse_categorical_accuracy: 0.9527 - val_loss: 0.1172 - val_sparse_c
ategorical_accuracy: 0.9637 - 19s/epoch - 40ms/step
Epoch 55/100
469/469 - 19s - loss: 0.1482 - sparse_categorical_accuracy: 0.9514 - val_loss: 0.1146 - val_sparse_c
ategorical_accuracy: 0.9639 - 19s/epoch - 40ms/step
Epoch 56/100
469/469 - 19s - loss: 0.1467 - sparse_categorical_accuracy: 0.9529 - val_loss: 0.0967 - val_sparse_c
ategorical_accuracy: 0.9670 - 19s/epoch - 40ms/step
Epoch 57/100
469/469 - 19s - loss: 0.1451 - sparse_categorical_accuracy: 0.9539 - val_loss: 0.0927 - val_sparse_c
ategorical_accuracy: 0.9700 - 19s/epoch - 40ms/step
Epoch 58/100
469/469 - 19s - loss: 0.1449 - sparse_categorical_accuracy: 0.9532 - val_loss: 0.0913 - val_sparse_c
ategorical_accuracy: 0.9710 - 19s/epoch - 40ms/step
Epoch 59/100
469/469 - 19s - loss: 0.1446 - sparse_categorical_accuracy: 0.9531 - val_loss: 0.0843 - val_sparse_c
ategorical_accuracy: 0.9727 - 19s/epoch - 40ms/step
Epoch 60/100
469/469 - 19s - loss: 0.1408 - sparse_categorical_accuracy: 0.9548 - val_loss: 0.1479 - val_sparse_c
ategorical_accuracy: 0.9532 - 19s/epoch - 40ms/step
Epoch 61/100
469/469 - 19s - loss: 0.1444 - sparse_categorical_accuracy: 0.9532 - val_loss: 0.0917 - val_sparse_c
ategorical_accuracy: 0.9709 - 19s/epoch - 40ms/step
Epoch 62/100
469/469 - 19s - loss: 0.1434 - sparse_categorical_accuracy: 0.9531 - val_loss: 0.0921 - val_sparse_c
ategorical_accuracy: 0.9703 - 19s/epoch - 40ms/step
Epoch 63/100
469/469 - 19s - loss: 0.1401 - sparse_categorical_accuracy: 0.9545 - val_loss: 0.1152 - val_sparse_c
ategorical_accuracy: 0.9621 - 19s/epoch - 40ms/step
Epoch 64/100
469/469 - 19s - loss: 0.1422 - sparse_categorical_accuracy: 0.9544 - val_loss: 0.1039 - val_sparse_c
ategorical_accuracy: 0.9663 - 19s/epoch - 40ms/step
Epoch 65/100
469/469 - 19s - loss: 0.1420 - sparse_categorical_accuracy: 0.9536 - val_loss: 0.1119 - val_sparse_c
ategorical_accuracy: 0.9641 - 19s/epoch - 40ms/step
Epoch 66/100
469/469 - 19s - loss: 0.1421 - sparse_categorical_accuracy: 0.9535 - val_loss: 0.0928 - val_sparse_c
ategorical_accuracy: 0.9702 - 19s/epoch - 40ms/step
```

```
Epoch 67/100
469/469 - 19s - loss: 0.1389 - sparse_categorical_accuracy: 0.9549 - val_loss: 0.1086 - val_sparse_c
ategorical_accuracy: 0.9647 - 19s/epoch - 40ms/step
Epoch 68/100
469/469 - 19s - loss: 0.1386 - sparse_categorical_accuracy: 0.9548 - val_loss: 0.1821 - val_sparse_c
ategorical_accuracy: 0.9431 - 19s/epoch - 40ms/step
Epoch 69/100
469/469 - 19s - loss: 0.1403 - sparse_categorical_accuracy: 0.9543 - val_loss: 0.0901 - val_sparse_c
ategorical_accuracy: 0.9700 - 19s/epoch - 40ms/step
Epoch 70/100
469/469 - 19s - loss: 0.1400 - sparse_categorical_accuracy: 0.9545 - val_loss: 0.0861 - val_sparse_c
ategorical_accuracy: 0.9719 - 19s/epoch - 40ms/step
Epoch 71/100
469/469 - 19s - loss: 0.1394 - sparse_categorical_accuracy: 0.9541 - val_loss: 0.0980 - val_sparse_c
ategorical_accuracy: 0.9678 - 19s/epoch - 40ms/step
Epoch 72/100
469/469 - 19s - loss: 0.1399 - sparse_categorical_accuracy: 0.9542 - val_loss: 0.0936 - val_sparse_c
ategorical_accuracy: 0.9708 - 19s/epoch - 40ms/step
Epoch 73/100
469/469 - 19s - loss: 0.1331 - sparse_categorical_accuracy: 0.9569 - val_loss: 0.0915 - val_sparse_c
ategorical_accuracy: 0.9715 - 19s/epoch - 40ms/step
Epoch 74/100
469/469 - 19s - loss: 0.1358 - sparse_categorical_accuracy: 0.9559 - val_loss: 0.1159 - val_sparse_c
ategorical_accuracy: 0.9613 - 19s/epoch - 40ms/step
Epoch 75/100
469/469 - 19s - loss: 0.1379 - sparse_categorical_accuracy: 0.9555 - val_loss: 0.0883 - val_sparse_c
ategorical_accuracy: 0.9710 - 19s/epoch - 40ms/step
Epoch 76/100
469/469 - 19s - loss: 0.1330 - sparse_categorical_accuracy: 0.9563 - val_loss: 0.1669 - val_sparse_c
ategorical_accuracy: 0.9460 - 19s/epoch - 40ms/step
Epoch 77/100
469/469 - 19s - loss: 0.1389 - sparse_categorical_accuracy: 0.9550 - val_loss: 0.0861 - val_sparse_c
ategorical_accuracy: 0.9731 - 19s/epoch - 40ms/step
Epoch 78/100
469/469 - 19s - loss: 0.1335 - sparse_categorical_accuracy: 0.9561 - val_loss: 0.0843 - val_sparse_c
ategorical_accuracy: 0.9730 - 19s/epoch - 40ms/step
Epoch 79/100
469/469 - 19s - loss: 0.1342 - sparse_categorical_accuracy: 0.9561 - val_loss: 0.1059 - val_sparse_c
ategorical_accuracy: 0.9644 - 19s/epoch - 40ms/step
Epoch 80/100
469/469 - 19s - loss: 0.1341 - sparse_categorical_accuracy: 0.9564 - val_loss: 0.0899 - val_sparse_c
ategorical_accuracy: 0.9704 - 19s/epoch - 40ms/step
Epoch 81/100
469/469 - 19s - loss: 0.1330 - sparse_categorical_accuracy: 0.9568 - val_loss: 0.0824 - val_sparse_c
ategorical_accuracy: 0.9731 - 19s/epoch - 40ms/step
Epoch 82/100
469/469 - 19s - loss: 0.1314 - sparse_categorical_accuracy: 0.9572 - val_loss: 0.1070 - val_sparse_c
ategorical_accuracy: 0.9677 - 19s/epoch - 40ms/step
Epoch 83/100
469/469 - 19s - loss: 0.1349 - sparse_categorical_accuracy: 0.9557 - val_loss: 0.0865 - val_sparse_c
ategorical_accuracy: 0.9731 - 19s/epoch - 40ms/step
Epoch 84/100
469/469 - 19s - loss: 0.1336 - sparse_categorical_accuracy: 0.9570 - val_loss: 0.1075 - val_sparse_c
ategorical_accuracy: 0.9652 - 19s/epoch - 40ms/step
Epoch 85/100
469/469 - 19s - loss: 0.1353 - sparse_categorical_accuracy: 0.9569 - val_loss: 0.0935 - val_sparse_c
ategorical_accuracy: 0.9693 - 19s/epoch - 40ms/step
Epoch 86/100
469/469 - 19s - loss: 0.1353 - sparse_categorical_accuracy: 0.9564 - val_loss: 0.1166 - val_sparse_c
ategorical_accuracy: 0.9637 - 19s/epoch - 40ms/step
Epoch 87/100
469/469 - 19s - loss: 0.1335 - sparse_categorical_accuracy: 0.9572 - val_loss: 0.1020 - val_sparse_c
ategorical_accuracy: 0.9665 - 19s/epoch - 40ms/step
Epoch 88/100
469/469 - 19s - loss: 0.1323 - sparse_categorical_accuracy: 0.9567 - val_loss: 0.1114 - val_sparse_c
ategorical_accuracy: 0.9635 - 19s/epoch - 40ms/step
Epoch 89/100
469/469 - 19s - loss: 0.1300 - sparse_categorical_accuracy: 0.9573 - val_loss: 0.0934 - val_sparse_c
ategorical_accuracy: 0.9701 - 19s/epoch - 40ms/step
Epoch 90/100
469/469 - 19s - loss: 0.1343 - sparse_categorical_accuracy: 0.9563 - val_loss: 0.0983 - val_sparse_c
ategorical_accuracy: 0.9671 - 19s/epoch - 40ms/step
Epoch 91/100
469/469 - 19s - loss: 0.1336 - sparse_categorical_accuracy: 0.9565 - val_loss: 0.1113 - val_sparse_c
ategorical_accuracy: 0.9632 - 19s/epoch - 40ms/step
Epoch 92/100
469/469 - 19s - loss: 0.1327 - sparse_categorical_accuracy: 0.9571 - val_loss: 0.1072 - val_sparse_c
ategorical_accuracy: 0.9663 - 19s/epoch - 40ms/step
Epoch 93/100
469/469 - 19s - loss: 0.1322 - sparse_categorical_accuracy: 0.9575 - val_loss: 0.0908 - val_sparse_c
ategorical_accuracy: 0.9719 - 19s/epoch - 40ms/step
Epoch 94/100
469/469 - 19s - loss: 0.1304 - sparse_categorical_accuracy: 0.9588 - val_loss: 0.0869 - val_sparse_c
```

```
ategorical_accuracy: 0.9730 - 19s/epoch - 40ms/step
Epoch 95/100
469/469 - 19s - loss: 0.1318 - sparse_categorical_accuracy: 0.9574 - val_loss: 0.1027 - val_sparse_c
ategorical_accuracy: 0.9665 - 19s/epoch - 40ms/step
Epoch 96/100
469/469 - 19s - loss: 0.1297 - sparse_categorical_accuracy: 0.9581 - val_loss: 0.1243 - val_sparse_c
ategorical_accuracy: 0.9594 - 19s/epoch - 40ms/step
Epoch 97/100
469/469 - 19s - loss: 0.1312 - sparse_categorical_accuracy: 0.9580 - val_loss: 0.0928 - val_sparse_c
ategorical_accuracy: 0.9700 - 19s/epoch - 40ms/step
Epoch 98/100
469/469 - 19s - loss: 0.1302 - sparse_categorical_accuracy: 0.9571 - val_loss: 0.0964 - val_sparse_c
ategorical_accuracy: 0.9689 - 19s/epoch - 40ms/step
Epoch 99/100
469/469 - 19s - loss: 0.1275 - sparse_categorical_accuracy: 0.9582 - val_loss: 0.0931 - val_sparse_c
ategorical_accuracy: 0.9703 - 19s/epoch - 40ms/step
Epoch 100/100
469/469 - 19s - loss: 0.1333 - sparse_categorical_accuracy: 0.9566 - val_loss: 0.0881 - val_sparse_c
ategorical_accuracy: 0.9710 - 19s/epoch - 40ms/step
313/313 - 2s - loss: 0.0881 - sparse_categorical_accuracy: 0.9710 - 2s/epoch - 5ms/step
```

Out[9]:

```
[0.08807934820652008, 0.9710000157356262]
```

In [ ]:

```
model5.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model5.fit(fX_train, fY_train,
                    batch_size=128,
                    epochs=100,
                    validation_data=(fX_test, fY_test),
                    verbose=2
                    )
model5.evaluate(fX_test, fY_test, verbose=2)
```

```
Epoch 1/100
469/469 - 19s - loss: 1.3642 - sparse_categorical_accuracy: 0.5213 - val_loss: 0.8171 - val_sparse_c
ategorical_accuracy: 0.7052 - 19s/epoch - 42ms/step
Epoch 2/100
469/469 - 18s - loss: 0.8037 - sparse_categorical_accuracy: 0.6999 - val_loss: 0.6868 - val_sparse_c
ategorical_accuracy: 0.7423 - 18s/epoch - 39ms/step
Epoch 3/100
469/469 - 18s - loss: 0.7214 - sparse_categorical_accuracy: 0.7292 - val_loss: 0.6426 - val_sparse_c
ategorical_accuracy: 0.7601 - 18s/epoch - 39ms/step
Epoch 4/100
469/469 - 18s - loss: 0.6721 - sparse_categorical_accuracy: 0.7470 - val_loss: 0.6062 - val_sparse_c
ategorical_accuracy: 0.7677 - 18s/epoch - 39ms/step
Epoch 5/100
469/469 - 18s - loss: 0.6517 - sparse_categorical_accuracy: 0.7555 - val_loss: 0.6119 - val_sparse_c
ategorical_accuracy: 0.7655 - 18s/epoch - 39ms/step
Epoch 6/100
469/469 - 18s - loss: 0.6296 - sparse_categorical_accuracy: 0.7652 - val_loss: 0.5703 - val_sparse_c
ategorical_accuracy: 0.7857 - 18s/epoch - 39ms/step
Epoch 7/100
469/469 - 18s - loss: 0.6139 - sparse_categorical_accuracy: 0.7720 - val_loss: 0.5691 - val_sparse_c
ategorical_accuracy: 0.7898 - 18s/epoch - 39ms/step
Epoch 8/100
469/469 - 18s - loss: 0.6008 - sparse_categorical_accuracy: 0.7775 - val_loss: 0.5514 - val_sparse_c
ategorical_accuracy: 0.7984 - 18s/epoch - 38ms/step
Epoch 9/100
469/469 - 18s - loss: 0.5911 - sparse_categorical_accuracy: 0.7809 - val_loss: 0.5480 - val_sparse_c
ategorical_accuracy: 0.7945 - 18s/epoch - 38ms/step
Epoch 10/100
469/469 - 18s - loss: 0.5826 - sparse_categorical_accuracy: 0.7842 - val_loss: 0.5367 - val_sparse_c
ategorical_accuracy: 0.7992 - 18s/epoch - 38ms/step
Epoch 11/100
469/469 - 18s - loss: 0.5774 - sparse_categorical_accuracy: 0.7868 - val_loss: 0.5407 - val_sparse_c
ategorical_accuracy: 0.8032 - 18s/epoch - 38ms/step
Epoch 12/100
469/469 - 18s - loss: 0.5697 - sparse_categorical_accuracy: 0.7894 - val_loss: 0.5386 - val_sparse_c
ategorical_accuracy: 0.7997 - 18s/epoch - 38ms/step
Epoch 13/100
469/469 - 18s - loss: 0.5664 - sparse_categorical_accuracy: 0.7901 - val_loss: 0.5344 - val_sparse_c
ategorical_accuracy: 0.8031 - 18s/epoch - 38ms/step
Epoch 14/100
469/469 - 18s - loss: 0.5625 - sparse_categorical_accuracy: 0.7916 - val_loss: 0.5484 - val_sparse_c
ategorical_accuracy: 0.7954 - 18s/epoch - 38ms/step
Epoch 15/100
469/469 - 18s - loss: 0.5577 - sparse_categorical_accuracy: 0.7951 - val_loss: 0.5229 - val_sparse_c
ategorical_accuracy: 0.8082 - 18s/epoch - 38ms/step
```

```
Epoch 16/100
469/469 - 18s - loss: 0.5551 - sparse_categorical_accuracy: 0.7943 - val_loss: 0.5204 - val_sparse_c
ategorical_accuracy: 0.8100 - 18s/epoch - 38ms/step
Epoch 17/100
469/469 - 18s - loss: 0.5535 - sparse_categorical_accuracy: 0.7944 - val_loss: 0.5182 - val_sparse_c
ategorical_accuracy: 0.8078 - 18s/epoch - 38ms/step
Epoch 18/100
469/469 - 18s - loss: 0.5477 - sparse_categorical_accuracy: 0.7972 - val_loss: 0.5146 - val_sparse_c
ategorical_accuracy: 0.8117 - 18s/epoch - 38ms/step
Epoch 19/100
469/469 - 18s - loss: 0.5438 - sparse_categorical_accuracy: 0.7987 - val_loss: 0.5128 - val_sparse_c
ategorical_accuracy: 0.8084 - 18s/epoch - 38ms/step
Epoch 20/100
469/469 - 18s - loss: 0.5401 - sparse_categorical_accuracy: 0.7991 - val_loss: 0.5250 - val_sparse_c
ategorical_accuracy: 0.8084 - 18s/epoch - 38ms/step
Epoch 21/100
469/469 - 18s - loss: 0.5425 - sparse_categorical_accuracy: 0.7991 - val_loss: 0.5129 - val_sparse_c
ategorical_accuracy: 0.8083 - 18s/epoch - 38ms/step
Epoch 22/100
469/469 - 18s - loss: 0.5368 - sparse_categorical_accuracy: 0.7997 - val_loss: 0.5009 - val_sparse_c
ategorical_accuracy: 0.8201 - 18s/epoch - 38ms/step
Epoch 23/100
469/469 - 18s - loss: 0.5355 - sparse_categorical_accuracy: 0.8014 - val_loss: 0.5072 - val_sparse_c
ategorical_accuracy: 0.8110 - 18s/epoch - 38ms/step
Epoch 24/100
469/469 - 18s - loss: 0.5335 - sparse_categorical_accuracy: 0.7999 - val_loss: 0.5085 - val_sparse_c
ategorical_accuracy: 0.8115 - 18s/epoch - 38ms/step
Epoch 25/100
469/469 - 18s - loss: 0.5319 - sparse_categorical_accuracy: 0.8031 - val_loss: 0.5089 - val_sparse_c
ategorical_accuracy: 0.8086 - 18s/epoch - 38ms/step
Epoch 26/100
469/469 - 18s - loss: 0.5303 - sparse_categorical_accuracy: 0.8051 - val_loss: 0.5106 - val_sparse_c
ategorical_accuracy: 0.8119 - 18s/epoch - 38ms/step
Epoch 27/100
469/469 - 18s - loss: 0.5283 - sparse_categorical_accuracy: 0.8022 - val_loss: 0.5131 - val_sparse_c
ategorical_accuracy: 0.8102 - 18s/epoch - 38ms/step
Epoch 28/100
469/469 - 18s - loss: 0.5259 - sparse_categorical_accuracy: 0.8049 - val_loss: 0.5149 - val_sparse_c
ategorical_accuracy: 0.8044 - 18s/epoch - 38ms/step
Epoch 29/100
469/469 - 18s - loss: 0.5264 - sparse_categorical_accuracy: 0.8047 - val_loss: 0.5095 - val_sparse_c
ategorical_accuracy: 0.8106 - 18s/epoch - 38ms/step
Epoch 30/100
469/469 - 18s - loss: 0.5239 - sparse_categorical_accuracy: 0.8058 - val_loss: 0.5168 - val_sparse_c
ategorical_accuracy: 0.8048 - 18s/epoch - 38ms/step
Epoch 31/100
469/469 - 18s - loss: 0.5210 - sparse_categorical_accuracy: 0.8067 - val_loss: 0.5101 - val_sparse_c
ategorical_accuracy: 0.8112 - 18s/epoch - 38ms/step
Epoch 32/100
469/469 - 18s - loss: 0.5174 - sparse_categorical_accuracy: 0.8081 - val_loss: 0.5056 - val_sparse_c
ategorical_accuracy: 0.8138 - 18s/epoch - 39ms/step
Epoch 33/100
469/469 - 18s - loss: 0.5185 - sparse_categorical_accuracy: 0.8084 - val_loss: 0.5031 - val_sparse_c
ategorical_accuracy: 0.8120 - 18s/epoch - 38ms/step
Epoch 34/100
469/469 - 18s - loss: 0.5213 - sparse_categorical_accuracy: 0.8065 - val_loss: 0.4952 - val_sparse_c
ategorical_accuracy: 0.8163 - 18s/epoch - 38ms/step
Epoch 35/100
469/469 - 18s - loss: 0.5177 - sparse_categorical_accuracy: 0.8060 - val_loss: 0.5048 - val_sparse_c
ategorical_accuracy: 0.8108 - 18s/epoch - 38ms/step
Epoch 36/100
469/469 - 18s - loss: 0.5171 - sparse_categorical_accuracy: 0.8075 - val_loss: 0.4880 - val_sparse_c
ategorical_accuracy: 0.8183 - 18s/epoch - 39ms/step
Epoch 37/100
469/469 - 18s - loss: 0.5155 - sparse_categorical_accuracy: 0.8084 - val_loss: 0.4918 - val_sparse_c
ategorical_accuracy: 0.8173 - 18s/epoch - 38ms/step
Epoch 38/100
469/469 - 18s - loss: 0.5138 - sparse_categorical_accuracy: 0.8091 - val_loss: 0.5031 - val_sparse_c
ategorical_accuracy: 0.8124 - 18s/epoch - 38ms/step
Epoch 39/100
469/469 - 18s - loss: 0.5123 - sparse_categorical_accuracy: 0.8084 - val_loss: 0.5040 - val_sparse_c
ategorical_accuracy: 0.8087 - 18s/epoch - 39ms/step
Epoch 40/100
469/469 - 18s - loss: 0.5140 - sparse_categorical_accuracy: 0.8086 - val_loss: 0.5018 - val_sparse_c
ategorical_accuracy: 0.8095 - 18s/epoch - 38ms/step
Epoch 41/100
469/469 - 18s - loss: 0.5116 - sparse_categorical_accuracy: 0.8085 - val_loss: 0.4981 - val_sparse_c
ategorical_accuracy: 0.8160 - 18s/epoch - 38ms/step
Epoch 42/100
469/469 - 18s - loss: 0.5112 - sparse_categorical_accuracy: 0.8102 - val_loss: 0.5017 - val_sparse_c
ategorical_accuracy: 0.8102 - 18s/epoch - 39ms/step
Epoch 43/100
469/469 - 18s - loss: 0.5108 - sparse_categorical_accuracy: 0.8081 - val_loss: 0.4954 - val_sparse_c
```

ategorical_accuracy: 0.8140 - 18s/epoch - 38ms/step
Epoch 44/100
469/469 - 18s - loss: 0.5075 - sparse_categorical_accuracy: 0.8106 - val_loss: 0.4912 - val_sparse_c
ategorical_accuracy: 0.8174 - 18s/epoch - 38ms/step
Epoch 45/100
469/469 - 18s - loss: 0.5089 - sparse_categorical_accuracy: 0.8088 - val_loss: 0.4910 - val_sparse_c
ategorical_accuracy: 0.8197 - 18s/epoch - 38ms/step
Epoch 46/100
469/469 - 18s - loss: 0.5099 - sparse_categorical_accuracy: 0.8090 - val_loss: 0.5083 - val_sparse_c
ategorical_accuracy: 0.8056 - 18s/epoch - 38ms/step
Epoch 47/100
469/469 - 18s - loss: 0.5081 - sparse_categorical_accuracy: 0.8091 - val_loss: 0.4923 - val_sparse_c
ategorical_accuracy: 0.8173 - 18s/epoch - 38ms/step
Epoch 48/100
469/469 - 18s - loss: 0.5047 - sparse_categorical_accuracy: 0.8101 - val_loss: 0.4842 - val_sparse_c
ategorical_accuracy: 0.8202 - 18s/epoch - 38ms/step
Epoch 49/100
469/469 - 18s - loss: 0.5014 - sparse_categorical_accuracy: 0.8131 - val_loss: 0.4905 - val_sparse_c
ategorical_accuracy: 0.8163 - 18s/epoch - 38ms/step
Epoch 50/100
469/469 - 18s - loss: 0.5041 - sparse_categorical_accuracy: 0.8110 - val_loss: 0.4942 - val_sparse_c
ategorical_accuracy: 0.8178 - 18s/epoch - 38ms/step
Epoch 51/100
469/469 - 18s - loss: 0.5064 - sparse_categorical_accuracy: 0.8100 - val_loss: 0.4846 - val_sparse_c
ategorical_accuracy: 0.8231 - 18s/epoch - 38ms/step
Epoch 52/100
469/469 - 18s - loss: 0.5038 - sparse_categorical_accuracy: 0.8126 - val_loss: 0.4860 - val_sparse_c
ategorical_accuracy: 0.8195 - 18s/epoch - 38ms/step
Epoch 53/100
469/469 - 18s - loss: 0.5016 - sparse_categorical_accuracy: 0.8130 - val_loss: 0.5048 - val_sparse_c
ategorical_accuracy: 0.8103 - 18s/epoch - 38ms/step
Epoch 54/100
469/469 - 18s - loss: 0.5013 - sparse_categorical_accuracy: 0.8132 - val_loss: 0.5104 - val_sparse_c
ategorical_accuracy: 0.8038 - 18s/epoch - 38ms/step
Epoch 55/100
469/469 - 18s - loss: 0.4979 - sparse_categorical_accuracy: 0.8132 - val_loss: 0.4895 - val_sparse_c
ategorical_accuracy: 0.8184 - 18s/epoch - 38ms/step
Epoch 56/100
469/469 - 18s - loss: 0.5013 - sparse_categorical_accuracy: 0.8124 - val_loss: 0.5079 - val_sparse_c
ategorical_accuracy: 0.8070 - 18s/epoch - 38ms/step
Epoch 57/100
469/469 - 18s - loss: 0.5024 - sparse_categorical_accuracy: 0.8117 - val_loss: 0.4919 - val_sparse_c
ategorical_accuracy: 0.8183 - 18s/epoch - 38ms/step
Epoch 58/100
469/469 - 18s - loss: 0.4982 - sparse_categorical_accuracy: 0.8157 - val_loss: 0.5002 - val_sparse_c
ategorical_accuracy: 0.8104 - 18s/epoch - 38ms/step
Epoch 59/100
469/469 - 18s - loss: 0.5013 - sparse_categorical_accuracy: 0.8108 - val_loss: 0.4843 - val_sparse_c
ategorical_accuracy: 0.8212 - 18s/epoch - 38ms/step
Epoch 60/100
469/469 - 18s - loss: 0.4976 - sparse_categorical_accuracy: 0.8137 - val_loss: 0.4850 - val_sparse_c
ategorical_accuracy: 0.8189 - 18s/epoch - 38ms/step
Epoch 61/100
469/469 - 18s - loss: 0.4980 - sparse_categorical_accuracy: 0.8142 - val_loss: 0.4856 - val_sparse_c
ategorical_accuracy: 0.8189 - 18s/epoch - 38ms/step
Epoch 62/100
469/469 - 18s - loss: 0.4955 - sparse_categorical_accuracy: 0.8152 - val_loss: 0.4872 - val_sparse_c
ategorical_accuracy: 0.8186 - 18s/epoch - 38ms/step
Epoch 63/100
469/469 - 18s - loss: 0.4997 - sparse_categorical_accuracy: 0.8117 - val_loss: 0.4950 - val_sparse_c
ategorical_accuracy: 0.8168 - 18s/epoch - 38ms/step
Epoch 64/100
469/469 - 18s - loss: 0.4954 - sparse_categorical_accuracy: 0.8156 - val_loss: 0.4796 - val_sparse_c
ategorical_accuracy: 0.8221 - 18s/epoch - 38ms/step
Epoch 65/100
469/469 - 18s - loss: 0.4943 - sparse_categorical_accuracy: 0.8156 - val_loss: 0.4845 - val_sparse_c
ategorical_accuracy: 0.8165 - 18s/epoch - 38ms/step
Epoch 66/100
469/469 - 18s - loss: 0.4946 - sparse_categorical_accuracy: 0.8148 - val_loss: 0.4919 - val_sparse_c
ategorical_accuracy: 0.8154 - 18s/epoch - 38ms/step
Epoch 67/100
469/469 - 18s - loss: 0.4963 - sparse_categorical_accuracy: 0.8141 - val_loss: 0.4764 - val_sparse_c
ategorical_accuracy: 0.8242 - 18s/epoch - 38ms/step
Epoch 68/100
469/469 - 18s - loss: 0.4963 - sparse_categorical_accuracy: 0.8149 - val_loss: 0.4842 - val_sparse_c
ategorical_accuracy: 0.8216 - 18s/epoch - 38ms/step
Epoch 69/100
469/469 - 18s - loss: 0.4953 - sparse_categorical_accuracy: 0.8151 - val_loss: 0.4866 - val_sparse_c
ategorical_accuracy: 0.8208 - 18s/epoch - 38ms/step
Epoch 70/100
469/469 - 18s - loss: 0.4961 - sparse_categorical_accuracy: 0.8140 - val_loss: 0.4780 - val_sparse_c
ategorical_accuracy: 0.8217 - 18s/epoch - 38ms/step
Epoch 71/100

```
469/469 - 18s - loss: 0.4935 - sparse_categorical_accuracy: 0.8155 - val_loss: 0.4897 - val_sparse_c
ategorical_accuracy: 0.8181 - 18s/epoch - 38ms/step
Epoch 72/100
469/469 - 18s - loss: 0.4931 - sparse_categorical_accuracy: 0.8164 - val_loss: 0.4812 - val_sparse_c
ategorical_accuracy: 0.8242 - 18s/epoch - 38ms/step
Epoch 73/100
469/469 - 18s - loss: 0.4923 - sparse_categorical_accuracy: 0.8152 - val_loss: 0.4862 - val_sparse_c
ategorical_accuracy: 0.8185 - 18s/epoch - 38ms/step
Epoch 74/100
469/469 - 18s - loss: 0.4877 - sparse_categorical_accuracy: 0.8154 - val_loss: 0.4806 - val_sparse_c
ategorical_accuracy: 0.8193 - 18s/epoch - 38ms/step
Epoch 75/100
469/469 - 18s - loss: 0.4907 - sparse_categorical_accuracy: 0.8168 - val_loss: 0.4801 - val_sparse_c
ategorical_accuracy: 0.8232 - 18s/epoch - 38ms/step
Epoch 76/100
469/469 - 18s - loss: 0.4901 - sparse_categorical_accuracy: 0.8169 - val_loss: 0.4776 - val_sparse_c
ategorical_accuracy: 0.8215 - 18s/epoch - 39ms/step
Epoch 77/100
469/469 - 18s - loss: 0.4915 - sparse_categorical_accuracy: 0.8155 - val_loss: 0.4822 - val_sparse_c
ategorical_accuracy: 0.8207 - 18s/epoch - 38ms/step
Epoch 78/100
469/469 - 18s - loss: 0.4900 - sparse_categorical_accuracy: 0.8166 - val_loss: 0.4722 - val_sparse_c
ategorical_accuracy: 0.8268 - 18s/epoch - 38ms/step
Epoch 79/100
469/469 - 18s - loss: 0.4909 - sparse_categorical_accuracy: 0.8162 - val_loss: 0.4769 - val_sparse_c
ategorical_accuracy: 0.8206 - 18s/epoch - 38ms/step
Epoch 80/100
469/469 - 18s - loss: 0.4904 - sparse_categorical_accuracy: 0.8173 - val_loss: 0.4778 - val_sparse_c
ategorical_accuracy: 0.8220 - 18s/epoch - 38ms/step
Epoch 81/100
469/469 - 18s - loss: 0.4890 - sparse_categorical_accuracy: 0.8172 - val_loss: 0.4767 - val_sparse_c
ategorical_accuracy: 0.8236 - 18s/epoch - 38ms/step
Epoch 82/100
469/469 - 18s - loss: 0.4888 - sparse_categorical_accuracy: 0.8186 - val_loss: 0.4753 - val_sparse_c
ategorical_accuracy: 0.8220 - 18s/epoch - 38ms/step
Epoch 83/100
469/469 - 18s - loss: 0.4892 - sparse_categorical_accuracy: 0.8176 - val_loss: 0.4795 - val_sparse_c
ategorical_accuracy: 0.8224 - 18s/epoch - 38ms/step
Epoch 84/100
469/469 - 18s - loss: 0.4851 - sparse_categorical_accuracy: 0.8189 - val_loss: 0.4827 - val_sparse_c
ategorical_accuracy: 0.8171 - 18s/epoch - 38ms/step
Epoch 85/100
469/469 - 18s - loss: 0.4895 - sparse_categorical_accuracy: 0.8173 - val_loss: 0.5081 - val_sparse_c
ategorical_accuracy: 0.8096 - 18s/epoch - 38ms/step
Epoch 86/100
469/469 - 18s - loss: 0.4871 - sparse_categorical_accuracy: 0.8176 - val_loss: 0.4763 - val_sparse_c
ategorical_accuracy: 0.8207 - 18s/epoch - 38ms/step
Epoch 87/100
469/469 - 18s - loss: 0.4869 - sparse_categorical_accuracy: 0.8183 - val_loss: 0.4785 - val_sparse_c
ategorical_accuracy: 0.8201 - 18s/epoch - 38ms/step
Epoch 88/100
469/469 - 18s - loss: 0.4865 - sparse_categorical_accuracy: 0.8180 - val_loss: 0.4792 - val_sparse_c
ategorical_accuracy: 0.8220 - 18s/epoch - 38ms/step
Epoch 89/100
469/469 - 18s - loss: 0.4841 - sparse_categorical_accuracy: 0.8195 - val_loss: 0.4821 - val_sparse_c
ategorical_accuracy: 0.8226 - 18s/epoch - 39ms/step
Epoch 90/100
469/469 - 18s - loss: 0.4847 - sparse_categorical_accuracy: 0.8177 - val_loss: 0.4810 - val_sparse_c
ategorical_accuracy: 0.8236 - 18s/epoch - 39ms/step
Epoch 91/100
469/469 - 18s - loss: 0.4837 - sparse_categorical_accuracy: 0.8197 - val_loss: 0.4757 - val_sparse_c
ategorical_accuracy: 0.8241 - 18s/epoch - 39ms/step
Epoch 92/100
469/469 - 18s - loss: 0.4894 - sparse_categorical_accuracy: 0.8162 - val_loss: 0.4785 - val_sparse_c
ategorical_accuracy: 0.8193 - 18s/epoch - 38ms/step
Epoch 93/100
469/469 - 18s - loss: 0.4822 - sparse_categorical_accuracy: 0.8189 - val_loss: 0.4768 - val_sparse_c
ategorical_accuracy: 0.8244 - 18s/epoch - 38ms/step
Epoch 94/100
469/469 - 18s - loss: 0.4857 - sparse_categorical_accuracy: 0.8194 - val_loss: 0.4712 - val_sparse_c
ategorical_accuracy: 0.8250 - 18s/epoch - 38ms/step
Epoch 95/100
469/469 - 18s - loss: 0.4835 - sparse_categorical_accuracy: 0.8190 - val_loss: 0.4727 - val_sparse_c
ategorical_accuracy: 0.8237 - 18s/epoch - 38ms/step
Epoch 96/100
469/469 - 18s - loss: 0.4822 - sparse_categorical_accuracy: 0.8197 - val_loss: 0.4778 - val_sparse_c
ategorical_accuracy: 0.8213 - 18s/epoch - 38ms/step
Epoch 97/100
469/469 - 18s - loss: 0.4819 - sparse_categorical_accuracy: 0.8194 - val_loss: 0.4940 - val_sparse_c
ategorical_accuracy: 0.8135 - 18s/epoch - 38ms/step
Epoch 98/100
469/469 - 18s - loss: 0.4828 - sparse_categorical_accuracy: 0.8180 - val_loss: 0.4741 - val_sparse_c
ategorical_accuracy: 0.8227 - 18s/epoch - 38ms/step
```

```
Epoch 99/100
469/469 - 18s - loss: 0.4807 - sparse_categorical_accuracy: 0.8195 - val_loss: 0.4759 - val_sparse_c
ategorical_accuracy: 0.8239 - 18s/epoch - 38ms/step
Epoch 100/100
469/469 - 18s - loss: 0.4798 - sparse_categorical_accuracy: 0.8192 - val_loss: 0.4743 - val_sparse_c
ategorical_accuracy: 0.8254 - 18s/epoch - 38ms/step
313/313 - 2s - loss: 0.4743 - sparse_categorical_accuracy: 0.8254 - 2s/epoch - 5ms/step
```

Out[ ]:

```
[0.47433599829673767, 0.8253999948501587]
```

In [20]:

```
# model compared with AlexNet
model6 = tf.keras.models.Sequential([
  tf.keras.layers.Input(shape=(28, 28, 1)),
  tf.keras.layers.Conv2D(32, (3, 3)),
  tf.keras.layers.Conv2D(20, (2, 2)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  tf.keras.layers.Flatten(),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.Dense(16, activation='relu'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Dense(10, activation='softmax')
])
model6.summary()
```

```
Model: "sequential_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_17 (Conv2D)          (None, 26, 26, 32)        320

 conv2d_18 (Conv2D)          (None, 25, 25, 20)        2580

 max_pooling2d_18 (MaxPoolin  (None, 12, 12, 20)       0
 g2D)

 max_pooling2d_19 (MaxPoolin  (None, 6, 6, 20)         0
 g2D)

 flatten_9 (Flatten)         (None, 720)               0

 dropout_8 (Dropout)         (None, 720)               0

 dense_27 (Dense)            (None, 16)                11536

 dense_28 (Dense)            (None, 16)                272

 batch_normalization_8 (Batc  (None, 16)               64
 hNormalization)

 dense_29 (Dense)            (None, 10)                170

=================================================================
Total params: 14,942
Trainable params: 14,910
Non-trainable params: 32
_________________________________________________________________
```

In [21]:

```
#Too long to run 1 epoch!
model6.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model6.fit(x_train, y_train,
                    batch_size=128,
                    epochs=10,
                    validation_data=(x_test, y_test),
                    verbose=2
                    )
model6.evaluate(x_test, y_test, verbose=2)
```

```
Epoch 1/10
469/469 - 53s - loss: 0.5337 - sparse_categorical_accuracy: 0.8677 - val_loss: 0.1252 - val_sparse_c
ategorical_accuracy: 0.9691 - 53s/epoch - 113ms/step
Epoch 2/10
469/469 - 47s - loss: 0.1448 - sparse_categorical_accuracy: 0.9614 - val_loss: 0.0956 - val_sparse_c
ategorical_accuracy: 0.9722 - 47s/epoch - 101ms/step
Epoch 3/10
469/469 - 48s - loss: 0.1075 - sparse_categorical_accuracy: 0.9688 - val_loss: 0.0644 - val_sparse_c
ategorical_accuracy: 0.9794 - 48s/epoch - 102ms/step
Epoch 4/10
469/469 - 48s - loss: 0.0900 - sparse_categorical_accuracy: 0.9732 - val_loss: 0.0604 - val_sparse_c
ategorical_accuracy: 0.9812 - 48s/epoch - 102ms/step
Epoch 5/10
469/469 - 47s - loss: 0.0817 - sparse_categorical_accuracy: 0.9749 - val_loss: 0.0564 - val_sparse_c
ategorical_accuracy: 0.9826 - 47s/epoch - 101ms/step
Epoch 6/10
469/469 - 47s - loss: 0.0754 - sparse_categorical_accuracy: 0.9770 - val_loss: 0.0563 - val_sparse_c
ategorical_accuracy: 0.9829 - 47s/epoch - 101ms/step
Epoch 7/10
469/469 - 47s - loss: 0.0689 - sparse_categorical_accuracy: 0.9786 - val_loss: 0.0508 - val_sparse_c
ategorical_accuracy: 0.9839 - 47s/epoch - 100ms/step
Epoch 8/10
469/469 - 47s - loss: 0.0659 - sparse_categorical_accuracy: 0.9794 - val_loss: 0.0478 - val_sparse_c
ategorical_accuracy: 0.9853 - 47s/epoch - 100ms/step
Epoch 9/10
469/469 - 48s - loss: 0.0608 - sparse_categorical_accuracy: 0.9813 - val_loss: 0.0479 - val_sparse_c
ategorical_accuracy: 0.9840 - 48s/epoch - 103ms/step
Epoch 10/10
469/469 - 48s - loss: 0.0603 - sparse_categorical_accuracy: 0.9806 - val_loss: 0.0523 - val_sparse_c
ategorical_accuracy: 0.9830 - 48s/epoch - 101ms/step
313/313 - 3s - loss: 0.0523 - sparse_categorical_accuracy: 0.9830 - 3s/epoch - 10ms/step
```

Out[21]:

```
[0.052256640046834946, 0.9829999804496765]
```

In [22]:

```
model6.compile(optimizer='adam',
               loss='sparse_categorical_crossentropy',
               metrics=['sparse_categorical_accuracy']
               )
model6.fit(fX_train, fY_train,
                     batch_size=128,
                     epochs=10,
                     validation_data=(fX_test, fY_test),
                     verbose=2
                     )
model6.evaluate(fX_test, fY_test, verbose=2)
```

```
Epoch 1/10
469/469 - 49s - loss: 0.9822 - sparse_categorical_accuracy: 0.7048 - val_loss: 0.5369 - val_sparse_c
ategorical_accuracy: 0.8130 - 49s/epoch - 105ms/step
Epoch 2/10
469/469 - 49s - loss: 0.4983 - sparse_categorical_accuracy: 0.8201 - val_loss: 0.4428 - val_sparse_c
ategorical_accuracy: 0.8417 - 49s/epoch - 105ms/step
Epoch 3/10
469/469 - 49s - loss: 0.4275 - sparse_categorical_accuracy: 0.8464 - val_loss: 0.3956 - val_sparse_c
ategorical_accuracy: 0.8604 - 49s/epoch - 105ms/step
Epoch 4/10
469/469 - 48s - loss: 0.3939 - sparse_categorical_accuracy: 0.8582 - val_loss: 0.3848 - val_sparse_c
ategorical_accuracy: 0.8620 - 48s/epoch - 103ms/step
Epoch 5/10
469/469 - 49s - loss: 0.3710 - sparse_categorical_accuracy: 0.8662 - val_loss: 0.3608 - val_sparse_c
ategorical_accuracy: 0.8701 - 49s/epoch - 104ms/step
Epoch 6/10
469/469 - 48s - loss: 0.3570 - sparse_categorical_accuracy: 0.8720 - val_loss: 0.3475 - val_sparse_c
ategorical_accuracy: 0.8771 - 48s/epoch - 102ms/step
Epoch 7/10
469/469 - 48s - loss: 0.3413 - sparse_categorical_accuracy: 0.8775 - val_loss: 0.3372 - val_sparse_c
ategorical_accuracy: 0.8809 - 48s/epoch - 102ms/step
Epoch 8/10
469/469 - 48s - loss: 0.3335 - sparse_categorical_accuracy: 0.8794 - val_loss: 0.3381 - val_sparse_c
ategorical_accuracy: 0.8822 - 48s/epoch - 102ms/step
Epoch 9/10
469/469 - 48s - loss: 0.3293 - sparse_categorical_accuracy: 0.8813 - val_loss: 0.3273 - val_sparse_c
ategorical_accuracy: 0.8847 - 48s/epoch - 103ms/step
Epoch 10/10
469/469 - 49s - loss: 0.3211 - sparse_categorical_accuracy: 0.8833 - val_loss: 0.3202 - val_sparse_c
ategorical_accuracy: 0.8876 - 49s/epoch - 104ms/step
313/313 - 3s - loss: 0.3202 - sparse_categorical_accuracy: 0.8876 - 3s/epoch - 10ms/step
```

Out[22]:

```
[0.3201732635498047, 0.8876000046730042]
```

In [21]:

In [ ]: