In [1]:

```
import tensorflow as tf
```

In [2]:

```
# Load Data
(x_train, y_train), (x_test, y_test) = tf.keras.datasets.fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-labels-idx1-
ubyte.gz
32768/29515 [================================] - 0s 2us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-images-idx3-
ubyte.gz
26427392/26421880 [==============================] - 4s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-labels-idx1-u
byte.gz
8192/5148 [===============================================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-images-idx3-u
byte.gz
4423680/4422102 [==============================] - 1s 0us/step
```

## Baseline Model

In [3]:

```
# 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 [4]:

```
# Baseline model compilation
# Learning rate 0.001
optimizer = tf.keras.optimizers.Adam(learning_rate=0.001)

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

In [5]:

```
# 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 - 1s - loss: 3.0479 - sparse_categorical_accuracy: 0.2256 - val_loss: 1.7689 - val_sparse_ca
tegorical_accuracy: 0.3199
Epoch 2/100
469/469 - 1s - loss: 1.6926 - sparse_categorical_accuracy: 0.3397 - val_loss: 1.6341 - val_sparse_ca
tegorical_accuracy: 0.3517
Epoch 3/100
469/469 - 1s - loss: 1.5966 - sparse_categorical_accuracy: 0.3520 - val_loss: 1.5751 - val_sparse_ca
tegorical_accuracy: 0.3547
Epoch 4/100
469/469 - 1s - loss: 1.5438 - sparse_categorical_accuracy: 0.3603 - val_loss: 1.5355 - val_sparse_ca
tegorical_accuracy: 0.3628
Epoch 5/100
469/469 - 1s - loss: 1.5112 - sparse_categorical_accuracy: 0.3658 - val_loss: 1.4985 - val_sparse_ca
tegorical_accuracy: 0.3681
Epoch 6/100
469/469 - 1s - loss: 1.4855 - sparse_categorical_accuracy: 0.3698 - val_loss: 1.4886 - val_sparse_ca
tegorical_accuracy: 0.3711
Epoch 7/100
469/469 - 1s - loss: 1.4772 - sparse_categorical_accuracy: 0.3702 - val_loss: 1.4886 - val_sparse_ca
tegorical_accuracy: 0.3741
Epoch 8/100
469/469 - 1s - loss: 1.3825 - sparse_categorical_accuracy: 0.4257 - val_loss: 1.3746 - val_sparse_ca
```

```
tegorical_accuracy: 0.4438
Epoch 9/100
469/469 - 1s - loss: 1.2631 - sparse_categorical_accuracy: 0.4649 - val_loss: 1.2530 - val_sparse_ca
tegorical_accuracy: 0.4648
Epoch 10/100
469/469 - 1s - loss: 1.0655 - sparse_categorical_accuracy: 0.5362 - val_loss: 0.9885 - val_sparse_ca
tegorical_accuracy: 0.5598
Epoch 11/100
469/469 - 1s - loss: 0.9395 - sparse_categorical_accuracy: 0.5800 - val_loss: 0.9447 - val_sparse_ca
tegorical_accuracy: 0.5997
Epoch 12/100
469/469 - 1s - loss: 0.8987 - sparse_categorical_accuracy: 0.6113 - val_loss: 0.8801 - val_sparse_ca
tegorical_accuracy: 0.6272
Epoch 13/100
469/469 - 1s - loss: 0.8691 - sparse_categorical_accuracy: 0.6267 - val_loss: 0.8794 - val_sparse_ca
tegorical_accuracy: 0.6302
Epoch 14/100
469/469 - 1s - loss: 0.8504 - sparse_categorical_accuracy: 0.6366 - val_loss: 0.8899 - val_sparse_ca
tegorical_accuracy: 0.6214
Epoch 15/100
469/469 - 1s - loss: 0.8474 - sparse_categorical_accuracy: 0.6360 - val_loss: 0.9469 - val_sparse_ca
tegorical_accuracy: 0.6444
Epoch 16/100
469/469 - 1s - loss: 0.8313 - sparse_categorical_accuracy: 0.6437 - val_loss: 0.8365 - val_sparse_ca
tegorical_accuracy: 0.6411
Epoch 17/100
469/469 - 1s - loss: 0.8322 - sparse_categorical_accuracy: 0.6409 - val_loss: 0.8536 - val_sparse_ca
tegorical_accuracy: 0.6352
Epoch 18/100
469/469 - 1s - loss: 0.8387 - sparse_categorical_accuracy: 0.6388 - val_loss: 0.8568 - val_sparse_ca
tegorical_accuracy: 0.6413
Epoch 19/100
469/469 - 1s - loss: 0.8205 - sparse_categorical_accuracy: 0.6449 - val_loss: 0.8600 - val_sparse_ca
tegorical_accuracy: 0.6336
Epoch 20/100
469/469 - 1s - loss: 0.8180 - sparse_categorical_accuracy: 0.6456 - val_loss: 0.8512 - val_sparse_ca
tegorical_accuracy: 0.6437
Epoch 21/100
469/469 - 1s - loss: 0.8114 - sparse_categorical_accuracy: 0.6475 - val_loss: 0.8448 - val_sparse_ca
tegorical_accuracy: 0.6347
Epoch 22/100
469/469 - 1s - loss: 0.8200 - sparse_categorical_accuracy: 0.6447 - val_loss: 0.8495 - val_sparse_ca
tegorical_accuracy: 0.6426
Epoch 23/100
469/469 - 1s - loss: 0.8012 - sparse_categorical_accuracy: 0.6518 - val_loss: 0.8691 - val_sparse_ca
tegorical_accuracy: 0.6441
Epoch 24/100
469/469 - 1s - loss: 0.8079 - sparse_categorical_accuracy: 0.6490 - val_loss: 0.8343 - val_sparse_ca
tegorical_accuracy: 0.6404
Epoch 25/100
469/469 - 1s - loss: 0.8032 - sparse_categorical_accuracy: 0.6493 - val_loss: 0.9195 - val_sparse_ca
tegorical_accuracy: 0.6418
Epoch 26/100
469/469 - 1s - loss: 0.8014 - sparse_categorical_accuracy: 0.6494 - val_loss: 0.8515 - val_sparse_ca
tegorical_accuracy: 0.6372
Epoch 27/100
469/469 - 1s - loss: 0.8083 - sparse_categorical_accuracy: 0.6513 - val_loss: 0.9022 - val_sparse_ca
tegorical_accuracy: 0.6256
Epoch 28/100
469/469 - 1s - loss: 0.8074 - sparse_categorical_accuracy: 0.6510 - val_loss: 0.8313 - val_sparse_ca
tegorical_accuracy: 0.6440
Epoch 29/100
469/469 - 1s - loss: 0.8006 - sparse_categorical_accuracy: 0.6571 - val_loss: 0.8351 - val_sparse_ca
tegorical_accuracy: 0.6422
Epoch 30/100
469/469 - 1s - loss: 0.7819 - sparse_categorical_accuracy: 0.6578 - val_loss: 0.8283 - val_sparse_ca
tegorical_accuracy: 0.6451
Epoch 31/100
469/469 - 1s - loss: 0.7931 - sparse_categorical_accuracy: 0.6524 - val_loss: 0.8537 - val_sparse_ca
tegorical_accuracy: 0.6435
Epoch 32/100
469/469 - 1s - loss: 0.7851 - sparse_categorical_accuracy: 0.6527 - val_loss: 0.8464 - val_sparse_ca
tegorical_accuracy: 0.6370
Epoch 33/100
469/469 - 1s - loss: 0.7852 - sparse_categorical_accuracy: 0.6569 - val_loss: 0.8797 - val_sparse_ca
tegorical_accuracy: 0.6449
Epoch 34/100
469/469 - 1s - loss: 0.7794 - sparse_categorical_accuracy: 0.6662 - val_loss: 0.8134 - val_sparse_ca
tegorical_accuracy: 0.6693
Epoch 35/100
469/469 - 1s - loss: 0.7482 - sparse_categorical_accuracy: 0.7000 - val_loss: 0.7743 - val_sparse_ca
tegorical_accuracy: 0.7028
Epoch 36/100
```

```
469/469 - 1s - loss: 0.7252 - sparse_categorical_accuracy: 0.7116 - val_loss: 0.7558 - val_sparse_ca
tegorical_accuracy: 0.7075
Epoch 37/100
469/469 - 1s - loss: 0.7022 - sparse_categorical_accuracy: 0.7196 - val_loss: 0.7443 - val_sparse_ca
tegorical_accuracy: 0.7161
Epoch 38/100
469/469 - 1s - loss: 0.6948 - sparse_categorical_accuracy: 0.7288 - val_loss: 0.7105 - val_sparse_ca
tegorical_accuracy: 0.7406
Epoch 39/100
469/469 - 1s - loss: 0.6682 - sparse_categorical_accuracy: 0.7437 - val_loss: 0.7160 - val_sparse_ca
tegorical_accuracy: 0.7451
Epoch 40/100
469/469 - 1s - loss: 0.6535 - sparse_categorical_accuracy: 0.7515 - val_loss: 0.6914 - val_sparse_ca
tegorical_accuracy: 0.7511
Epoch 41/100
469/469 - 1s - loss: 0.6460 - sparse_categorical_accuracy: 0.7576 - val_loss: 0.6687 - val_sparse_ca
tegorical_accuracy: 0.7598
Epoch 42/100
469/469 - 1s - loss: 0.6396 - sparse_categorical_accuracy: 0.7591 - val_loss: 0.6826 - val_sparse_ca
tegorical_accuracy: 0.7499
Epoch 43/100
469/469 - 1s - loss: 0.6255 - sparse_categorical_accuracy: 0.7655 - val_loss: 0.6818 - val_sparse_ca
tegorical_accuracy: 0.7394
Epoch 44/100
469/469 - 1s - loss: 0.6217 - sparse_categorical_accuracy: 0.7671 - val_loss: 0.6897 - val_sparse_ca
tegorical_accuracy: 0.7522
Epoch 45/100
469/469 - 1s - loss: 0.6184 - sparse_categorical_accuracy: 0.7687 - val_loss: 0.6470 - val_sparse_ca
tegorical_accuracy: 0.7626
Epoch 46/100
469/469 - 1s - loss: 0.6182 - sparse_categorical_accuracy: 0.7700 - val_loss: 0.6450 - val_sparse_ca
tegorical_accuracy: 0.7645
Epoch 47/100
469/469 - 1s - loss: 0.6124 - sparse_categorical_accuracy: 0.7717 - val_loss: 0.6586 - val_sparse_ca
tegorical_accuracy: 0.7626
Epoch 48/100
469/469 - 1s - loss: 0.5982 - sparse_categorical_accuracy: 0.7751 - val_loss: 0.6512 - val_sparse_ca
tegorical_accuracy: 0.7589
Epoch 49/100
469/469 - 1s - loss: 0.6012 - sparse_categorical_accuracy: 0.7727 - val_loss: 0.6429 - val_sparse_ca
tegorical_accuracy: 0.7688
Epoch 50/100
469/469 - 1s - loss: 0.5960 - sparse_categorical_accuracy: 0.7764 - val_loss: 0.6621 - val_sparse_ca
tegorical_accuracy: 0.7645
Epoch 51/100
469/469 - 1s - loss: 0.6081 - sparse_categorical_accuracy: 0.7740 - val_loss: 0.6381 - val_sparse_ca
tegorical_accuracy: 0.7695
Epoch 52/100
469/469 - 1s - loss: 0.5930 - sparse_categorical_accuracy: 0.7778 - val_loss: 0.6474 - val_sparse_ca
tegorical_accuracy: 0.7662
Epoch 53/100
469/469 - 1s - loss: 0.5908 - sparse_categorical_accuracy: 0.7796 - val_loss: 0.6691 - val_sparse_ca
tegorical_accuracy: 0.7647
Epoch 54/100
469/469 - 1s - loss: 0.5977 - sparse_categorical_accuracy: 0.7768 - val_loss: 0.6440 - val_sparse_ca
tegorical_accuracy: 0.7620
Epoch 55/100
469/469 - 1s - loss: 0.5826 - sparse_categorical_accuracy: 0.7812 - val_loss: 0.6279 - val_sparse_ca
tegorical_accuracy: 0.7738
Epoch 56/100
469/469 - 1s - loss: 0.5795 - sparse_categorical_accuracy: 0.7841 - val_loss: 0.6341 - val_sparse_ca
tegorical_accuracy: 0.7778
Epoch 57/100
469/469 - 1s - loss: 0.5819 - sparse_categorical_accuracy: 0.7835 - val_loss: 0.6764 - val_sparse_ca
tegorical_accuracy: 0.7613
Epoch 58/100
469/469 - 1s - loss: 0.5771 - sparse_categorical_accuracy: 0.7831 - val_loss: 0.6409 - val_sparse_ca
tegorical_accuracy: 0.7711
Epoch 59/100
469/469 - 1s - loss: 0.5719 - sparse_categorical_accuracy: 0.7865 - val_loss: 0.6665 - val_sparse_ca
tegorical_accuracy: 0.7587
Epoch 60/100
469/469 - 1s - loss: 0.5876 - sparse_categorical_accuracy: 0.7800 - val_loss: 0.6440 - val_sparse_ca
tegorical_accuracy: 0.7690
Epoch 61/100
469/469 - 1s - loss: 0.5770 - sparse_categorical_accuracy: 0.7851 - val_loss: 0.6206 - val_sparse_ca
tegorical_accuracy: 0.7821
Epoch 62/100
469/469 - 1s - loss: 0.5775 - sparse_categorical_accuracy: 0.7839 - val_loss: 0.6650 - val_sparse_ca
tegorical_accuracy: 0.7516
Epoch 63/100
469/469 - 1s - loss: 0.5756 - sparse_categorical_accuracy: 0.7875 - val_loss: 0.6278 - val_sparse_ca
tegorical_accuracy: 0.7754
```

```
Epoch 64/100
469/469 - 1s - loss: 0.5726 - sparse_categorical_accuracy: 0.7849 - val_loss: 0.6569 - val_sparse_ca
tegorical_accuracy: 0.7673
Epoch 65/100
469/469 - 1s - loss: 0.5702 - sparse_categorical_accuracy: 0.7879 - val_loss: 0.6286 - val_sparse_ca
tegorical_accuracy: 0.7710
Epoch 66/100
469/469 - 1s - loss: 0.5681 - sparse_categorical_accuracy: 0.7873 - val_loss: 0.6338 - val_sparse_ca
tegorical_accuracy: 0.7755
Epoch 67/100
469/469 - 1s - loss: 0.5617 - sparse_categorical_accuracy: 0.7887 - val_loss: 0.6126 - val_sparse_ca
tegorical_accuracy: 0.7843
Epoch 68/100
469/469 - 1s - loss: 0.5612 - sparse_categorical_accuracy: 0.7891 - val_loss: 0.7142 - val_sparse_ca
tegorical_accuracy: 0.7451
Epoch 69/100
469/469 - 1s - loss: 0.5611 - sparse_categorical_accuracy: 0.7892 - val_loss: 0.6316 - val_sparse_ca
tegorical_accuracy: 0.7744
Epoch 70/100
469/469 - 1s - loss: 0.5557 - sparse_categorical_accuracy: 0.7916 - val_loss: 0.6313 - val_sparse_ca
tegorical_accuracy: 0.7744
Epoch 71/100
469/469 - 1s - loss: 0.5595 - sparse_categorical_accuracy: 0.7904 - val_loss: 0.6879 - val_sparse_ca
tegorical_accuracy: 0.7452
Epoch 72/100
469/469 - 1s - loss: 0.5630 - sparse_categorical_accuracy: 0.7885 - val_loss: 0.6591 - val_sparse_ca
tegorical_accuracy: 0.7483
Epoch 73/100
469/469 - 1s - loss: 0.5574 - sparse_categorical_accuracy: 0.7903 - val_loss: 0.6343 - val_sparse_ca
tegorical_accuracy: 0.7758
Epoch 74/100
469/469 - 1s - loss: 0.5636 - sparse_categorical_accuracy: 0.7892 - val_loss: 0.6414 - val_sparse_ca
tegorical_accuracy: 0.7568
Epoch 75/100
469/469 - 1s - loss: 0.5650 - sparse_categorical_accuracy: 0.7866 - val_loss: 0.6263 - val_sparse_ca
tegorical_accuracy: 0.7728
Epoch 76/100
469/469 - 1s - loss: 0.5464 - sparse_categorical_accuracy: 0.7946 - val_loss: 0.6052 - val_sparse_ca
tegorical_accuracy: 0.7809
Epoch 77/100
469/469 - 1s - loss: 0.5445 - sparse_categorical_accuracy: 0.7950 - val_loss: 0.6187 - val_sparse_ca
tegorical_accuracy: 0.7830
Epoch 78/100
469/469 - 1s - loss: 0.5530 - sparse_categorical_accuracy: 0.7919 - val_loss: 0.6313 - val_sparse_ca
tegorical_accuracy: 0.7713
Epoch 79/100
469/469 - 1s - loss: 0.5487 - sparse_categorical_accuracy: 0.7944 - val_loss: 0.6239 - val_sparse_ca
tegorical_accuracy: 0.7759
Epoch 80/100
469/469 - 1s - loss: 0.5482 - sparse_categorical_accuracy: 0.7947 - val_loss: 0.6061 - val_sparse_ca
tegorical_accuracy: 0.7791
Epoch 81/100
469/469 - 1s - loss: 0.5452 - sparse_categorical_accuracy: 0.7977 - val_loss: 0.6112 - val_sparse_ca
tegorical_accuracy: 0.7835
Epoch 82/100
469/469 - 1s - loss: 0.5476 - sparse_categorical_accuracy: 0.7972 - val_loss: 0.5969 - val_sparse_ca
tegorical_accuracy: 0.7880
Epoch 83/100
469/469 - 1s - loss: 0.5374 - sparse_categorical_accuracy: 0.7991 - val_loss: 0.6148 - val_sparse_ca
tegorical_accuracy: 0.7832
Epoch 84/100
469/469 - 1s - loss: 0.5443 - sparse_categorical_accuracy: 0.7972 - val_loss: 0.7188 - val_sparse_ca
tegorical_accuracy: 0.7331
Epoch 85/100
469/469 - 1s - loss: 0.5511 - sparse_categorical_accuracy: 0.7936 - val_loss: 0.6116 - val_sparse_ca
tegorical_accuracy: 0.7722
Epoch 86/100
469/469 - 1s - loss: 0.5325 - sparse_categorical_accuracy: 0.8014 - val_loss: 0.6109 - val_sparse_ca
tegorical_accuracy: 0.7865
Epoch 87/100
469/469 - 1s - loss: 0.5416 - sparse_categorical_accuracy: 0.7994 - val_loss: 0.6093 - val_sparse_ca
tegorical_accuracy: 0.7857
Epoch 88/100
469/469 - 1s - loss: 0.5355 - sparse_categorical_accuracy: 0.7986 - val_loss: 0.5964 - val_sparse_ca
tegorical_accuracy: 0.7820
Epoch 89/100
469/469 - 1s - loss: 0.5385 - sparse_categorical_accuracy: 0.7975 - val_loss: 0.6067 - val_sparse_ca
tegorical_accuracy: 0.7872
Epoch 90/100
469/469 - 1s - loss: 0.5339 - sparse_categorical_accuracy: 0.8011 - val_loss: 0.6044 - val_sparse_ca
tegorical_accuracy: 0.7907
Epoch 91/100
469/469 - 1s - loss: 0.5316 - sparse_categorical_accuracy: 0.8030 - val_loss: 0.6080 - val_sparse_ca
```

```
tegorical_accuracy: 0.7866
Epoch 92/100
469/469 - 1s - loss: 0.5433 - sparse_categorical_accuracy: 0.7970 - val_loss: 0.5991 - val_sparse_ca
tegorical_accuracy: 0.7848
Epoch 93/100
469/469 - 1s - loss: 0.5256 - sparse_categorical_accuracy: 0.8054 - val_loss: 0.6332 - val_sparse_ca
tegorical_accuracy: 0.7752
Epoch 94/100
469/469 - 1s - loss: 0.5334 - sparse_categorical_accuracy: 0.8013 - val_loss: 0.6054 - val_sparse_ca
tegorical_accuracy: 0.7862
Epoch 95/100
469/469 - 1s - loss: 0.5315 - sparse_categorical_accuracy: 0.8022 - val_loss: 0.6144 - val_sparse_ca
tegorical_accuracy: 0.7799
Epoch 96/100
469/469 - 1s - loss: 0.5260 - sparse_categorical_accuracy: 0.8057 - val_loss: 0.6060 - val_sparse_ca
tegorical_accuracy: 0.7810
Epoch 97/100
469/469 - 1s - loss: 0.5305 - sparse_categorical_accuracy: 0.8016 - val_loss: 0.5992 - val_sparse_ca
tegorical_accuracy: 0.7905
Epoch 98/100
469/469 - 1s - loss: 0.5264 - sparse_categorical_accuracy: 0.8071 - val_loss: 0.6071 - val_sparse_ca
tegorical_accuracy: 0.7851
Epoch 99/100
469/469 - 1s - loss: 0.5264 - sparse_categorical_accuracy: 0.8042 - val_loss: 0.5991 - val_sparse_ca
tegorical_accuracy: 0.7879
Epoch 100/100
469/469 - 1s - loss: 0.5294 - sparse_categorical_accuracy: 0.8028 - val_loss: 0.5960 - val_sparse_ca
tegorical_accuracy: 0.7901
```

In [6]:

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

```
313/313 - 0s - loss: 0.5960 - sparse_categorical_accuracy: 0.7901
```

Out[6]:

```
[0.5960487723350525, 0.7900999784469604]
```

In [7]:

```
# Learning rate 0.0001
optimizer = tf.keras.optimizers.Adam(learning_rate=0.0001)

model.compile(optimizer=optimizer,
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
             )
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 - 1s - loss: 0.5069 - sparse_categorical_accuracy: 0.8130 - val_loss: 0.5828 - val_sparse_ca
tegorical_accuracy: 0.7944
Epoch 2/100
469/469 - 1s - loss: 0.5022 - sparse_categorical_accuracy: 0.8135 - val_loss: 0.5814 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 3/100
469/469 - 1s - loss: 0.4978 - sparse_categorical_accuracy: 0.8159 - val_loss: 0.5829 - val_sparse_ca
tegorical_accuracy: 0.7924
Epoch 4/100
469/469 - 1s - loss: 0.4972 - sparse_categorical_accuracy: 0.8149 - val_loss: 0.5795 - val_sparse_ca
tegorical_accuracy: 0.7968
Epoch 5/100
469/469 - 1s - loss: 0.4959 - sparse_categorical_accuracy: 0.8147 - val_loss: 0.5825 - val_sparse_ca
tegorical_accuracy: 0.7932
Epoch 6/100
469/469 - 1s - loss: 0.4940 - sparse_categorical_accuracy: 0.8162 - val_loss: 0.5800 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 7/100
469/469 - 1s - loss: 0.4933 - sparse_categorical_accuracy: 0.8178 - val_loss: 0.5818 - val_sparse_ca
tegorical_accuracy: 0.7934
Epoch 8/100
469/469 - 1s - loss: 0.4928 - sparse_categorical_accuracy: 0.8180 - val_loss: 0.5818 - val_sparse_ca
tegorical_accuracy: 0.7964
Epoch 9/100
469/469 - 1s - loss: 0.4924 - sparse_categorical_accuracy: 0.8189 - val_loss: 0.5802 - val_sparse_ca
tegorical_accuracy: 0.7992
Epoch 10/100
```

```
469/469 - 1s - loss: 0.4925 - sparse_categorical_accuracy: 0.8188 - val_loss: 0.5786 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 11/100
469/469 - 1s - loss: 0.4929 - sparse_categorical_accuracy: 0.8183 - val_loss: 0.5815 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 12/100
469/469 - 1s - loss: 0.4918 - sparse_categorical_accuracy: 0.8184 - val_loss: 0.5828 - val_sparse_ca
tegorical_accuracy: 0.7961
Epoch 13/100
469/469 - 1s - loss: 0.4911 - sparse_categorical_accuracy: 0.8192 - val_loss: 0.5837 - val_sparse_ca
tegorical_accuracy: 0.7953
Epoch 14/100
469/469 - 1s - loss: 0.4905 - sparse_categorical_accuracy: 0.8194 - val_loss: 0.5794 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 15/100
469/469 - 1s - loss: 0.4906 - sparse_categorical_accuracy: 0.8195 - val_loss: 0.5823 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 16/100
469/469 - 1s - loss: 0.4903 - sparse_categorical_accuracy: 0.8195 - val_loss: 0.5793 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 17/100
469/469 - 1s - loss: 0.4897 - sparse_categorical_accuracy: 0.8193 - val_loss: 0.5797 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 18/100
469/469 - 1s - loss: 0.4898 - sparse_categorical_accuracy: 0.8192 - val_loss: 0.5811 - val_sparse_ca
tegorical_accuracy: 0.7955
Epoch 19/100
469/469 - 1s - loss: 0.4890 - sparse_categorical_accuracy: 0.8205 - val_loss: 0.5833 - val_sparse_ca
tegorical_accuracy: 0.7936
Epoch 20/100
469/469 - 1s - loss: 0.4891 - sparse_categorical_accuracy: 0.8187 - val_loss: 0.5816 - val_sparse_ca
tegorical_accuracy: 0.7957
Epoch 21/100
469/469 - 1s - loss: 0.4886 - sparse_categorical_accuracy: 0.8201 - val_loss: 0.5812 - val_sparse_ca
tegorical_accuracy: 0.7944
Epoch 22/100
469/469 - 1s - loss: 0.4881 - sparse_categorical_accuracy: 0.8195 - val_loss: 0.5801 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 23/100
469/469 - 1s - loss: 0.4869 - sparse_categorical_accuracy: 0.8207 - val_loss: 0.5848 - val_sparse_ca
tegorical_accuracy: 0.7966
Epoch 24/100
469/469 - 1s - loss: 0.4884 - sparse_categorical_accuracy: 0.8199 - val_loss: 0.5840 - val_sparse_ca
tegorical_accuracy: 0.7965
Epoch 25/100
469/469 - 1s - loss: 0.4881 - sparse_categorical_accuracy: 0.8204 - val_loss: 0.5835 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 26/100
469/469 - 1s - loss: 0.4868 - sparse_categorical_accuracy: 0.8210 - val_loss: 0.5815 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 27/100
469/469 - 1s - loss: 0.4864 - sparse_categorical_accuracy: 0.8207 - val_loss: 0.5838 - val_sparse_ca
tegorical_accuracy: 0.7957
Epoch 28/100
469/469 - 1s - loss: 0.4862 - sparse_categorical_accuracy: 0.8209 - val_loss: 0.5835 - val_sparse_ca
tegorical_accuracy: 0.7948
Epoch 29/100
469/469 - 1s - loss: 0.4864 - sparse_categorical_accuracy: 0.8210 - val_loss: 0.5865 - val_sparse_ca
tegorical_accuracy: 0.7963
Epoch 30/100
469/469 - 1s - loss: 0.4867 - sparse_categorical_accuracy: 0.8209 - val_loss: 0.5858 - val_sparse_ca
tegorical_accuracy: 0.7948
Epoch 31/100
469/469 - 1s - loss: 0.4861 - sparse_categorical_accuracy: 0.8212 - val_loss: 0.5846 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 32/100
469/469 - 1s - loss: 0.4856 - sparse_categorical_accuracy: 0.8208 - val_loss: 0.5843 - val_sparse_ca
tegorical_accuracy: 0.7968
Epoch 33/100
469/469 - 1s - loss: 0.4851 - sparse_categorical_accuracy: 0.8208 - val_loss: 0.5829 - val_sparse_ca
tegorical_accuracy: 0.7972
Epoch 34/100
469/469 - 1s - loss: 0.4849 - sparse_categorical_accuracy: 0.8207 - val_loss: 0.5855 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 35/100
469/469 - 1s - loss: 0.4853 - sparse_categorical_accuracy: 0.8210 - val_loss: 0.5863 - val_sparse_ca
tegorical_accuracy: 0.7956
Epoch 36/100
469/469 - 1s - loss: 0.4848 - sparse_categorical_accuracy: 0.8215 - val_loss: 0.5873 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 37/100
469/469 - 1s - loss: 0.4846 - sparse_categorical_accuracy: 0.8211 - val_loss: 0.5846 - val_sparse_ca
tegorical_accuracy: 0.7973
```

```
Epoch 38/100
469/469 - 1s - loss: 0.4843 - sparse_categorical_accuracy: 0.8223 - val_loss: 0.5862 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 39/100
469/469 - 1s - loss: 0.4847 - sparse_categorical_accuracy: 0.8214 - val_loss: 0.5887 - val_sparse_ca
tegorical_accuracy: 0.7959
Epoch 40/100
469/469 - 1s - loss: 0.4844 - sparse_categorical_accuracy: 0.8215 - val_loss: 0.5867 - val_sparse_ca
tegorical_accuracy: 0.7963
Epoch 41/100
469/469 - 1s - loss: 0.4838 - sparse_categorical_accuracy: 0.8219 - val_loss: 0.5839 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 42/100
469/469 - 1s - loss: 0.4843 - sparse_categorical_accuracy: 0.8214 - val_loss: 0.5867 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 43/100
469/469 - 1s - loss: 0.4842 - sparse_categorical_accuracy: 0.8218 - val_loss: 0.5889 - val_sparse_ca
tegorical_accuracy: 0.7983
Epoch 44/100
469/469 - 1s - loss: 0.4844 - sparse_categorical_accuracy: 0.8213 - val_loss: 0.5926 - val_sparse_ca
tegorical_accuracy: 0.7951
Epoch 45/100
469/469 - 1s - loss: 0.4843 - sparse_categorical_accuracy: 0.8218 - val_loss: 0.5886 - val_sparse_ca
tegorical_accuracy: 0.7934
Epoch 46/100
469/469 - 1s - loss: 0.4833 - sparse_categorical_accuracy: 0.8219 - val_loss: 0.5886 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 47/100
469/469 - 1s - loss: 0.4834 - sparse_categorical_accuracy: 0.8224 - val_loss: 0.5901 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 48/100
469/469 - 1s - loss: 0.4831 - sparse_categorical_accuracy: 0.8215 - val_loss: 0.5914 - val_sparse_ca
tegorical_accuracy: 0.7941
Epoch 49/100
469/469 - 1s - loss: 0.4828 - sparse_categorical_accuracy: 0.8221 - val_loss: 0.5927 - val_sparse_ca
tegorical_accuracy: 0.7961
Epoch 50/100
469/469 - 1s - loss: 0.4832 - sparse_categorical_accuracy: 0.8220 - val_loss: 0.5884 - val_sparse_ca
tegorical_accuracy: 0.7966
Epoch 51/100
469/469 - 1s - loss: 0.4821 - sparse_categorical_accuracy: 0.8229 - val_loss: 0.5928 - val_sparse_ca
tegorical_accuracy: 0.7957
Epoch 52/100
469/469 - 1s - loss: 0.4822 - sparse_categorical_accuracy: 0.8219 - val_loss: 0.5871 - val_sparse_ca
tegorical_accuracy: 0.7962
Epoch 53/100
469/469 - 1s - loss: 0.4820 - sparse_categorical_accuracy: 0.8228 - val_loss: 0.5919 - val_sparse_ca
tegorical_accuracy: 0.7961
Epoch 54/100
469/469 - 1s - loss: 0.4817 - sparse_categorical_accuracy: 0.8233 - val_loss: 0.5949 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 55/100
469/469 - 1s - loss: 0.4838 - sparse_categorical_accuracy: 0.8212 - val_loss: 0.5937 - val_sparse_ca
tegorical_accuracy: 0.7969
Epoch 56/100
469/469 - 1s - loss: 0.4821 - sparse_categorical_accuracy: 0.8228 - val_loss: 0.5983 - val_sparse_ca
tegorical_accuracy: 0.7957
Epoch 57/100
469/469 - 1s - loss: 0.4817 - sparse_categorical_accuracy: 0.8231 - val_loss: 0.5999 - val_sparse_ca
tegorical_accuracy: 0.7909
Epoch 58/100
469/469 - 1s - loss: 0.4810 - sparse_categorical_accuracy: 0.8231 - val_loss: 0.5945 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 59/100
469/469 - 1s - loss: 0.4809 - sparse_categorical_accuracy: 0.8233 - val_loss: 0.5927 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 60/100
469/469 - 1s - loss: 0.4809 - sparse_categorical_accuracy: 0.8228 - val_loss: 0.5954 - val_sparse_ca
tegorical_accuracy: 0.7958
Epoch 61/100
469/469 - 1s - loss: 0.4810 - sparse_categorical_accuracy: 0.8223 - val_loss: 0.5974 - val_sparse_ca
tegorical_accuracy: 0.7966
Epoch 62/100
469/469 - 1s - loss: 0.4805 - sparse_categorical_accuracy: 0.8227 - val_loss: 0.5982 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 63/100
469/469 - 1s - loss: 0.4801 - sparse_categorical_accuracy: 0.8232 - val_loss: 0.5967 - val_sparse_ca
tegorical_accuracy: 0.7960
Epoch 64/100
469/469 - 1s - loss: 0.4809 - sparse_categorical_accuracy: 0.8231 - val_loss: 0.5941 - val_sparse_ca
tegorical_accuracy: 0.7948
Epoch 65/100
469/469 - 1s - loss: 0.4805 - sparse_categorical_accuracy: 0.8230 - val_loss: 0.5959 - val_sparse_ca
```

```
tegorical_accuracy: 0.7945
Epoch 66/100
469/469 - 1s - loss: 0.4804 - sparse_categorical_accuracy: 0.8236 - val_loss: 0.5969 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 67/100
469/469 - 1s - loss: 0.4796 - sparse_categorical_accuracy: 0.8241 - val_loss: 0.5953 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 68/100
469/469 - 1s - loss: 0.4804 - sparse_categorical_accuracy: 0.8232 - val_loss: 0.5948 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 69/100
469/469 - 1s - loss: 0.4810 - sparse_categorical_accuracy: 0.8227 - val_loss: 0.5950 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 70/100
469/469 - 1s - loss: 0.4800 - sparse_categorical_accuracy: 0.8237 - val_loss: 0.5979 - val_sparse_ca
tegorical_accuracy: 0.7994
Epoch 71/100
469/469 - 1s - loss: 0.4802 - sparse_categorical_accuracy: 0.8231 - val_loss: 0.5983 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 72/100
469/469 - 1s - loss: 0.4791 - sparse_categorical_accuracy: 0.8239 - val_loss: 0.5946 - val_sparse_ca
tegorical_accuracy: 0.7989
Epoch 73/100
469/469 - 1s - loss: 0.4799 - sparse_categorical_accuracy: 0.8232 - val_loss: 0.5978 - val_sparse_ca
tegorical_accuracy: 0.7959
Epoch 74/100
469/469 - 1s - loss: 0.4794 - sparse_categorical_accuracy: 0.8236 - val_loss: 0.5939 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 75/100
469/469 - 1s - loss: 0.4800 - sparse_categorical_accuracy: 0.8235 - val_loss: 0.5996 - val_sparse_ca
tegorical_accuracy: 0.7963
Epoch 76/100
469/469 - 1s - loss: 0.4792 - sparse_categorical_accuracy: 0.8239 - val_loss: 0.5990 - val_sparse_ca
tegorical_accuracy: 0.7965
Epoch 77/100
469/469 - 1s - loss: 0.4799 - sparse_categorical_accuracy: 0.8234 - val_loss: 0.6012 - val_sparse_ca
tegorical_accuracy: 0.7952
Epoch 78/100
469/469 - 1s - loss: 0.4781 - sparse_categorical_accuracy: 0.8242 - val_loss: 0.6036 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 79/100
469/469 - 1s - loss: 0.4784 - sparse_categorical_accuracy: 0.8234 - val_loss: 0.5983 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 80/100
469/469 - 1s - loss: 0.4782 - sparse_categorical_accuracy: 0.8238 - val_loss: 0.5981 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 81/100
469/469 - 1s - loss: 0.4791 - sparse_categorical_accuracy: 0.8236 - val_loss: 0.6002 - val_sparse_ca
tegorical_accuracy: 0.7958
Epoch 82/100
469/469 - 1s - loss: 0.4789 - sparse_categorical_accuracy: 0.8244 - val_loss: 0.6011 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 83/100
469/469 - 1s - loss: 0.4782 - sparse_categorical_accuracy: 0.8245 - val_loss: 0.6019 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 84/100
469/469 - 1s - loss: 0.4781 - sparse_categorical_accuracy: 0.8243 - val_loss: 0.6015 - val_sparse_ca
tegorical_accuracy: 0.7991
Epoch 85/100
469/469 - 1s - loss: 0.4779 - sparse_categorical_accuracy: 0.8246 - val_loss: 0.5995 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 86/100
469/469 - 1s - loss: 0.4795 - sparse_categorical_accuracy: 0.8234 - val_loss: 0.6024 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 87/100
469/469 - 1s - loss: 0.4798 - sparse_categorical_accuracy: 0.8226 - val_loss: 0.6014 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 88/100
469/469 - 1s - loss: 0.4781 - sparse_categorical_accuracy: 0.8242 - val_loss: 0.6023 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 89/100
469/469 - 1s - loss: 0.4773 - sparse_categorical_accuracy: 0.8247 - val_loss: 0.6021 - val_sparse_ca
tegorical_accuracy: 0.7967
Epoch 90/100
469/469 - 1s - loss: 0.4781 - sparse_categorical_accuracy: 0.8242 - val_loss: 0.5997 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 91/100
469/469 - 1s - loss: 0.4777 - sparse_categorical_accuracy: 0.8241 - val_loss: 0.6023 - val_sparse_ca
tegorical_accuracy: 0.7992
Epoch 92/100
469/469 - 1s - loss: 0.4773 - sparse_categorical_accuracy: 0.8250 - val_loss: 0.6045 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 93/100
```

```
469/469 - 1s - loss: 0.4773 - sparse_categorical_accuracy: 0.8245 - val_loss: 0.6087 - val_sparse_ca
tegorical_accuracy: 0.7968
Epoch 94/100
469/469 - 1s - loss: 0.4792 - sparse_categorical_accuracy: 0.8236 - val_loss: 0.6005 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 95/100
469/469 - 1s - loss: 0.4772 - sparse_categorical_accuracy: 0.8250 - val_loss: 0.6016 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 96/100
469/469 - 1s - loss: 0.4776 - sparse_categorical_accuracy: 0.8243 - val_loss: 0.6010 - val_sparse_ca
tegorical_accuracy: 0.7985
Epoch 97/100
469/469 - 1s - loss: 0.4765 - sparse_categorical_accuracy: 0.8252 - val_loss: 0.6077 - val_sparse_ca
tegorical_accuracy: 0.7948
Epoch 98/100
469/469 - 1s - loss: 0.4764 - sparse_categorical_accuracy: 0.8253 - val_loss: 0.6048 - val_sparse_ca
tegorical_accuracy: 0.7969
Epoch 99/100
469/469 - 1s - loss: 0.4762 - sparse_categorical_accuracy: 0.8259 - val_loss: 0.6027 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 100/100
469/469 - 1s - loss: 0.4772 - sparse_categorical_accuracy: 0.8247 - val_loss: 0.6074 - val_sparse_ca
tegorical_accuracy: 0.7957
```

In [8]:

```
# Learning rate 0.0001
model.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 0s - loss: 0.6074 - sparse_categorical_accuracy: 0.7957
```

Out[8]:

```
[0.6074172854423523, 0.7957000136375427]
```

In [9]:

```
# Learning rate 0.00001
optimizer = tf.keras.optimizers.Adam(learning_rate=0.00001)

model.compile(optimizer=optimizer,
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
             )
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 - 1s - loss: 0.4751 - sparse_categorical_accuracy: 0.8258 - val_loss: 0.6023 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 2/100
469/469 - 1s - loss: 0.4738 - sparse_categorical_accuracy: 0.8259 - val_loss: 0.6027 - val_sparse_ca
tegorical_accuracy: 0.7990
Epoch 3/100
469/469 - 1s - loss: 0.4735 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6023 - val_sparse_ca
tegorical_accuracy: 0.7985
Epoch 4/100
469/469 - 1s - loss: 0.4733 - sparse_categorical_accuracy: 0.8265 - val_loss: 0.6031 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 5/100
469/469 - 1s - loss: 0.4732 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6038 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 6/100
469/469 - 1s - loss: 0.4731 - sparse_categorical_accuracy: 0.8263 - val_loss: 0.6040 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 7/100
469/469 - 1s - loss: 0.4730 - sparse_categorical_accuracy: 0.8265 - val_loss: 0.6042 - val_sparse_ca
tegorical_accuracy: 0.7985
Epoch 8/100
469/469 - 1s - loss: 0.4729 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6043 - val_sparse_ca
tegorical_accuracy: 0.7983
Epoch 9/100
469/469 - 1s - loss: 0.4728 - sparse_categorical_accuracy: 0.8263 - val_loss: 0.6042 - val_sparse_ca
tegorical_accuracy: 0.7991
Epoch 10/100
469/469 - 1s - loss: 0.4729 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6038 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 11/100
469/469 - 1s - loss: 0.4728 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6054 - val_sparse_ca
tegorical_accuracy: 0.7988
```

```
Epoch 12/100
469/469 - 1s - loss: 0.4728 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6045 - val_sparse_ca
tegorical_accuracy: 0.7983
Epoch 13/100
469/469 - 1s - loss: 0.4728 - sparse_categorical_accuracy: 0.8265 - val_loss: 0.6047 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 14/100
469/469 - 1s - loss: 0.4726 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6054 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 15/100
469/469 - 1s - loss: 0.4727 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6049 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 16/100
469/469 - 1s - loss: 0.4726 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6056 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 17/100
469/469 - 1s - loss: 0.4727 - sparse_categorical_accuracy: 0.8265 - val_loss: 0.6058 - val_sparse_ca
tegorical_accuracy: 0.7987
Epoch 18/100
469/469 - 1s - loss: 0.4726 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6056 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 19/100
469/469 - 1s - loss: 0.4726 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6058 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 20/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6052 - val_sparse_ca
tegorical_accuracy: 0.7996
Epoch 21/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6060 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 22/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6049 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 23/100
469/469 - 1s - loss: 0.4724 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6062 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 24/100
469/469 - 1s - loss: 0.4726 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6058 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 25/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6056 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 26/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6059 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 27/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6060 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 28/100
469/469 - 1s - loss: 0.4725 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6062 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 29/100
469/469 - 1s - loss: 0.4724 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6065 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 30/100
469/469 - 1s - loss: 0.4723 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6073 - val_sparse_ca
tegorical_accuracy: 0.7969
Epoch 31/100
469/469 - 1s - loss: 0.4724 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6069 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 32/100
469/469 - 1s - loss: 0.4724 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6064 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 33/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6062 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 34/100
469/469 - 1s - loss: 0.4723 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6066 - val_sparse_ca
tegorical_accuracy: 0.7985
Epoch 35/100
469/469 - 1s - loss: 0.4723 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6071 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 36/100
469/469 - 1s - loss: 0.4723 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6071 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 37/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6068 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 38/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6066 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 39/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6068 - val_sparse_ca
```

```
tegorical_accuracy: 0.7981
Epoch 40/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6060 - val_sparse_ca
tegorical_accuracy: 0.7984
Epoch 41/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6068 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 42/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6069 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 43/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6064 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 44/100
469/469 - 1s - loss: 0.4722 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6075 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 45/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6076 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 46/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6075 - val_sparse_ca
tegorical_accuracy: 0.7990
Epoch 47/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8264 - val_loss: 0.6069 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 48/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6078 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 49/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6076 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 50/100
469/469 - 1s - loss: 0.4720 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6079 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 51/100
469/469 - 1s - loss: 0.4720 - sparse_categorical_accuracy: 0.8266 - val_loss: 0.6077 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 52/100
469/469 - 1s - loss: 0.4721 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6078 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 53/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6075 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 54/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6074 - val_sparse_ca
tegorical_accuracy: 0.7981
Epoch 55/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6075 - val_sparse_ca
tegorical_accuracy: 0.7972
Epoch 56/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6079 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 57/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6077 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 58/100
469/469 - 1s - loss: 0.4720 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6076 - val_sparse_ca
tegorical_accuracy: 0.7971
Epoch 59/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6073 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 60/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6079 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 61/100
469/469 - 1s - loss: 0.4719 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6089 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 62/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6085 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 63/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6083 - val_sparse_ca
tegorical_accuracy: 0.7972
Epoch 64/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8275 - val_loss: 0.6084 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 65/100
469/469 - 1s - loss: 0.4717 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6081 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 66/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6083 - val_sparse_ca
tegorical_accuracy: 0.7987
Epoch 67/100
```

```
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6083 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 68/100
469/469 - 1s - loss: 0.4718 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6087 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 69/100
469/469 - 1s - loss: 0.4717 - sparse_categorical_accuracy: 0.8274 - val_loss: 0.6098 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 70/100
469/469 - 1s - loss: 0.4717 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6092 - val_sparse_ca
tegorical_accuracy: 0.7969
Epoch 71/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8267 - val_loss: 0.6084 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 72/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8269 - val_loss: 0.6088 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 73/100
469/469 - 1s - loss: 0.4717 - sparse_categorical_accuracy: 0.8274 - val_loss: 0.6092 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 74/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6089 - val_sparse_ca
tegorical_accuracy: 0.7968
Epoch 75/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8272 - val_loss: 0.6088 - val_sparse_ca
tegorical_accuracy: 0.7975
Epoch 76/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8270 - val_loss: 0.6086 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 77/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6084 - val_sparse_ca
tegorical_accuracy: 0.7986
Epoch 78/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6085 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 79/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6089 - val_sparse_ca
tegorical_accuracy: 0.7970
Epoch 80/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6083 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 81/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6092 - val_sparse_ca
tegorical_accuracy: 0.7973
Epoch 82/100
469/469 - 1s - loss: 0.4716 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6091 - val_sparse_ca
tegorical_accuracy: 0.7969
Epoch 83/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6082 - val_sparse_ca
tegorical_accuracy: 0.7972
Epoch 84/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6095 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 85/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6089 - val_sparse_ca
tegorical_accuracy: 0.7976
Epoch 86/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6088 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 87/100
469/469 - 1s - loss: 0.4715 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6097 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 88/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6091 - val_sparse_ca
tegorical_accuracy: 0.7979
Epoch 89/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6096 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 90/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6099 - val_sparse_ca
tegorical_accuracy: 0.7982
Epoch 91/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6094 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 92/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8268 - val_loss: 0.6091 - val_sparse_ca
tegorical_accuracy: 0.7985
Epoch 93/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8275 - val_loss: 0.6102 - val_sparse_ca
tegorical_accuracy: 0.7987
Epoch 94/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6095 - val_sparse_ca
tegorical_accuracy: 0.7985
```

```
Epoch 95/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8274 - val_loss: 0.6094 - val_sparse_ca
tegorical_accuracy: 0.7978
Epoch 96/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8273 - val_loss: 0.6095 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 97/100
469/469 - 1s - loss: 0.4714 - sparse_categorical_accuracy: 0.8275 - val_loss: 0.6098 - val_sparse_ca
tegorical_accuracy: 0.7977
Epoch 98/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8271 - val_loss: 0.6109 - val_sparse_ca
tegorical_accuracy: 0.7974
Epoch 99/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8276 - val_loss: 0.6091 - val_sparse_ca
tegorical_accuracy: 0.7980
Epoch 100/100
469/469 - 1s - loss: 0.4713 - sparse_categorical_accuracy: 0.8276 - val_loss: 0.6095 - val_sparse_ca
tegorical_accuracy: 0.7990
```

In [10]:

```
# Learning rate 0.00001
model.evaluate(x_test, y_test, verbose=2)
```

```
313/313 - 0s - loss: 0.6095 - sparse_categorical_accuracy: 0.7990
```

Out[10]:

```
[0.6095350384712219, 0.7990000247955322]
```

In [11]:

```
# SGD
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')
])

model.compile(optimizer='sgd',
              loss='sparse_categorical_crossentropy',
              metrics=['sparse_categorical_accuracy']
             )

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 - 1s - loss: 4.1699 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.3032 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 2/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0982 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 3/100
469/469 - 1s - loss: 2.3028 - sparse_categorical_accuracy: 0.0967 - val_loss: 2.3032 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 4/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0972 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 5/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0982 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 6/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0974 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 7/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0981 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 8/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0979 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 9/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0971 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 10/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0973 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 11/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3031 - val_sparse_ca
```

```
tegorical_accuracy: 0.1000
Epoch 12/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0973 - val_loss: 2.3031 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 13/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0981 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 14/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 15/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0988 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 16/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0973 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 17/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0960 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 18/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0970 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 19/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0968 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 20/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0966 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 21/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 22/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0983 - val_loss: 2.3030 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 23/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0964 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 24/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 25/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0977 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 26/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0970 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 27/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 28/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0967 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 29/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0977 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 30/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0980 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 31/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0969 - val_loss: 2.3029 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 32/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 33/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0966 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 34/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0978 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 35/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0966 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 36/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 37/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0970 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 38/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0981 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 39/100
```

```
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0974 - val_loss: 2.3028 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 40/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0993 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 41/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0962 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 42/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 43/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0983 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 44/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0974 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 45/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0970 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 46/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0956 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 47/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0980 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 48/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.3027 - val_sparse_ca
tegorical_accuracy: 0.0999
Epoch 49/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0972 - val_loss: 2.3026 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 50/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0974 - val_loss: 2.3026 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 51/100
469/469 - 1s - loss: 2.3025 - sparse_categorical_accuracy: 0.0980 - val_loss: 2.3026 - val_sparse_ca
tegorical_accuracy: 0.1000
Epoch 52/100
469/469 - 1s - loss: 2.3024 - sparse_categorical_accuracy: 0.0955 - val_loss: 2.3023 - val_sparse_ca
tegorical_accuracy: 0.1001
Epoch 53/100
469/469 - 1s - loss: 2.3023 - sparse_categorical_accuracy: 0.0982 - val_loss: 2.3020 - val_sparse_ca
tegorical_accuracy: 0.1003
Epoch 54/100
469/469 - 1s - loss: 2.3021 - sparse_categorical_accuracy: 0.0978 - val_loss: 2.3016 - val_sparse_ca
tegorical_accuracy: 0.1004
Epoch 55/100
469/469 - 1s - loss: 2.3020 - sparse_categorical_accuracy: 0.0975 - val_loss: 2.3014 - val_sparse_ca
tegorical_accuracy: 0.1006
Epoch 56/100
469/469 - 1s - loss: 2.3016 - sparse_categorical_accuracy: 0.0977 - val_loss: 2.3016 - val_sparse_ca
tegorical_accuracy: 0.1004
Epoch 57/100
469/469 - 1s - loss: 2.3018 - sparse_categorical_accuracy: 0.0985 - val_loss: 2.3012 - val_sparse_ca
tegorical_accuracy: 0.1005
Epoch 58/100
469/469 - 1s - loss: 2.3018 - sparse_categorical_accuracy: 0.0978 - val_loss: 2.3010 - val_sparse_ca
tegorical_accuracy: 0.1004
Epoch 59/100
469/469 - 1s - loss: 2.3007 - sparse_categorical_accuracy: 0.0984 - val_loss: 2.2964 - val_sparse_ca
tegorical_accuracy: 0.1061
Epoch 60/100
469/469 - 1s - loss: 2.2637 - sparse_categorical_accuracy: 0.1191 - val_loss: 2.2126 - val_sparse_ca
tegorical_accuracy: 0.1472
Epoch 61/100
469/469 - 1s - loss: 2.1646 - sparse_categorical_accuracy: 0.1663 - val_loss: 2.0838 - val_sparse_ca
tegorical_accuracy: 0.2027
Epoch 62/100
469/469 - 1s - loss: 2.0371 - sparse_categorical_accuracy: 0.2175 - val_loss: 2.0069 - val_sparse_ca
tegorical_accuracy: 0.2330
Epoch 63/100
469/469 - 1s - loss: 1.9881 - sparse_categorical_accuracy: 0.2352 - val_loss: 1.8927 - val_sparse_ca
tegorical_accuracy: 0.2530
Epoch 64/100
469/469 - 1s - loss: 1.8158 - sparse_categorical_accuracy: 0.2908 - val_loss: 1.7579 - val_sparse_ca
tegorical_accuracy: 0.3021
Epoch 65/100
469/469 - 1s - loss: 1.7669 - sparse_categorical_accuracy: 0.2788 - val_loss: 1.6618 - val_sparse_ca
tegorical_accuracy: 0.3573
Epoch 66/100
469/469 - 1s - loss: 1.5590 - sparse_categorical_accuracy: 0.3406 - val_loss: 1.5188 - val_sparse_ca
tegorical_accuracy: 0.3438
```

```
Epoch 67/100
469/469 - 1s - loss: 1.4704 - sparse_categorical_accuracy: 0.3495 - val_loss: 1.4799 - val_sparse_ca
tegorical_accuracy: 0.3320
Epoch 68/100
469/469 - 1s - loss: 1.4223 - sparse_categorical_accuracy: 0.3596 - val_loss: 1.4811 - val_sparse_ca
tegorical_accuracy: 0.3142
Epoch 69/100
469/469 - 1s - loss: 1.3937 - sparse_categorical_accuracy: 0.3657 - val_loss: 1.3939 - val_sparse_ca
tegorical_accuracy: 0.3798
Epoch 70/100
469/469 - 1s - loss: 1.4371 - sparse_categorical_accuracy: 0.3597 - val_loss: 1.7483 - val_sparse_ca
tegorical_accuracy: 0.2903
Epoch 71/100
469/469 - 1s - loss: 1.6981 - sparse_categorical_accuracy: 0.2813 - val_loss: 1.6548 - val_sparse_ca
tegorical_accuracy: 0.2960
Epoch 72/100
469/469 - 1s - loss: 2.0228 - sparse_categorical_accuracy: 0.1892 - val_loss: 2.3262 - val_sparse_ca
tegorical_accuracy: 0.1056
Epoch 73/100
469/469 - 1s - loss: 2.2517 - sparse_categorical_accuracy: 0.1008 - val_loss: 2.1872 - val_sparse_ca
tegorical_accuracy: 0.1087
Epoch 74/100
469/469 - 1s - loss: 2.1293 - sparse_categorical_accuracy: 0.1784 - val_loss: 2.0777 - val_sparse_ca
tegorical_accuracy: 0.1998
Epoch 75/100
469/469 - 1s - loss: 2.0333 - sparse_categorical_accuracy: 0.1991 - val_loss: 1.9935 - val_sparse_ca
tegorical_accuracy: 0.1999
Epoch 76/100
469/469 - 1s - loss: 1.9582 - sparse_categorical_accuracy: 0.1996 - val_loss: 1.9265 - val_sparse_ca
tegorical_accuracy: 0.2000
Epoch 77/100
469/469 - 1s - loss: 1.9035 - sparse_categorical_accuracy: 0.2007 - val_loss: 1.8773 - val_sparse_ca
tegorical_accuracy: 0.1995
Epoch 78/100
469/469 - 1s - loss: 1.8585 - sparse_categorical_accuracy: 0.1995 - val_loss: 1.8434 - val_sparse_ca
tegorical_accuracy: 0.1999
Epoch 79/100
469/469 - 1s - loss: 1.8250 - sparse_categorical_accuracy: 0.1994 - val_loss: 1.8354 - val_sparse_ca
tegorical_accuracy: 0.1953
Epoch 80/100
469/469 - 1s - loss: 1.8008 - sparse_categorical_accuracy: 0.1980 - val_loss: 1.8011 - val_sparse_ca
tegorical_accuracy: 0.1977
Epoch 81/100
469/469 - 1s - loss: 1.7802 - sparse_categorical_accuracy: 0.1978 - val_loss: 1.7721 - val_sparse_ca
tegorical_accuracy: 0.1999
Epoch 82/100
469/469 - 1s - loss: 1.7657 - sparse_categorical_accuracy: 0.2001 - val_loss: 1.7639 - val_sparse_ca
tegorical_accuracy: 0.2001
Epoch 83/100
469/469 - 1s - loss: 1.7530 - sparse_categorical_accuracy: 0.1992 - val_loss: 1.7473 - val_sparse_ca
tegorical_accuracy: 0.1983
Epoch 84/100
469/469 - 1s - loss: 1.7430 - sparse_categorical_accuracy: 0.2002 - val_loss: 1.7535 - val_sparse_ca
tegorical_accuracy: 0.1996
Epoch 85/100
469/469 - 1s - loss: 1.7358 - sparse_categorical_accuracy: 0.1980 - val_loss: 1.7310 - val_sparse_ca
tegorical_accuracy: 0.1993
Epoch 86/100
469/469 - 1s - loss: 1.7283 - sparse_categorical_accuracy: 0.1990 - val_loss: 1.7257 - val_sparse_ca
tegorical_accuracy: 0.1989
Epoch 87/100
469/469 - 1s - loss: 1.7238 - sparse_categorical_accuracy: 0.1991 - val_loss: 1.7229 - val_sparse_ca
tegorical_accuracy: 0.1983
Epoch 88/100
469/469 - 1s - loss: 1.7234 - sparse_categorical_accuracy: 0.1979 - val_loss: 1.7307 - val_sparse_ca
tegorical_accuracy: 0.2002
Epoch 89/100
469/469 - 1s - loss: 1.7158 - sparse_categorical_accuracy: 0.1989 - val_loss: 1.7153 - val_sparse_ca
tegorical_accuracy: 0.1996
Epoch 90/100
469/469 - 1s - loss: 1.7150 - sparse_categorical_accuracy: 0.1968 - val_loss: 1.7180 - val_sparse_ca
tegorical_accuracy: 0.1977
Epoch 91/100
469/469 - 1s - loss: 1.7084 - sparse_categorical_accuracy: 0.1951 - val_loss: 1.7092 - val_sparse_ca
tegorical_accuracy: 0.2001
Epoch 92/100
469/469 - 1s - loss: 1.7035 - sparse_categorical_accuracy: 0.1966 - val_loss: 1.7063 - val_sparse_ca
tegorical_accuracy: 0.1984
Epoch 93/100
469/469 - 1s - loss: 1.7034 - sparse_categorical_accuracy: 0.1986 - val_loss: 1.7040 - val_sparse_ca
tegorical_accuracy: 0.2005
Epoch 94/100
469/469 - 1s - loss: 1.6985 - sparse_categorical_accuracy: 0.1990 - val_loss: 1.7016 - val_sparse_ca
```

```
tegorical_accuracy: 0.1999
Epoch 95/100
469/469 - 1s - loss: 1.6979 - sparse_categorical_accuracy: 0.1992 - val_loss: 1.7018 - val_sparse_ca
tegorical_accuracy: 0.1998
Epoch 96/100
469/469 - 1s - loss: 1.7495 - sparse_categorical_accuracy: 0.1951 - val_loss: 3.1656 - val_sparse_ca
tegorical_accuracy: 0.1015
Epoch 97/100
469/469 - 1s - loss: 2.9357 - sparse_categorical_accuracy: 0.1002 - val_loss: 2.7323 - val_sparse_ca
tegorical_accuracy: 0.1013
Epoch 98/100
469/469 - 1s - loss: 2.5954 - sparse_categorical_accuracy: 0.0995 - val_loss: 2.4841 - val_sparse_ca
tegorical_accuracy: 0.1013
Epoch 99/100
469/469 - 1s - loss: 2.4214 - sparse_categorical_accuracy: 0.1002 - val_loss: 2.3723 - val_sparse_ca
tegorical_accuracy: 0.1013
Epoch 100/100
469/469 - 1s - loss: 2.3477 - sparse_categorical_accuracy: 0.0989 - val_loss: 2.3278 - val_sparse_ca
tegorical_accuracy: 0.1013
```

In [12]:

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

```
313/313 - 0s - loss: 2.3278 - sparse_categorical_accuracy: 0.1013
```

Out[12]:

```
[2.327831506729126, 0.10130000114440918]
```