```
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow.keras.datasets import cifar10
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import accuracy_score, confusion_matrix, precision_score, recall_score
import seaborn as sns

# Load the CIFAR-10 dataset
(X, Y), (X_test, Y_test) = cifar10.load_data()

# Class labels for CIFAR-10
class_labels = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'truck']

# Display a few images from the dataset
plt.figure(figsize=(15, 3))
for i in range(5):
    plt.subplot(1, 5, i + 1)
    plt.imshow(X[i])
    plt.title(class_labels[Y[i][0]])
    plt.axis('off')
plt.show()

# Normalize the data
scaler = MinMaxScaler()
X_scaled = X.reshape(-1, 32*32*3).astype(float)
X_scaled = scaler.fit_transform(X_scaled).reshape(-1, 32, 32, 3)
X_test_scaled = X_test.reshape(-1, 32*32*3).astype(float)
X_test_scaled = scaler.transform(X_test_scaled).reshape(-1, 32, 32, 3)

# Split the data into training, validation, and testing sets
X_temp, X_test_scaled, Y_temp, Y_test = train_test_split(X_scaled, Y, test_size=0.2, random_state=42)
X_train, X_val, Y_train, Y_val = train_test_split(X_temp, Y_temp, test_size=0.25, random_state=42)

# Define the CNN model
model = Sequential([
    Conv2D(32, (3, 3), activation='relu', input_shape=(32, 32, 3)),
    MaxPooling2D((2, 2)),
    Conv2D(32, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Conv2D(32, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Flatten(),
    Dense(128, activation='relu'),
    Dropout(0.5),
    Dense(256, activation='relu'),
    Dropout(0.5),
    Dense(128, activation='relu'),
    Dropout(0.5),
    Dense(10, activation='softmax')
])

# Compile the model
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy', metrics=['accuracy'])

# Show model summary
model.summary()

# Train the model
history = model.fit(X_train, Y_train, epochs=20, validation_data=(X_val, Y_val))

# Plot training and validation loss
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()

# Evaluate the model on the test set
test_loss, test_accuracy = model.evaluate(X_test_scaled, Y_test, verbose=0)

# Predict on test set
```

```
y_pred = model.predict(X_test_scaled)
y_pred_labels = np.argmax(y_pred, axis=1)
conf_matrix = confusion_matrix(Y_test, y_pred_labels)

# Display confusion matrix
plt.figure(figsize=(10, 8))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap='Blues', xticklabels=class_labels, yticklabels=class_labels)
plt.xlabel('Predicted Labels')
plt.ylabel('True Labels')
plt.title('Confusion Matrix')
plt.show()

# Calculate precision and recall
precision = precision_score(Y_test, y_pred_labels, average='weighted')
recall = recall_score(Y_test, y_pred_labels, average='weighted')

# Output accuracy, precision, and recall
print(f"Train accuracy: {history.history['accuracy'][-1]}")
print(f"Test accuracy: {test_accuracy}")
print(f"Precision: {precision}")
print(f"Recall: {recall}")


learning_rates = [0.0001, 0.035, 0.07, 0.3]
train_losses = []
val_losses = []

for lr in learning_rates:
    print(f"Training model with learning rate: {lr}")

    model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=lr), loss='sparse_categorical_crossentropy', metrics=['accuracy'])
    history = model.fit(X_train, Y_train, epochs=20, validation_data=(X_val, Y_val), verbose=1)

    train_losses.append(history.history['loss'])
    val_losses.append(history.history['val_loss'])

plt.figure(figsize=(10, 6))
for i, lr in enumerate(learning_rates):
    plt.plot(train_losses[i], label=f'Training Loss (LR={lr})')
    plt.plot(val_losses[i], label=f'Validation Loss (LR={lr})')

plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and Validation Loss for Different Learning Rates')
plt.legend()
plt.show()
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 4s 0us/step
```


```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 30, 30, 32)        896

 max_pooling2d (MaxPooling2  (None, 15, 15, 32)        0
 D)

 conv2d_1 (Conv2D)           (None, 13, 13, 32)        9248

 max_pooling2d_1 (MaxPoolin  (None, 6, 6, 32)          0
 g2D)

 flatten (Flatten)           (None, 1152)              0

 dense (Dense)               (None, 128)               147584

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 256)               33024

 dropout_1 (Dropout)         (None, 256)               0

 dense_2 (Dense)             (None, 128)               32896

 dropout_2 (Dropout)         (None, 128)               0

 dense_3 (Dense)             (None, 10)                1290

=================================================================
Total params: 224938 (878.66 KB)
Trainable params: 224938 (878.66 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
Epoch 1/20
938/938 [==============================] - 58s 59ms/step - loss: 1.9732 - accuracy: 0.2474 - val_loss: 1.6163 - val_accuracy: 0.4137
Epoch 2/20
938/938 [==============================] - 35s 37ms/step - loss: 1.5796 - accuracy: 0.4207 - val_loss: 1.3633 - val_accuracy: 0.5087
Epoch 3/20
938/938 [==============================] - 34s 37ms/step - loss: 1.4321 - accuracy: 0.4839 - val_loss: 1.2879 - val_accuracy: 0.5411
Epoch 4/20
938/938 [==============================] - 50s 53ms/step - loss: 1.3540 - accuracy: 0.5205 - val_loss: 1.2192 - val_accuracy: 0.5629
Epoch 5/20
938/938 [==============================] - 36s 39ms/step - loss: 1.2701 - accuracy: 0.5516 - val_loss: 1.1563 - val_accuracy: 0.5909
Epoch 6/20
938/938 [==============================] - 37s 39ms/step - loss: 1.2361 - accuracy: 0.5665 - val_loss: 1.1666 - val_accuracy: 0.5888
Epoch 7/20
938/938 [==============================] - 37s 40ms/step - loss: 1.1847 - accuracy: 0.5862 - val_loss: 1.1406 - val_accuracy: 0.6039
Epoch 8/20
938/938 [==============================] - 37s 40ms/step - loss: 1.1502 - accuracy: 0.6003 - val_loss: 1.1135 - val_accuracy: 0.6131
Epoch 9/20
938/938 [==============================] - 36s 39ms/step - loss: 1.1077 - accuracy: 0.6126 - val_loss: 1.1214 - val_accuracy: 0.6135
Epoch 10/20
938/938 [==============================] - 34s 36ms/step - loss: 1.0712 - accuracy: 0.6279 - val_loss: 1.0835 - val_accuracy: 0.6214
Epoch 11/20
938/938 [==============================] - 36s 39ms/step - loss: 1.0599 - accuracy: 0.6347 - val_loss: 1.0423 - val_accuracy: 0.6395
Epoch 12/20
938/938 [==============================] - 39s 41ms/step - loss: 1.0304 - accuracy: 0.6456 - val_loss: 1.0819 - val_accuracy: 0.6255
Epoch 13/20
938/938 [==============================] - 42s 44ms/step - loss: 1.0102 - accuracy: 0.6537 - val_loss: 1.0578 - val_accuracy: 0.6390
Epoch 14/20
938/938 [==============================] - 37s 40ms/step - loss: 0.9826 - accuracy: 0.6658 - val_loss: 1.0564 - val_accuracy: 0.6389
Epoch 15/20
938/938 [==============================] - 34s 36ms/step - loss: 0.9730 - accuracy: 0.6639 - val_loss: 1.0462 - val_accuracy: 0.6450
Epoch 16/20
938/938 [==============================] - 36s 38ms/step - loss: 0.9529 - accuracy: 0.6740 - val_loss: 1.0411 - val_accuracy: 0.6458
Epoch 17/20
938/938 [==============================] - 34s 36ms/step - loss: 0.9390 - accuracy: 0.6754 - val_loss: 1.0138 - val_accuracy: 0.6563
Epoch 18/20
```

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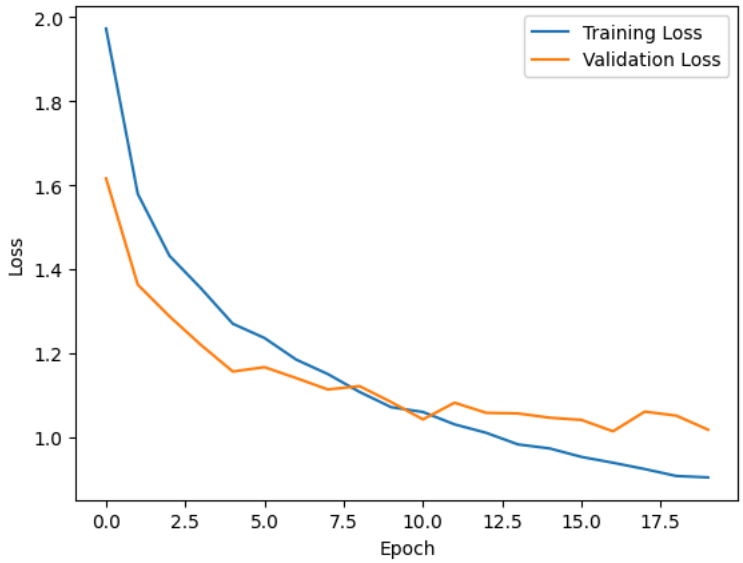
938/938 [==============================] - 37s 39ms/step - loss: 0.9239 - accuracy: 0.6835 - val_loss: 1.0607 - val_accuracy: 0.6374
Epoch 19/20
938/938 [==============================] - 34s 36ms/step - loss: 0.9073 - accuracy: 0.6901 - val_loss: 1.0512 - val_accuracy: 0.6446
Epoch 20/20
938/938 [==============================] - 35s 37ms/step - loss: 0.9040 - accuracy: 0.6905 - val_loss: 1.0176 - val_accuracy: 0.6574
```




```
313/313 [==============================] - 3s 10ms/step
```


```
Train accuracy: 0.690500020980835
Test accuracy: 0.6524999737739563
Precision: 0.6521358050803083
Recall: 0.6525
Training model with learning rate: 0.0001
Epoch 1/20
938/938 [==============================] - 39s 40ms/step - loss: 0.7871 - accuracy: 0.7274 - val_loss: 1.0098 - val_accuracy: 0.6670
Epoch 2/20
938/938 [==============================] - 37s 40ms/step - loss: 0.7540 - accuracy: 0.7392 - val_loss: 1.0142 - val_accuracy: 0.6661
Epoch 3/20
```

```
938/938 [==============================] - 40s 43ms/step - loss: 0.7327 - accuracy: 0.7468 - val_loss: 1.0265 - val_accuracy: 0.6696
Epoch 4/20
938/938 [==============================] - 46s 49ms/step - loss: 0.7357 - accuracy: 0.7461 - val_loss: 1.0182 - val_accuracy: 0.6676
Epoch 5/20
938/938 [==============================] - 37s 40ms/step - loss: 0.7245 - accuracy: 0.7494 - val_loss: 1.0290 - val_accuracy: 0.6660
Epoch 6/20
938/938 [==============================] - 36s 39ms/step - loss: 0.7184 - accuracy: 0.7497 - val_loss: 1.0284 - val_accuracy: 0.6688
Epoch 7/20
938/938 [==============================] - 39s 42ms/step - loss: 0.7108 - accuracy: 0.7507 - val_loss: 1.0314 - val_accuracy: 0.6661
Epoch 8/20
938/938 [==============================] - 40s 43ms/step - loss: 0.7017 - accuracy: 0.7541 - val_loss: 1.0362 - val_accuracy: 0.6680
Epoch 9/20
938/938 [==============================] - 39s 42ms/step - loss: 0.6829 - accuracy: 0.7595 - val_loss: 1.0415 - val_accuracy: 0.6689
Epoch 10/20
938/938 [==============================] - 38s 40ms/step - loss: 0.6850 - accuracy: 0.7612 - val_loss: 1.0404 - val_accuracy: 0.6665
Epoch 11/20
938/938 [==============================] - 38s 41ms/step - loss: 0.6820 - accuracy: 0.7647 - val_loss: 1.0386 - val_accuracy: 0.6713
Epoch 12/20
938/938 [==============================] - 37s 39ms/step - loss: 0.6744 - accuracy: 0.7655 - val_loss: 1.0399 - val_accuracy: 0.6668
Epoch 13/20
938/938 [==============================] - 37s 40ms/step - loss: 0.6704 - accuracy: 0.7680 - val_loss: 1.0415 - val_accuracy: 0.6707
Epoch 14/20
938/938 [==============================] - 37s 40ms/step - loss: 0.6664 - accuracy: 0.7680 - val_loss: 1.0502 - val_accuracy: 0.6720
Epoch 15/20
938/938 [==============================] - 39s 42ms/step - loss: 0.6594 - accuracy: 0.7697 - val_loss: 1.0531 - val_accuracy: 0.6695
Epoch 16/20
938/938 [==============================] - 36s 39ms/step - loss: 0.6508 - accuracy: 0.7745 - val_loss: 1.0583 - val_accuracy: 0.6703
Epoch 17/20
938/938 [==============================] - 38s 41ms/step - loss: 0.6526 - accuracy: 0.7698 - val_loss: 1.0589 - val_accuracy: 0.6713
Epoch 18/20
938/938 [==============================] - 37s 39ms/step - loss: 0.6451 - accuracy: 0.7745 - val_loss: 1.0568 - val_accuracy: 0.6699
Epoch 19/20
938/938 [==============================] - 37s 40ms/step - loss: 0.6445 - accuracy: 0.7758 - val_loss: 1.0651 - val_accuracy: 0.6705
Epoch 20/20
938/938 [==============================] - 39s 42ms/step - loss: 0.6325 - accuracy: 0.7772 - val_loss: 1.0703 - val_accuracy: 0.6704
Training model with learning rate: 0.001
Epoch 1/20
938/938 [==============================] - 39s 40ms/step - loss: 0.7971 - accuracy: 0.7258 - val_loss: 1.0476 - val_accuracy: 0.6525
Epoch 2/20
938/938 [==============================] - 39s 42ms/step - loss: 0.7974 - accuracy: 0.7230 - val_loss: 1.0645 - val_accuracy: 0.6576
Epoch 3/20
938/938 [==============================] - 35s 38ms/step - loss: 0.8089 - accuracy: 0.7231 - val_loss: 1.0609 - val_accuracy: 0.6487
Epoch 4/20
938/938 [==============================] - 41s 43ms/step - loss: 0.8045 - accuracy: 0.7244 - val_loss: 1.0470 - val_accuracy: 0.6535
Epoch 5/20
938/938 [==============================] - 35s 37ms/step - loss: 0.8067 - accuracy: 0.7244 - val_loss: 1.0317 - val_accuracy: 0.6557
Epoch 6/20
938/938 [==============================] - 38s 40ms/step - loss: 0.7860 - accuracy: 0.7306 - val_loss: 1.0920 - val_accuracy: 0.6487
Epoch 7/20
938/938 [==============================] - 42s 45ms/step - loss: 0.7914 - accuracy: 0.7253 - val_loss: 1.0893 - val_accuracy: 0.6467
Epoch 8/20
938/938 [==============================] - 36s 38ms/step - loss: 0.7755 - accuracy: 0.7342 - val_loss: 1.1089 - val_accuracy: 0.6455
Epoch 9/20
938/938 [==============================] - 37s 40ms/step - loss: 0.7707 - accuracy: 0.7363 - val_loss: 1.1170 - val_accuracy: 0.6472
Epoch 10/20
938/938 [==============================] - 37s 40ms/step - loss: 0.7754 - accuracy: 0.7340 - val_loss: 1.0784 - val_accuracy: 0.6540
Epoch 11/20
938/938 [==============================] - 38s 40ms/step - loss: 0.7654 - accuracy: 0.7367 - val_loss: 1.0783 - val_accuracy: 0.6543
Epoch 12/20
938/938 [==============================] - 38s 41ms/step - loss: 0.7470 - accuracy: 0.7429 - val_loss: 1.0691 - val_accuracy: 0.6527
Epoch 13/20
938/938 [==============================] - 40s 42ms/step - loss: 0.7508 - accuracy: 0.7417 - val_loss: 1.1086 - val_accuracy: 0.6525
Epoch 14/20
938/938 [==============================] - 38s 41ms/step - loss: 0.7393 - accuracy: 0.7472 - val_loss: 1.0680 - val_accuracy: 0.6504
Epoch 15/20
938/938 [==============================] - 38s 40ms/step - loss: 0.7382 - accuracy: 0.7498 - val_loss: 1.0815 - val_accuracy: 0.6431
Epoch 16/20
938/938 [==============================] - 37s 40ms/step - loss: 0.7231 - accuracy: 0.7527 - val_loss: 1.1638 - val_accuracy: 0.6456
Epoch 17/20
938/938 [==============================] - 36s 38ms/step - loss: 0.7247 - accuracy: 0.7553 - val_loss: 1.1365 - val_accuracy: 0.6425
Epoch 18/20
938/938 [==============================] - 38s 41ms/step - loss: 0.7141 - accuracy: 0.7559 - val_loss: 1.1035 - val_accuracy: 0.6490
Epoch 19/20
938/938 [==============================] - 38s 40ms/step - loss: 0.7144 - accuracy: 0.7580 - val_loss: 1.0744 - val_accuracy: 0.6487
Epoch 20/20
938/938 [==============================] - 38s 41ms/step - loss: 0.7143 - accuracy: 0.7554 - val_loss: 1.0831 - val_accuracy: 0.6511
Training model with learning rate: 0.01
Epoch 1/20
938/938 [==============================] - 40s 41ms/step - loss: 2.1091 - accuracy: 0.2347 - val_loss: 2.2509 - val_accuracy: 0.1561
Epoch 2/20
938/938 [==============================] - 35s 37ms/step - loss: 2.1199 - accuracy: 0.1991 - val_loss: 2.1869 - val_accuracy: 0.1497
Epoch 3/20
938/938 [==============================] - 38s 41ms/step - loss: 2.1304 - accuracy: 0.1844 - val_loss: 2.0272 - val_accuracy: 0.2002
Epoch 4/20
938/938 [==============================] - 36s 38ms/step - loss: 2.1470 - accuracy: 0.1735 - val_loss: 2.2355 - val_accuracy: 0.1870
```

```
Epoch 5/20
938/938 [==============================] - 40s 43ms/step - loss: 2.1461 - accuracy: 0.1788 - val_loss: 2.0830 - val_accuracy: 0.2008
Epoch 6/20
938/938 [==============================] - 37s 39ms/step - loss: 2.1487 - accuracy: 0.1751 - val_loss: 2.0407 - val_accuracy: 0.1970
Epoch 7/20
938/938 [==============================] - 37s 40ms/step - loss: 2.1067 - accuracy: 0.1853 - val_loss: 2.0368 - val_accuracy: 0.1886
Epoch 8/20
938/938 [==============================] - 38s 41ms/step - loss: 2.1191 - accuracy: 0.1764 - val_loss: 2.0447 - val_accuracy: 0.1896
Epoch 9/20
938/938 [==============================] - 37s 40ms/step - loss: 2.1189 - accuracy: 0.1768 - val_loss: 2.0915 - val_accuracy: 0.1934
Epoch 10/20
938/938 [==============================] - 38s 40ms/step - loss: 2.2656 - accuracy: 0.1258 - val_loss: 2.2945 - val_accuracy: 0.0968
Epoch 11/20
938/938 [==============================] - 37s 39ms/step - loss: 2.3048 - accuracy: 0.1016 - val_loss: 2.3036 - val_accuracy: 0.1011
Epoch 12/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3082 - accuracy: 0.0989 - val_loss: 2.3051 - val_accuracy: 0.0981
Epoch 13/20
938/938 [==============================] - 41s 43ms/step - loss: 2.3042 - accuracy: 0.1000 - val_loss: 2.3036 - val_accuracy: 0.0984
Epoch 14/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3039 - accuracy: 0.1007 - val_loss: 2.3038 - val_accuracy: 0.0981
Epoch 15/20
938/938 [==============================] - 37s 39ms/step - loss: 2.3041 - accuracy: 0.0999 - val_loss: 2.3052 - val_accuracy: 0.0974
Epoch 16/20
938/938 [==============================] - 38s 41ms/step - loss: 2.3038 - accuracy: 0.0998 - val_loss: 2.3041 - val_accuracy: 0.1000
Epoch 17/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3042 - accuracy: 0.0989 - val_loss: 2.3050 - val_accuracy: 0.0984
Epoch 18/20
938/938 [==============================] - 36s 39ms/step - loss: 2.3041 - accuracy: 0.1007 - val_loss: 2.3041 - val_accuracy: 0.1000
Epoch 19/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3041 - accuracy: 0.0974 - val_loss: 2.3033 - val_accuracy: 0.1024
Epoch 20/20
938/938 [==============================] - 36s 38ms/step - loss: 2.3039 - accuracy: 0.1012 - val_loss: 2.3038 - val_accuracy: 0.0971
Training model with learning rate: 0.1
Epoch 1/20
938/938 [==============================] - 36s 38ms/step - loss: 2.3148 - accuracy: 0.1030 - val_loss: 2.3202 - val_accuracy: 0.1000
Epoch 2/20
938/938 [==============================] - 40s 43ms/step - loss: 2.3150 - accuracy: 0.1019 - val_loss: 2.3124 - val_accuracy: 0.1011
Epoch 3/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3153 - accuracy: 0.1012 - val_loss: 2.3083 - val_accuracy: 0.1024
Epoch 4/20
938/938 [==============================] - 38s 41ms/step - loss: 2.3160 - accuracy: 0.0963 - val_loss: 2.3196 - val_accuracy: 0.0974
Epoch 5/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3160 - accuracy: 0.0941 - val_loss: 2.3129 - val_accuracy: 0.1011
Epoch 6/20
938/938 [==============================] - 37s 39ms/step - loss: 2.3158 - accuracy: 0.1006 - val_loss: 2.3180 - val_accuracy: 0.1054
Epoch 7/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3152 - accuracy: 0.1006 - val_loss: 2.3085 - val_accuracy: 0.1000
Epoch 8/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3164 - accuracy: 0.1019 - val_loss: 2.3097 - val_accuracy: 0.1011
Epoch 9/20
938/938 [==============================] - 36s 38ms/step - loss: 2.3153 - accuracy: 0.0976 - val_loss: 2.3103 - val_accuracy: 0.0984
Epoch 10/20
938/938 [==============================] - 39s 41ms/step - loss: 2.3145 - accuracy: 0.1012 - val_loss: 2.3126 - val_accuracy: 0.1054
Epoch 11/20
938/938 [==============================] - 38s 41ms/step - loss: 2.3153 - accuracy: 0.0997 - val_loss: 2.3149 - val_accuracy: 0.0971
Epoch 12/20
938/938 [==============================] - 35s 38ms/step - loss: 2.3149 - accuracy: 0.0986 - val_loss: 2.3064 - val_accuracy: 0.1024
Epoch 13/20
938/938 [==============================] - 36s 38ms/step - loss: 2.3143 - accuracy: 0.1004 - val_loss: 2.3201 - val_accuracy: 0.1000
Epoch 14/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3158 - accuracy: 0.1004 - val_loss: 2.3155 - val_accuracy: 0.1000
Epoch 15/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3146 - accuracy: 0.1001 - val_loss: 2.3265 - val_accuracy: 0.0981
Epoch 16/20
938/938 [==============================] - 36s 39ms/step - loss: 2.3155 - accuracy: 0.1018 - val_loss: 2.3234 - val_accuracy: 0.0981
Epoch 17/20
938/938 [==============================] - 37s 40ms/step - loss: 2.3159 - accuracy: 0.0992 - val_loss: 2.3192 - val_accuracy: 0.1011
Epoch 18/20
938/938 [==============================] - 38s 41ms/step - loss: 2.3154 - accuracy: 0.0989 - val_loss: 2.3105 - val_accuracy: 0.1011
Epoch 19/20
938/938 [==============================] - 35s 37ms/step - loss: 2.3147 - accuracy: 0.0971 - val_loss: 2.3131 - val_accuracy: 0.0971
Epoch 20/20
938/938 [==============================] - 37s 39ms/step - loss: 2.3149 - accuracy: 0.0991 - val_loss: 2.3179 - val_accuracy: 0.1000
```