CNN-SeqSelfAttention

This notebook was inspired to Tonmoy with some attempts to tune by us

(i) Importing the necessary packages

In [ ]:
```
import numpy as np
import pandas as pd
import tensorflow as tf
import keras
from keras_self_attention import SeqSelfAttention

from keras import layers
from keras.models import Sequential,Model
from keras.layers import Dense, Activation, Flatten,Dropout, MultiHeadAttent
from keras.layers import Conv2D,LSTM,BatchNormalization,MaxPooling2D,Reshape
from keras.utils import to_categorical
import matplotlib.pyplot as plt

tf.compat.v1.random.set_random_seed(0)
```

(ii) Preprocessing the dataset and preparing the training, validation, and test datasets

In [ ]:
```python
def data_prep(X,y,sub_sample,average,noise):

    total_X = None
    total_y = None

    # Trimming the data (sample,22,1000) -> (sample,22,500)
    X = X[:,:,0:500]
    print('Shape of X after trimming:',X.shape)

    # Maxpooling the data (sample,22,1000) -> (sample,22,500/sub_sample)
    X_max = np.max(X.reshape(X.shape[0], X.shape[1], -1, sub_sample), axis=3


    total_X = X_max
    total_y = y
    print('Shape of X after maxpooling:',total_X.shape)

    # Averaging + noise
    X_average = np.mean(X.reshape(X.shape[0], X.shape[1], -1, average),axis=
    X_average = X_average + np.random.normal(0.0, 0.5, X_average.shape)

    total_X = np.vstack((total_X, X_average))
    total_y = np.hstack((total_y, y))
    print('Shape of X after averaging+noise and concatenating:',total_X.shap

    # Subsampling

    for i in range(sub_sample):

        X_subsample = X[:, :, i::sub_sample] + \
                            (np.random.normal(0.0, 0.5, X[:, :,i::sub_sample

        total_X = np.vstack((total_X, X_subsample))
        total_y = np.hstack((total_y, y))


    print('Shape of X after subsampling and concatenating:',total_X.shape)
    return total_X,total_y
```

In [ ]:

```
## Loading the dataset


X_test = np.load("X_test.npy")
y_test = np.load("y_test.npy")
person_train_valid = np.load("person_train_valid.npy")
X_train_valid = np.load("X_train_valid.npy")
y_train_valid = np.load("y_train_valid.npy")
person_test = np.load("person_test.npy")

## Adjusting the labels so that

# Cue onset left - 0
# Cue onset right - 1
# Cue onset foot - 2
# Cue onset tongue - 3

y_train_valid -= 769
y_test -= 769



## Random splitting and reshaping the data
# First generating the training and validation indices using random splittin

ind_valid = np.random.choice(2115, 375, replace=False)
ind_train = np.array(list(set(range(2115)).difference(set(ind_valid))))

# Creating the training and validation sets using the generated indices
(X_train, X_valid) = X_train_valid[ind_train], X_train_valid[ind_valid]
(y_train, y_valid) = y_train_valid[ind_train], y_train_valid[ind_valid]


## Preprocessing the dataset
x_train,y_train = data_prep(X_train,y_train,2,2,True)
x_valid,y_valid = data_prep(X_valid,y_valid,2,2,True)
X_test_prep,y_test_prep = data_prep(X_test,y_test,2,2,True)


print('Shape of training set:',x_train.shape)
print('Shape of validation set:',x_valid.shape)
print('Shape of training labels:',y_train.shape)
print('Shape of validation labels:',y_valid.shape)
print('Shape of testing set:',X_test_prep.shape)
print('Shape of testing labels:',y_test_prep.shape)


# Converting the labels to categorical variables for multiclass classificati
y_train = to_categorical(y_train, 4)
y_valid = to_categorical(y_valid, 4)
y_test = to_categorical(y_test_prep, 4)
print('Shape of training labels after categorical conversion:',y_train.shape
print('Shape of validation labels after categorical conversion:',y_valid.sha
print('Shape of test labels after categorical conversion:',y_test.shape)

# Adding width of the segment to be 1
x_train = x_train.reshape(x_train.shape[0], x_train.shape[1], x_train.shape[
```

```
x_valid = x_valid.reshape(x_valid.shape[0], x_valid.shape[1], x_train.shape[
x_test = X_test_prep.reshape(X_test_prep.shape[0], X_test_prep.shape[1], X_t
print('Shape of training set after adding width info:',x_train.shape)
print('Shape of validation set after adding width info:',x_valid.shape)
print('Shape of test set after adding width info:',x_test.shape)


# Reshaping the training and validation dataset
x_train = np.swapaxes(x_train, 1,3)
x_train = np.swapaxes(x_train, 1,2)
x_valid = np.swapaxes(x_valid, 1,3)
x_valid = np.swapaxes(x_valid, 1,2)
x_test = np.swapaxes(x_test, 1,3)
x_test = np.swapaxes(x_test, 1,2)
print('Shape of training set after dimension reshaping:',x_train.shape)
print('Shape of validation set after dimension reshaping:',x_valid.shape)
print('Shape of test set after dimension reshaping:',x_test.shape)

keras.backend.clear_session()
```

```
Shape of X after trimming: (1740, 22, 500)
Shape of X after maxpooling: (1740, 22, 250)
Shape of X after averaging+noise and concatenating: (3480, 22, 250)
Shape of X after subsampling and concatenating: (6960, 22, 250)
Shape of X after trimming: (375, 22, 500)
Shape of X after maxpooling: (375, 22, 250)
Shape of X after averaging+noise and concatenating: (750, 22, 250)
Shape of X after subsampling and concatenating: (1500, 22, 250)
Shape of X after trimming: (443, 22, 500)
Shape of X after maxpooling: (443, 22, 250)
Shape of X after averaging+noise and concatenating: (886, 22, 250)
Shape of X after subsampling and concatenating: (1772, 22, 250)
Shape of training set: (6960, 22, 250)
Shape of validation set: (1500, 22, 250)
Shape of training labels: (6960,)
Shape of validation labels: (1500,)
Shape of testing set: (1772, 22, 250)
Shape of testing labels: (1772,)
Shape of training labels after categorical conversion: (6960, 4)
Shape of validation labels after categorical conversion: (1500, 4)
Shape of test labels after categorical conversion: (1772, 4)
Shape of training set after adding width info: (6960, 22, 250, 1)
Shape of validation set after adding width info: (1500, 22, 250, 1)
Shape of test set after adding width info: (1772, 22, 250, 1)
Shape of training set after dimension reshaping: (6960, 250, 1, 22)
Shape of validation set after dimension reshaping: (1500, 250, 1, 22)
Shape of test set after dimension reshaping: (1772, 250, 1, 22)
```

(iii) (CNN-Self-Attention) Defining the architecture of the hybrid CNN-LSTM model

In [ ]:
```
# Building the CNN model using functional class
def build_model():
# models = []

    n_frames = 250
    n_channels = 22
    # Conv. block 1
    In1 = keras.Input(shape =(250,1,22) )
    c1 = Conv2D(filters=30, kernel_size=(11,1), padding='same', activation='
    p1 =  MaxPooling2D(pool_size=(4,1), padding='same')(c1) # Read the keras
    b1 = BatchNormalization()(p1)
    d1 = Dropout(0.8)(b1)

    # Conv. block 2
    c2 = Conv2D(filters=60, kernel_size=(9,1), padding='same', activation='s
    p2 =  MaxPooling2D(pool_size=(4,1), padding='same')(c2) # Read the keras
    b2 = BatchNormalization()(p2)
    d2 = Dropout(0.7)(b2)

    # Conv. block 3
    c3 = Conv2D(filters=120, kernel_size=(5,1), padding='same', activation='
    p3 =  MaxPooling2D(pool_size=(4,1), padding='same')(c3) # Read the keras
    b3 = BatchNormalization()(p3)
    d3 = Dropout(0.6)(b3)

    c4 = Conv2D(filters=240, kernel_size=(3,1), padding='same', activation='
    p4 =  MaxPooling2D(pool_size=(4,1), padding='same')(c4) # Read the keras
    b4 = BatchNormalization()(p4)
    d4 = Dropout(0.5)(b4)

    # self attention block
    selfatt = tf.squeeze(d4, axis=2)
    selfatt = SeqSelfAttention(attention_activation='gelu')(selfatt)
    selfatt = GlobalAveragePooling1D()(selfatt)

    # Add fully connected layers
    fc1 = Dense(64, activation='relu')(selfatt)
    fc1_dropout = Dropout(rate=0.5)(fc1)
    fc2 = Dense(4, activation='softmax')(fc1_dropout)

    # Define the final model
    final_model = Model(inputs=In1, outputs=[fc2])

    # # Printing the model summary
    final_model.compile(loss='categorical_crossentropy',
            optimizer='adam',
            metrics=['accuracy'])
    final_model.summary()
    return final_model
```

(iv)(CNN-LSTM) Defining the hyperparameters of the hybrid CNN-LSTM model

In [ ]:
```
# Model parameters
epochs = 300
initial_learning_rate = 1e-3
decay_steps = 1000
decay_rate = 0.99

lr_schedule = tf.keras.optimizers.schedules.ExponentialDecay(
    initial_learning_rate,
    decay_steps=decay_steps,
    decay_rate=decay_rate
)

optimizer = keras.optimizers.Adam(learning_rate=lr_schedule)
```

(v)Attention at the end

In [ ]:
```
# Compiling the model
keras.backend.clear_session()

# Training and validating the model

batch_sizes = [32,64,128]
import matplotlib.pyplot as plt

hybrid_cnn_lstm_model = build_model()
# Compiling the model
hybrid_cnn_lstm_model.compile(loss='categorical_crossentropy',
               optimizer=optimizer,
               metrics=['accuracy'])

# Training and validating the model
acc = 0.73
class myCallback(tf.keras.callbacks.Callback):
        def on_epoch_end(self, epoch, logs={}):
                if((logs.get('val_accuracy') > acc)):
                        print("\nval accuracy high enough and difference bet
                        self.model.stop_training = True

# Instantiate a callback object
callback = myCallback()
# callback = keras.callbacks.EarlyStopping(monitor='val_loss', patience=10)
hybrid_cnn_lstm_model_results = hybrid_cnn_lstm_model.fit(x_train,
                y_train,
                batch_size=32,
                epochs=epochs,
                validation_data=(x_valid, y_valid),
                verbose=True,
                callbacks = [callback]
                )
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 250, 1, 22)]      0

 conv2d (Conv2D)             (None, 250, 1, 30)        7290

 max_pooling2d (MaxPooling2D  (None, 63, 1, 30)        0
 )

 batch_normalization (BatchN  (None, 63, 1, 30)        120
 ormalization)

 dropout (Dropout)           (None, 63, 1, 30)         0

 conv2d_1 (Conv2D)           (None, 63, 1, 60)         16260

 max_pooling2d_1 (MaxPooling  (None, 16, 1, 60)        0
 2D)

 batch_normalization_1 (Batc  (None, 16, 1, 60)        240
 hNormalization)

 dropout_1 (Dropout)         (None, 16, 1, 60)         0

 conv2d_2 (Conv2D)           (None, 16, 1, 120)        36120

 max_pooling2d_2 (MaxPooling  (None, 4, 1, 120)        0
 2D)

 batch_normalization_2 (Batc  (None, 4, 1, 120)        480
 hNormalization)

 dropout_2 (Dropout)         (None, 4, 1, 120)         0

 conv2d_3 (Conv2D)           (None, 4, 1, 240)         86640

 max_pooling2d_3 (MaxPooling  (None, 1, 1, 240)        0
 2D)

 batch_normalization_3 (Batc  (None, 1, 1, 240)        960
 hNormalization)

 dropout_3 (Dropout)         (None, 1, 1, 240)         0

 tf.compat.v1.squeeze (TFOpL  (None, 1, 240)           0
 ambda)

 seq_self_attention (SeqSelf  (None, 1, 240)           15425
 Attention)

 global_average_pooling1d (G  (None, 240)              0
 lobalAveragePooling1D)

 dense (Dense)               (None, 64)                15424
```

```
 dropout_4 (Dropout)         (None, 64)                0

 dense_1 (Dense)             (None, 4)                 260

=================================================================
Total params: 179,219
Trainable params: 178,319
Non-trainable params: 900
_________________________________________________________________
Epoch 1/300
218/218 [==============================] - 4s 14ms/step - loss: 2.0168 - ac
curacy: 0.2511 - val_loss: 1.4256 - val_accuracy: 0.2720
Epoch 2/300
218/218 [==============================] - 3s 15ms/step - loss: 1.5723 - ac
curacy: 0.2645 - val_loss: 1.3932 - val_accuracy: 0.2720
Epoch 3/300
218/218 [==============================] - 3s 14ms/step - loss: 1.4544 - ac
curacy: 0.2670 - val_loss: 1.3795 - val_accuracy: 0.2667
Epoch 4/300
218/218 [==============================] - 4s 18ms/step - loss: 1.4107 - ac
curacy: 0.2707 - val_loss: 1.3814 - val_accuracy: 0.2680
Epoch 5/300
218/218 [==============================] - 3s 15ms/step - loss: 1.4007 - ac
curacy: 0.2740 - val_loss: 1.3816 - val_accuracy: 0.2740
Epoch 6/300
218/218 [==============================] - 3s 15ms/step - loss: 1.3872 - ac
curacy: 0.2763 - val_loss: 1.3782 - val_accuracy: 0.2807
Epoch 7/300
218/218 [==============================] - 4s 17ms/step - loss: 1.3792 - ac
curacy: 0.2865 - val_loss: 1.3789 - val_accuracy: 0.2767
Epoch 8/300
218/218 [==============================] - 3s 15ms/step - loss: 1.3788 - ac
curacy: 0.2772 - val_loss: 1.3762 - val_accuracy: 0.2867
Epoch 9/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3747 - ac
curacy: 0.2912 - val_loss: 1.3781 - val_accuracy: 0.2773
Epoch 10/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3723 - ac
curacy: 0.2920 - val_loss: 1.3802 - val_accuracy: 0.2993
Epoch 11/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3601 - ac
curacy: 0.3195 - val_loss: 1.3610 - val_accuracy: 0.2960
Epoch 12/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3547 - ac
curacy: 0.3236 - val_loss: 1.3573 - val_accuracy: 0.3060
Epoch 13/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3361 - ac
curacy: 0.3437 - val_loss: 1.3372 - val_accuracy: 0.3127
Epoch 14/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3325 - ac
curacy: 0.3458 - val_loss: 1.3455 - val_accuracy: 0.3107
Epoch 15/300
218/218 [==============================] - 3s 14ms/step - loss: 1.3198 - ac
curacy: 0.3612 - val_loss: 1.3095 - val_accuracy: 0.3840
Epoch 16/300
```

```
218/218 [==============================] - 3s 14ms/step - loss: 1.3052 - ac
curacy: 0.3761 - val_loss: 1.3052 - val_accuracy: 0.3700
Epoch 17/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2919 - ac
curacy: 0.3787 - val_loss: 1.3137 - val_accuracy: 0.3400
Epoch 18/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2799 - ac
curacy: 0.4009 - val_loss: 1.2754 - val_accuracy: 0.3900
Epoch 19/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2698 - ac
curacy: 0.4046 - val_loss: 1.3078 - val_accuracy: 0.3700
Epoch 20/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2562 - ac
curacy: 0.4109 - val_loss: 1.2546 - val_accuracy: 0.3913
Epoch 21/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2535 - ac
curacy: 0.4190 - val_loss: 1.2611 - val_accuracy: 0.3773
Epoch 22/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2408 - ac
curacy: 0.4249 - val_loss: 1.2488 - val_accuracy: 0.4073
Epoch 23/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2230 - ac
curacy: 0.4425 - val_loss: 1.2628 - val_accuracy: 0.3727
Epoch 24/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2225 - ac
curacy: 0.4476 - val_loss: 1.2547 - val_accuracy: 0.3733
Epoch 25/300
218/218 [==============================] - 3s 15ms/step - loss: 1.2171 - ac
curacy: 0.4441 - val_loss: 1.2371 - val_accuracy: 0.4087
Epoch 26/300
218/218 [==============================] - 3s 14ms/step - loss: 1.2101 - ac
curacy: 0.4474 - val_loss: 1.2268 - val_accuracy: 0.4227
Epoch 27/300
218/218 [==============================] - 3s 15ms/step - loss: 1.2093 - ac
curacy: 0.4460 - val_loss: 1.2175 - val_accuracy: 0.4333
Epoch 28/300
218/218 [==============================] - 3s 16ms/step - loss: 1.2044 - ac
curacy: 0.4556 - val_loss: 1.2295 - val_accuracy: 0.4493
Epoch 29/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1899 - ac
curacy: 0.4615 - val_loss: 1.2126 - val_accuracy: 0.4360
Epoch 30/300
218/218 [==============================] - 3s 15ms/step - loss: 1.2003 - ac
curacy: 0.4537 - val_loss: 1.2128 - val_accuracy: 0.4593
Epoch 31/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1867 - ac
curacy: 0.4664 - val_loss: 1.2029 - val_accuracy: 0.4687
Epoch 32/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1817 - ac
curacy: 0.4733 - val_loss: 1.2153 - val_accuracy: 0.4193
Epoch 33/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1787 - ac
curacy: 0.4726 - val_loss: 1.1927 - val_accuracy: 0.4700
Epoch 34/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1686 - ac
curacy: 0.4772 - val_loss: 1.2066 - val_accuracy: 0.4473
```

```
Epoch 35/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1747 - ac
curacy: 0.4825 - val_loss: 1.1915 - val_accuracy: 0.4747
Epoch 36/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1660 - ac
curacy: 0.4819 - val_loss: 1.1909 - val_accuracy: 0.4513
Epoch 37/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1577 - ac
curacy: 0.4825 - val_loss: 1.2013 - val_accuracy: 0.4567
Epoch 38/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1555 - ac
curacy: 0.4898 - val_loss: 1.1875 - val_accuracy: 0.4800
Epoch 39/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1356 - ac
curacy: 0.5032 - val_loss: 1.1509 - val_accuracy: 0.4987
Epoch 40/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1382 - ac
curacy: 0.5109 - val_loss: 1.1679 - val_accuracy: 0.4813
Epoch 41/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1493 - ac
curacy: 0.5033 - val_loss: 1.1466 - val_accuracy: 0.5233
Epoch 42/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1235 - ac
curacy: 0.5155 - val_loss: 1.1349 - val_accuracy: 0.5247
Epoch 43/300
218/218 [==============================] - 4s 16ms/step - loss: 1.1241 - ac
curacy: 0.5168 - val_loss: 1.1264 - val_accuracy: 0.5153
Epoch 44/300
218/218 [==============================] - 3s 14ms/step - loss: 1.1172 - ac
curacy: 0.5240 - val_loss: 1.1199 - val_accuracy: 0.5347
Epoch 45/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1101 - ac
curacy: 0.5306 - val_loss: 1.1233 - val_accuracy: 0.5227
Epoch 46/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1086 - ac
curacy: 0.5280 - val_loss: 1.1228 - val_accuracy: 0.5260
Epoch 47/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1130 - ac
curacy: 0.5323 - val_loss: 1.1104 - val_accuracy: 0.5173
Epoch 48/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0981 - ac
curacy: 0.5421 - val_loss: 1.1077 - val_accuracy: 0.5333
Epoch 49/300
218/218 [==============================] - 3s 15ms/step - loss: 1.1007 - ac
curacy: 0.5297 - val_loss: 1.1121 - val_accuracy: 0.5320
Epoch 50/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0872 - ac
curacy: 0.5394 - val_loss: 1.0993 - val_accuracy: 0.5600
Epoch 51/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0763 - ac
curacy: 0.5457 - val_loss: 1.0881 - val_accuracy: 0.5567
Epoch 52/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0754 - ac
curacy: 0.5543 - val_loss: 1.0767 - val_accuracy: 0.5593
Epoch 53/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0785 - ac
```

```
curacy: 0.5507 - val_loss: 1.0654 - val_accuracy: 0.5687
Epoch 54/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0780 - ac
curacy: 0.5507 - val_loss: 1.0614 - val_accuracy: 0.5533
Epoch 55/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0595 - ac
curacy: 0.5585 - val_loss: 1.0747 - val_accuracy: 0.5653
Epoch 56/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0625 - ac
curacy: 0.5583 - val_loss: 1.0577 - val_accuracy: 0.5447
Epoch 57/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0499 - ac
curacy: 0.5601 - val_loss: 1.0412 - val_accuracy: 0.5653
Epoch 58/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0552 - ac
curacy: 0.5649 - val_loss: 1.0378 - val_accuracy: 0.5700
Epoch 59/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0462 - ac
curacy: 0.5661 - val_loss: 1.0221 - val_accuracy: 0.5807
Epoch 60/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0331 - ac
curacy: 0.5716 - val_loss: 1.0317 - val_accuracy: 0.5680
Epoch 61/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0399 - ac
curacy: 0.5727 - val_loss: 1.0149 - val_accuracy: 0.5887
Epoch 62/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0330 - ac
curacy: 0.5753 - val_loss: 1.0180 - val_accuracy: 0.5827
Epoch 63/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0382 - ac
curacy: 0.5823 - val_loss: 1.0146 - val_accuracy: 0.5827
Epoch 64/300
218/218 [==============================] - 3s 16ms/step - loss: 1.0276 - ac
curacy: 0.5770 - val_loss: 0.9921 - val_accuracy: 0.5913
Epoch 65/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0179 - ac
curacy: 0.5879 - val_loss: 1.0140 - val_accuracy: 0.5673
Epoch 66/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0159 - ac
curacy: 0.5812 - val_loss: 0.9827 - val_accuracy: 0.5973
Epoch 67/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0095 - ac
curacy: 0.5891 - val_loss: 0.9887 - val_accuracy: 0.6107
Epoch 68/300
218/218 [==============================] - 3s 15ms/step - loss: 1.0017 - ac
curacy: 0.5898 - val_loss: 0.9859 - val_accuracy: 0.5967
Epoch 69/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9987 - ac
curacy: 0.5981 - val_loss: 0.9772 - val_accuracy: 0.6160
Epoch 70/300
218/218 [==============================] - 3s 14ms/step - loss: 1.0044 - ac
curacy: 0.5953 - val_loss: 0.9594 - val_accuracy: 0.6187
Epoch 71/300
218/218 [==============================] - 3s 16ms/step - loss: 0.9993 - ac
curacy: 0.5909 - val_loss: 0.9747 - val_accuracy: 0.6113
Epoch 72/300
```

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218/218 [==============================] - 3s 15ms/step - loss: 1.0034 - ac
curacy: 0.5914 - val_loss: 0.9672 - val_accuracy: 0.6300
Epoch 73/300
218/218 [==============================] - 3s 16ms/step - loss: 0.9914 - ac
curacy: 0.5953 - val_loss: 0.9646 - val_accuracy: 0.6280
Epoch 74/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9867 - ac
curacy: 0.6026 - val_loss: 0.9425 - val_accuracy: 0.6287
Epoch 75/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9857 - ac
curacy: 0.5980 - val_loss: 0.9492 - val_accuracy: 0.6247
Epoch 76/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9766 - ac
curacy: 0.6019 - val_loss: 0.9416 - val_accuracy: 0.6233
Epoch 77/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9677 - ac
curacy: 0.6069 - val_loss: 0.9531 - val_accuracy: 0.6147
Epoch 78/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9521 - ac
curacy: 0.6114 - val_loss: 0.9284 - val_accuracy: 0.6200
Epoch 79/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9755 - ac
curacy: 0.6098 - val_loss: 0.9257 - val_accuracy: 0.6340
Epoch 80/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9587 - ac
curacy: 0.6096 - val_loss: 0.9299 - val_accuracy: 0.6180
Epoch 81/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9618 - ac
curacy: 0.6122 - val_loss: 0.9382 - val_accuracy: 0.6400
Epoch 82/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9433 - ac
curacy: 0.6191 - val_loss: 0.9188 - val_accuracy: 0.6320
Epoch 83/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9577 - ac
curacy: 0.6111 - val_loss: 0.9246 - val_accuracy: 0.6320
Epoch 84/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9548 - ac
curacy: 0.6128 - val_loss: 0.8958 - val_accuracy: 0.6480
Epoch 85/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9483 - ac
curacy: 0.6263 - val_loss: 0.8905 - val_accuracy: 0.6413
Epoch 86/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9617 - ac
curacy: 0.6108 - val_loss: 0.8969 - val_accuracy: 0.6527
Epoch 87/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9498 - ac
curacy: 0.6267 - val_loss: 0.8967 - val_accuracy: 0.6480
Epoch 88/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9456 - ac
curacy: 0.6134 - val_loss: 0.8981 - val_accuracy: 0.6447
Epoch 89/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9494 - ac
curacy: 0.6132 - val_loss: 0.8953 - val_accuracy: 0.6360
Epoch 90/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9390 - ac
curacy: 0.6233 - val_loss: 0.8784 - val_accuracy: 0.6447
```

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Epoch 91/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9453 - ac
curacy: 0.6167 - val_loss: 0.8902 - val_accuracy: 0.6420
Epoch 92/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9368 - ac
curacy: 0.6204 - val_loss: 0.8958 - val_accuracy: 0.6353
Epoch 93/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9331 - ac
curacy: 0.6310 - val_loss: 0.8938 - val_accuracy: 0.6447
Epoch 94/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9345 - ac
curacy: 0.6264 - val_loss: 0.8774 - val_accuracy: 0.6480
Epoch 95/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9241 - ac
curacy: 0.6303 - val_loss: 0.8753 - val_accuracy: 0.6587
Epoch 96/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9313 - ac
curacy: 0.6302 - val_loss: 0.8929 - val_accuracy: 0.6447
Epoch 97/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9311 - ac
curacy: 0.6307 - val_loss: 0.8948 - val_accuracy: 0.6427
Epoch 98/300
218/218 [==============================] - 3s 16ms/step - loss: 0.9347 - ac
curacy: 0.6287 - val_loss: 0.8800 - val_accuracy: 0.6373
Epoch 99/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9240 - ac
curacy: 0.6351 - val_loss: 0.8899 - val_accuracy: 0.6407
Epoch 100/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9180 - ac
curacy: 0.6299 - val_loss: 0.8936 - val_accuracy: 0.6380
Epoch 101/300
218/218 [==============================] - 3s 15ms/step - loss: 0.9224 - ac
curacy: 0.6356 - val_loss: 0.8694 - val_accuracy: 0.6573
Epoch 102/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9200 - ac
curacy: 0.6361 - val_loss: 0.8829 - val_accuracy: 0.6427
Epoch 103/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9252 - ac
curacy: 0.6338 - val_loss: 0.8786 - val_accuracy: 0.6393
Epoch 104/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9285 - ac
curacy: 0.6290 - val_loss: 0.8868 - val_accuracy: 0.6493
Epoch 105/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9032 - ac
curacy: 0.6366 - val_loss: 0.8827 - val_accuracy: 0.6333
Epoch 106/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9035 - ac
curacy: 0.6352 - val_loss: 0.8669 - val_accuracy: 0.6700
Epoch 107/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9063 - ac
curacy: 0.6385 - val_loss: 0.8633 - val_accuracy: 0.6533
Epoch 108/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9074 - ac
curacy: 0.6372 - val_loss: 0.8580 - val_accuracy: 0.6527
Epoch 109/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9171 - ac
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curacy: 0.6299 - val_loss: 0.8571 - val_accuracy: 0.6753
Epoch 110/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9001 - ac
curacy: 0.6467 - val_loss: 0.8469 - val_accuracy: 0.6647
Epoch 111/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9083 - ac
curacy: 0.6326 - val_loss: 0.8562 - val_accuracy: 0.6553
Epoch 112/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9064 - ac
curacy: 0.6358 - val_loss: 0.8592 - val_accuracy: 0.6580
Epoch 113/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8957 - ac
curacy: 0.6411 - val_loss: 0.8361 - val_accuracy: 0.6653
Epoch 114/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8912 - ac
curacy: 0.6481 - val_loss: 0.8464 - val_accuracy: 0.6673
Epoch 115/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9073 - ac
curacy: 0.6424 - val_loss: 0.8586 - val_accuracy: 0.6560
Epoch 116/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9029 - ac
curacy: 0.6421 - val_loss: 0.8502 - val_accuracy: 0.6607
Epoch 117/300
218/218 [==============================] - 3s 14ms/step - loss: 0.9008 - ac
curacy: 0.6478 - val_loss: 0.8452 - val_accuracy: 0.6593
Epoch 118/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8920 - ac
curacy: 0.6497 - val_loss: 0.8317 - val_accuracy: 0.6740
Epoch 119/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8969 - ac
curacy: 0.6448 - val_loss: 0.8531 - val_accuracy: 0.6580
Epoch 120/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8928 - ac
curacy: 0.6501 - val_loss: 0.8450 - val_accuracy: 0.6633
Epoch 121/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8928 - ac
curacy: 0.6481 - val_loss: 0.8441 - val_accuracy: 0.6513
Epoch 122/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8966 - ac
curacy: 0.6468 - val_loss: 0.8444 - val_accuracy: 0.6620
Epoch 123/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8912 - ac
curacy: 0.6478 - val_loss: 0.8398 - val_accuracy: 0.6473
Epoch 124/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8901 - ac
curacy: 0.6401 - val_loss: 0.8177 - val_accuracy: 0.6647
Epoch 125/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8904 - ac
curacy: 0.6451 - val_loss: 0.8372 - val_accuracy: 0.6753
Epoch 126/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8898 - ac
curacy: 0.6409 - val_loss: 0.8351 - val_accuracy: 0.6587
Epoch 127/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8872 - ac
curacy: 0.6503 - val_loss: 0.8351 - val_accuracy: 0.6680
Epoch 128/300
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218/218 [==============================] - 3s 14ms/step - loss: 0.8766 - ac
curacy: 0.6579 - val_loss: 0.8316 - val_accuracy: 0.6760
Epoch 129/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8911 - ac
curacy: 0.6480 - val_loss: 0.8288 - val_accuracy: 0.6680
Epoch 130/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8792 - ac
curacy: 0.6438 - val_loss: 0.8332 - val_accuracy: 0.6707
Epoch 131/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8684 - ac
curacy: 0.6559 - val_loss: 0.8165 - val_accuracy: 0.6720
Epoch 132/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8778 - ac
curacy: 0.6536 - val_loss: 0.8223 - val_accuracy: 0.6787
Epoch 133/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8645 - ac
curacy: 0.6628 - val_loss: 0.8365 - val_accuracy: 0.6673
Epoch 134/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8770 - ac
curacy: 0.6537 - val_loss: 0.8285 - val_accuracy: 0.6707
Epoch 135/300
218/218 [==============================] - 4s 16ms/step - loss: 0.8835 - ac
curacy: 0.6532 - val_loss: 0.8322 - val_accuracy: 0.6613
Epoch 136/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8697 - ac
curacy: 0.6570 - val_loss: 0.8322 - val_accuracy: 0.6680
Epoch 137/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8748 - ac
curacy: 0.6537 - val_loss: 0.8191 - val_accuracy: 0.6760
Epoch 138/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8652 - ac
curacy: 0.6569 - val_loss: 0.8331 - val_accuracy: 0.6673
Epoch 139/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8734 - ac
curacy: 0.6566 - val_loss: 0.8306 - val_accuracy: 0.6733
Epoch 140/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8675 - ac
curacy: 0.6539 - val_loss: 0.8267 - val_accuracy: 0.6747
Epoch 141/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8735 - ac
curacy: 0.6595 - val_loss: 0.8348 - val_accuracy: 0.6787
Epoch 142/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8632 - ac
curacy: 0.6612 - val_loss: 0.8191 - val_accuracy: 0.6720
Epoch 143/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8559 - ac
curacy: 0.6605 - val_loss: 0.8340 - val_accuracy: 0.6753
Epoch 144/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8550 - ac
curacy: 0.6609 - val_loss: 0.8101 - val_accuracy: 0.6780
Epoch 145/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8545 - ac
curacy: 0.6638 - val_loss: 0.8196 - val_accuracy: 0.6727
Epoch 146/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8616 - ac
curacy: 0.6639 - val_loss: 0.8012 - val_accuracy: 0.6847
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Epoch 147/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8641 - ac
curacy: 0.6652 - val_loss: 0.8185 - val_accuracy: 0.6847
Epoch 148/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8506 - ac
curacy: 0.6655 - val_loss: 0.8199 - val_accuracy: 0.6747
Epoch 149/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8440 - ac
curacy: 0.6701 - val_loss: 0.8176 - val_accuracy: 0.6807
Epoch 150/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8453 - ac
curacy: 0.6688 - val_loss: 0.8117 - val_accuracy: 0.6873
Epoch 151/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8474 - ac
curacy: 0.6710 - val_loss: 0.8127 - val_accuracy: 0.6727
Epoch 152/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8617 - ac
curacy: 0.6672 - val_loss: 0.8074 - val_accuracy: 0.6873
Epoch 153/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8620 - ac
curacy: 0.6631 - val_loss: 0.8065 - val_accuracy: 0.6840
Epoch 154/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8484 - ac
curacy: 0.6672 - val_loss: 0.8223 - val_accuracy: 0.6720
Epoch 155/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8476 - ac
curacy: 0.6649 - val_loss: 0.8126 - val_accuracy: 0.6733
Epoch 156/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8544 - ac
curacy: 0.6602 - val_loss: 0.8142 - val_accuracy: 0.6833
Epoch 157/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8564 - ac
curacy: 0.6649 - val_loss: 0.8077 - val_accuracy: 0.6787
Epoch 158/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8532 - ac
curacy: 0.6707 - val_loss: 0.8185 - val_accuracy: 0.6720
Epoch 159/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8497 - ac
curacy: 0.6677 - val_loss: 0.8079 - val_accuracy: 0.6827
Epoch 160/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8532 - ac
curacy: 0.6714 - val_loss: 0.8115 - val_accuracy: 0.6793
Epoch 161/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8457 - ac
curacy: 0.6691 - val_loss: 0.8274 - val_accuracy: 0.6800
Epoch 162/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8462 - ac
curacy: 0.6661 - val_loss: 0.8115 - val_accuracy: 0.6907
Epoch 163/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8336 - ac
curacy: 0.6693 - val_loss: 0.8123 - val_accuracy: 0.6787
Epoch 164/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8325 - ac
curacy: 0.6698 - val_loss: 0.7994 - val_accuracy: 0.6847
Epoch 165/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8440 - ac
```

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curacy: 0.6662 - val_loss: 0.8121 - val_accuracy: 0.6860
Epoch 166/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8322 - ac
curacy: 0.6773 - val_loss: 0.7937 - val_accuracy: 0.6960
Epoch 167/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8472 - ac
curacy: 0.6694 - val_loss: 0.7945 - val_accuracy: 0.6867
Epoch 168/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8404 - ac
curacy: 0.6736 - val_loss: 0.8104 - val_accuracy: 0.6893
Epoch 169/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8144 - ac
curacy: 0.6764 - val_loss: 0.8099 - val_accuracy: 0.6873
Epoch 170/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8482 - ac
curacy: 0.6624 - val_loss: 0.8267 - val_accuracy: 0.6807
Epoch 171/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8246 - ac
curacy: 0.6766 - val_loss: 0.8021 - val_accuracy: 0.6980
Epoch 172/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8475 - ac
curacy: 0.6677 - val_loss: 0.7989 - val_accuracy: 0.6907
Epoch 173/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8215 - ac
curacy: 0.6744 - val_loss: 0.7995 - val_accuracy: 0.6880
Epoch 174/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8460 - ac
curacy: 0.6658 - val_loss: 0.7989 - val_accuracy: 0.6980
Epoch 175/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8281 - ac
curacy: 0.6753 - val_loss: 0.7841 - val_accuracy: 0.7000
Epoch 176/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8322 - ac
curacy: 0.6793 - val_loss: 0.8024 - val_accuracy: 0.6793
Epoch 177/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8373 - ac
curacy: 0.6753 - val_loss: 0.7986 - val_accuracy: 0.6880
Epoch 178/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8278 - ac
curacy: 0.6793 - val_loss: 0.7926 - val_accuracy: 0.6887
Epoch 179/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8267 - ac
curacy: 0.6724 - val_loss: 0.7980 - val_accuracy: 0.6887
Epoch 180/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8219 - ac
curacy: 0.6861 - val_loss: 0.8141 - val_accuracy: 0.6827
Epoch 181/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8173 - ac
curacy: 0.6862 - val_loss: 0.7946 - val_accuracy: 0.6887
Epoch 182/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8296 - ac
curacy: 0.6763 - val_loss: 0.7824 - val_accuracy: 0.7000
Epoch 183/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8358 - ac
curacy: 0.6717 - val_loss: 0.7904 - val_accuracy: 0.6887
Epoch 184/300
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218/218 [==============================] - 3s 14ms/step - loss: 0.8003 - ac
curacy: 0.6912 - val_loss: 0.7849 - val_accuracy: 0.6853
Epoch 185/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8127 - ac
curacy: 0.6802 - val_loss: 0.7966 - val_accuracy: 0.6920
Epoch 186/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8278 - ac
curacy: 0.6772 - val_loss: 0.7958 - val_accuracy: 0.6987
Epoch 187/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8022 - ac
curacy: 0.6869 - val_loss: 0.7979 - val_accuracy: 0.6913
Epoch 188/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8121 - ac
curacy: 0.6819 - val_loss: 0.7994 - val_accuracy: 0.6853
Epoch 189/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8315 - ac
curacy: 0.6708 - val_loss: 0.7895 - val_accuracy: 0.6907
Epoch 190/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8261 - ac
curacy: 0.6843 - val_loss: 0.7963 - val_accuracy: 0.6927
Epoch 191/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8102 - ac
curacy: 0.6875 - val_loss: 0.7918 - val_accuracy: 0.6800
Epoch 192/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8142 - ac
curacy: 0.6825 - val_loss: 0.7829 - val_accuracy: 0.6840
Epoch 193/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8187 - ac
curacy: 0.6812 - val_loss: 0.7874 - val_accuracy: 0.6927
Epoch 194/300
218/218 [==============================] - 3s 14ms/step - loss: 0.8091 - ac
curacy: 0.6895 - val_loss: 0.7932 - val_accuracy: 0.6980
Epoch 195/300
218/218 [==============================] - 4s 17ms/step - loss: 0.7962 - ac
curacy: 0.6889 - val_loss: 0.7708 - val_accuracy: 0.7073
Epoch 196/300
218/218 [==============================] - 4s 19ms/step - loss: 0.8132 - ac
curacy: 0.6751 - val_loss: 0.7964 - val_accuracy: 0.6987
Epoch 197/300
218/218 [==============================] - 3s 16ms/step - loss: 0.8008 - ac
curacy: 0.6921 - val_loss: 0.7975 - val_accuracy: 0.7007
Epoch 198/300
218/218 [==============================] - 4s 16ms/step - loss: 0.7931 - ac
curacy: 0.6858 - val_loss: 0.7893 - val_accuracy: 0.6953
Epoch 199/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8154 - ac
curacy: 0.6816 - val_loss: 0.7822 - val_accuracy: 0.6967
Epoch 200/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8058 - ac
curacy: 0.6874 - val_loss: 0.7844 - val_accuracy: 0.6953
Epoch 201/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8170 - ac
curacy: 0.6793 - val_loss: 0.7749 - val_accuracy: 0.6940
Epoch 202/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8239 - ac
curacy: 0.6769 - val_loss: 0.7814 - val_accuracy: 0.6967
```

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Epoch 203/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7947 - ac
curacy: 0.6974 - val_loss: 0.7917 - val_accuracy: 0.6833
Epoch 204/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8142 - ac
curacy: 0.6826 - val_loss: 0.7879 - val_accuracy: 0.6993
Epoch 205/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8207 - ac
curacy: 0.6773 - val_loss: 0.7804 - val_accuracy: 0.7047
Epoch 206/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8062 - ac
curacy: 0.6846 - val_loss: 0.7917 - val_accuracy: 0.6947
Epoch 207/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8185 - ac
curacy: 0.6868 - val_loss: 0.7834 - val_accuracy: 0.6973
Epoch 208/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8031 - ac
curacy: 0.6898 - val_loss: 0.7828 - val_accuracy: 0.7140
Epoch 209/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8019 - ac
curacy: 0.6816 - val_loss: 0.7952 - val_accuracy: 0.6980
Epoch 210/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8113 - ac
curacy: 0.6832 - val_loss: 0.7946 - val_accuracy: 0.7013
Epoch 211/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8034 - ac
curacy: 0.6874 - val_loss: 0.7900 - val_accuracy: 0.6933
Epoch 212/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7868 - ac
curacy: 0.6912 - val_loss: 0.7852 - val_accuracy: 0.6940
Epoch 213/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8103 - ac
curacy: 0.6862 - val_loss: 0.7932 - val_accuracy: 0.6913
Epoch 214/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8057 - ac
curacy: 0.6841 - val_loss: 0.7882 - val_accuracy: 0.6827
Epoch 215/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8061 - ac
curacy: 0.6886 - val_loss: 0.7858 - val_accuracy: 0.6960
Epoch 216/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8000 - ac
curacy: 0.6912 - val_loss: 0.7990 - val_accuracy: 0.6933
Epoch 217/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7949 - ac
curacy: 0.6908 - val_loss: 0.7805 - val_accuracy: 0.7033
Epoch 218/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7924 - ac
curacy: 0.7013 - val_loss: 0.7933 - val_accuracy: 0.6900
Epoch 219/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7944 - ac
curacy: 0.6977 - val_loss: 0.7838 - val_accuracy: 0.7020
Epoch 220/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7961 - ac
curacy: 0.6905 - val_loss: 0.7958 - val_accuracy: 0.6960
Epoch 221/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8037 - ac
```

```
curacy: 0.6937 - val_loss: 0.7798 - val_accuracy: 0.6967
Epoch 222/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7902 - ac
curacy: 0.6938 - val_loss: 0.7805 - val_accuracy: 0.7100
Epoch 223/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7910 - ac
curacy: 0.6996 - val_loss: 0.8013 - val_accuracy: 0.6860
Epoch 224/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7959 - ac
curacy: 0.6862 - val_loss: 0.7726 - val_accuracy: 0.7033
Epoch 225/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7895 - ac
curacy: 0.6974 - val_loss: 0.7804 - val_accuracy: 0.7020
Epoch 226/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7857 - ac
curacy: 0.6958 - val_loss: 0.7907 - val_accuracy: 0.6947
Epoch 227/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7949 - ac
curacy: 0.6930 - val_loss: 0.7842 - val_accuracy: 0.6947
Epoch 228/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7760 - ac
curacy: 0.7034 - val_loss: 0.7833 - val_accuracy: 0.6893
Epoch 229/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7888 - ac
curacy: 0.6947 - val_loss: 0.7745 - val_accuracy: 0.6987
Epoch 230/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7857 - ac
curacy: 0.6898 - val_loss: 0.7810 - val_accuracy: 0.7033
Epoch 231/300
218/218 [==============================] - 4s 17ms/step - loss: 0.7878 - ac
curacy: 0.6974 - val_loss: 0.7680 - val_accuracy: 0.7080
Epoch 232/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7885 - ac
curacy: 0.6960 - val_loss: 0.7849 - val_accuracy: 0.7007
Epoch 233/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7808 - ac
curacy: 0.6958 - val_loss: 0.7803 - val_accuracy: 0.7027
Epoch 234/300
218/218 [==============================] - 3s 15ms/step - loss: 0.8025 - ac
curacy: 0.6864 - val_loss: 0.7728 - val_accuracy: 0.7160
Epoch 235/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7765 - ac
curacy: 0.7042 - val_loss: 0.7765 - val_accuracy: 0.7093
Epoch 236/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7921 - ac
curacy: 0.6931 - val_loss: 0.7571 - val_accuracy: 0.7127
Epoch 237/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7819 - ac
curacy: 0.6955 - val_loss: 0.7729 - val_accuracy: 0.7153
Epoch 238/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7865 - ac
curacy: 0.6958 - val_loss: 0.7722 - val_accuracy: 0.7120
Epoch 239/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7827 - ac
curacy: 0.6924 - val_loss: 0.7738 - val_accuracy: 0.7120
Epoch 240/300
```

```
218/218 [==============================] - 3s 14ms/step - loss: 0.7883 - ac
curacy: 0.6955 - val_loss: 0.7809 - val_accuracy: 0.7060
Epoch 241/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7885 - ac
curacy: 0.6954 - val_loss: 0.7805 - val_accuracy: 0.7073
Epoch 242/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7938 - ac
curacy: 0.6922 - val_loss: 0.7896 - val_accuracy: 0.7100
Epoch 243/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7833 - ac
curacy: 0.6940 - val_loss: 0.7702 - val_accuracy: 0.7100
Epoch 244/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7860 - ac
curacy: 0.7013 - val_loss: 0.7783 - val_accuracy: 0.7067
Epoch 245/300
218/218 [==============================] - 4s 17ms/step - loss: 0.7848 - ac
curacy: 0.6934 - val_loss: 0.7831 - val_accuracy: 0.7107
Epoch 246/300
218/218 [==============================] - 4s 18ms/step - loss: 0.7934 - ac
curacy: 0.6905 - val_loss: 0.7670 - val_accuracy: 0.7227
Epoch 247/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7823 - ac
curacy: 0.6941 - val_loss: 0.7670 - val_accuracy: 0.7073
Epoch 248/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7749 - ac
curacy: 0.7056 - val_loss: 0.7864 - val_accuracy: 0.6960
Epoch 249/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7709 - ac
curacy: 0.7070 - val_loss: 0.7611 - val_accuracy: 0.7133
Epoch 250/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7763 - ac
curacy: 0.7011 - val_loss: 0.7634 - val_accuracy: 0.7167
Epoch 251/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7714 - ac
curacy: 0.6957 - val_loss: 0.7571 - val_accuracy: 0.7080
Epoch 252/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7743 - ac
curacy: 0.6968 - val_loss: 0.7765 - val_accuracy: 0.7080
Epoch 253/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7687 - ac
curacy: 0.7032 - val_loss: 0.7812 - val_accuracy: 0.7093
Epoch 254/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7860 - ac
curacy: 0.6970 - val_loss: 0.7713 - val_accuracy: 0.7213
Epoch 255/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7687 - ac
curacy: 0.7057 - val_loss: 0.7505 - val_accuracy: 0.7153
Epoch 256/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7743 - ac
curacy: 0.6955 - val_loss: 0.7613 - val_accuracy: 0.7113
Epoch 257/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7733 - ac
curacy: 0.7089 - val_loss: 0.7638 - val_accuracy: 0.7093
Epoch 258/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7662 - ac
curacy: 0.7004 - val_loss: 0.7738 - val_accuracy: 0.7113
```

```
Epoch 259/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7748 - ac
curacy: 0.7060 - val_loss: 0.7614 - val_accuracy: 0.7067
Epoch 260/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7774 - ac
curacy: 0.7003 - val_loss: 0.7770 - val_accuracy: 0.7027
Epoch 261/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7577 - ac
curacy: 0.7088 - val_loss: 0.7674 - val_accuracy: 0.7173
Epoch 262/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7704 - ac
curacy: 0.6980 - val_loss: 0.7681 - val_accuracy: 0.7100
Epoch 263/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7767 - ac
curacy: 0.6983 - val_loss: 0.7647 - val_accuracy: 0.7160
Epoch 264/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7677 - ac
curacy: 0.7019 - val_loss: 0.7717 - val_accuracy: 0.7033
Epoch 265/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7934 - ac
curacy: 0.6993 - val_loss: 0.7482 - val_accuracy: 0.7193
Epoch 266/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7698 - ac
curacy: 0.7004 - val_loss: 0.7708 - val_accuracy: 0.7147
Epoch 267/300
218/218 [==============================] - 4s 17ms/step - loss: 0.7769 - ac
curacy: 0.7055 - val_loss: 0.7570 - val_accuracy: 0.7040
Epoch 268/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7549 - ac
curacy: 0.7036 - val_loss: 0.7565 - val_accuracy: 0.7087
Epoch 269/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7721 - ac
curacy: 0.6986 - val_loss: 0.7735 - val_accuracy: 0.7020
Epoch 270/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7726 - ac
curacy: 0.6981 - val_loss: 0.7740 - val_accuracy: 0.7060
Epoch 271/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7788 - ac
curacy: 0.6983 - val_loss: 0.7652 - val_accuracy: 0.7120
Epoch 272/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7774 - ac
curacy: 0.7014 - val_loss: 0.7718 - val_accuracy: 0.7167
Epoch 273/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7675 - ac
curacy: 0.7046 - val_loss: 0.7724 - val_accuracy: 0.7147
Epoch 274/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7695 - ac
curacy: 0.7026 - val_loss: 0.7682 - val_accuracy: 0.7100
Epoch 275/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7650 - ac
curacy: 0.7029 - val_loss: 0.7778 - val_accuracy: 0.7060
Epoch 276/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7732 - ac
curacy: 0.7029 - val_loss: 0.7809 - val_accuracy: 0.7033
Epoch 277/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7732 - ac
```

```
curacy: 0.7027 - val_loss: 0.7703 - val_accuracy: 0.7007
Epoch 278/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7691 - ac
curacy: 0.7046 - val_loss: 0.7699 - val_accuracy: 0.7167
Epoch 279/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7570 - ac
curacy: 0.7029 - val_loss: 0.7591 - val_accuracy: 0.7113
Epoch 280/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7739 - ac
curacy: 0.6993 - val_loss: 0.7622 - val_accuracy: 0.7140
Epoch 281/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7543 - ac
curacy: 0.7034 - val_loss: 0.7614 - val_accuracy: 0.7173
Epoch 282/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7723 - ac
curacy: 0.7055 - val_loss: 0.7574 - val_accuracy: 0.7060
Epoch 283/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7607 - ac
curacy: 0.7129 - val_loss: 0.7503 - val_accuracy: 0.7193
Epoch 284/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7732 - ac
curacy: 0.6944 - val_loss: 0.7693 - val_accuracy: 0.7027
Epoch 285/300
218/218 [==============================] - 3s 14ms/step - loss: 0.7660 - ac
curacy: 0.6968 - val_loss: 0.7675 - val_accuracy: 0.7133
Epoch 286/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7517 - ac
curacy: 0.7151 - val_loss: 0.7482 - val_accuracy: 0.7213
Epoch 287/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7707 - ac
curacy: 0.7039 - val_loss: 0.7610 - val_accuracy: 0.7113
Epoch 288/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7680 - ac
curacy: 0.7017 - val_loss: 0.7626 - val_accuracy: 0.7167
Epoch 289/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7527 - ac
curacy: 0.7086 - val_loss: 0.7659 - val_accuracy: 0.7187
Epoch 290/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7696 - ac
curacy: 0.7001 - val_loss: 0.7622 - val_accuracy: 0.7153
Epoch 291/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7628 - ac
curacy: 0.7065 - val_loss: 0.7657 - val_accuracy: 0.7067
Epoch 292/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7536 - ac
curacy: 0.7065 - val_loss: 0.7678 - val_accuracy: 0.7053
Epoch 293/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7564 - ac
curacy: 0.7091 - val_loss: 0.7646 - val_accuracy: 0.7107
Epoch 294/300
218/218 [==============================] - 3s 16ms/step - loss: 0.7580 - ac
curacy: 0.7091 - val_loss: 0.7542 - val_accuracy: 0.7140
Epoch 295/300
218/218 [==============================] - 3s 15ms/step - loss: 0.7521 - ac
curacy: 0.7109 - val_loss: 0.7635 - val_accuracy: 0.7160
Epoch 296/300
```

```
218/218 [==============================] - 3s 15ms/step - loss: 0.7527 - ac
curacy: 0.7060 - val_loss: 0.7545 - val_accuracy: 0.7220
Epoch 297/300
169/218 [======================>.......] - ETA: 0s - loss: 0.7493 - accurac
y: 0.7110
```

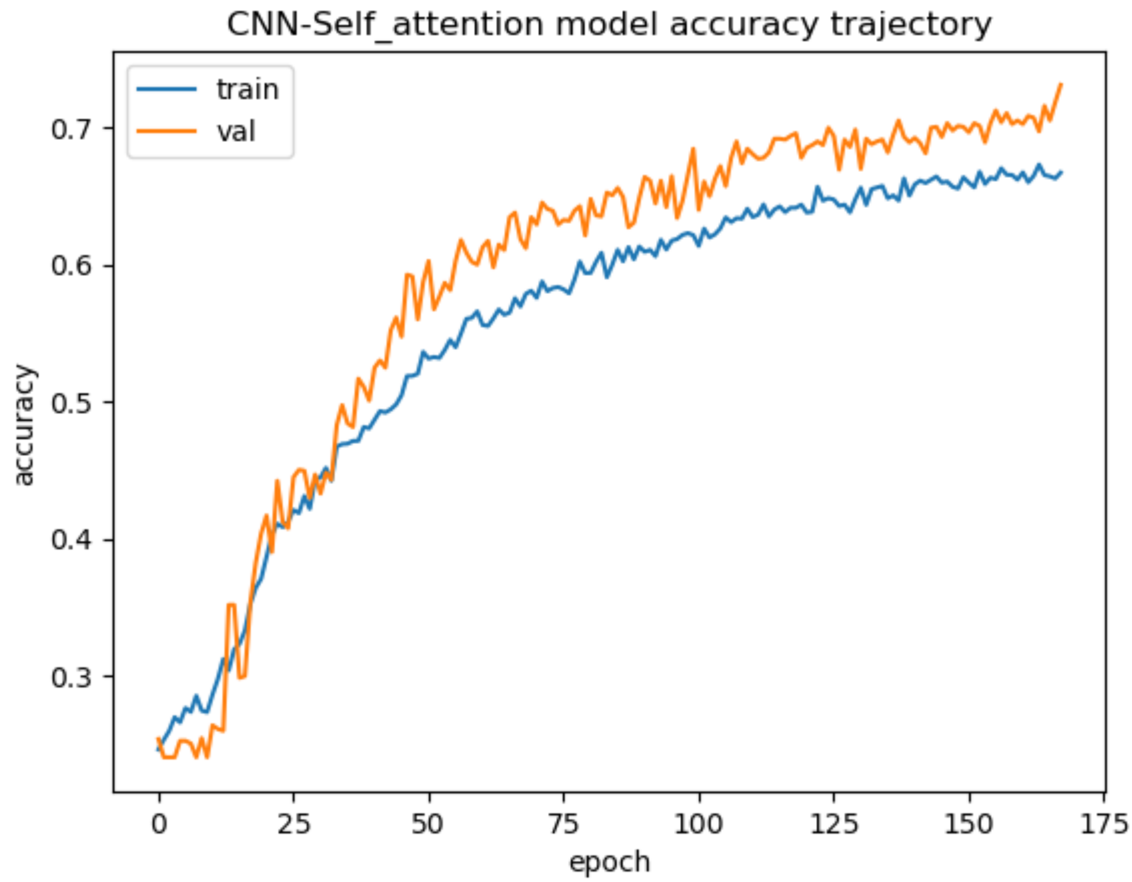
(vi)(CNN-Attention) Visualizing the accuracy and loss trajectory

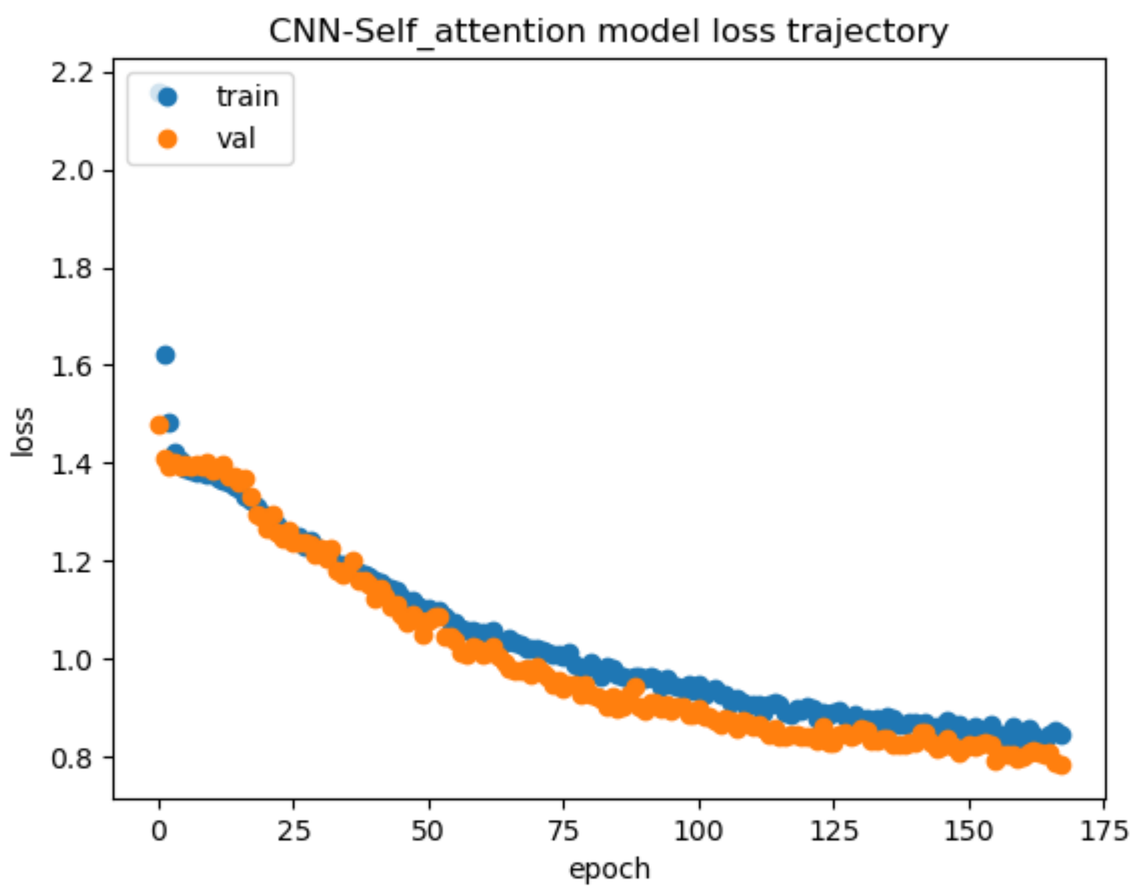
In [ ]:

```
import matplotlib.pyplot as plt

# Plotting accuracy trajectory
plt.plot(hybrid_cnn_lstm_model_results.history['accuracy'])
plt.plot(hybrid_cnn_lstm_model_results.history['val_accuracy'])
plt.title('CNN-Self_attention model accuracy trajectory')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()

# Plotting loss trajectory
plt.plot(hybrid_cnn_lstm_model_results.history['loss'],'o')
plt.plot(hybrid_cnn_lstm_model_results.history['val_loss'],'o')
plt.title('CNN-Self_attention model loss trajectory')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
```


CNN-Self_attention model accuracy trajectory
train
val
accuracy
epoch
0.3
0.4
0.5
0.6
0.7
0
25
50
75
100
125
150
175


CNN-Self_attention model loss trajectory
train
val
loss
epoch
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
0
25
50
75
100
125
150
175

(vii)(CNN-Self-Attention) Testing the performance of the hybrid CNN-Self-Attention model on the held out test set

In [ ]:
```
## Testing the hybrid CNN-LSTM model

hybrid_cnn_lstm_score = hybrid_cnn_lstm_model.evaluate(x_test, y_test, verbo
print('Test accuracy of the hybrid CNN-attention model:',hybrid_cnn_lstm_sco
```

```
Test accuracy of the hybrid CNN-attention model: 0.6805869340896606
```

In [ ]: