```
import matplotlib as mpl
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
from sklearn.preprocessing import MinMaxScaler
from scipy import stats
import seaborn as sns
import tensorflow as tf
from tensorflow import keras
import sklearn
import sys
import io

n_steps = 50
forecast = 10

def plot_learning_curves(loss, val_loss):
    plt.figure()
    plt.plot(np.arange(len(loss)), loss, "b.-", label="Training loss")
    plt.plot(np.arange(len(val_loss)), val_loss, "r.-", label="Validation loss")
    plt.gca().xaxis.set_major_locator(mpl.ticker.MaxNLocator(integer=True))
    plt.legend(fontsize=14)
    plt.xlabel("Epochs")
    plt.ylabel("Loss")
    plt.grid(True)

#LOAD DATA
data_west = pd.read_csv('denoised_data_1015_south.csv')
data_west_o = np.array(data_west.FLOW)
# #EXRTEND DATA
array_to_concatinate = data_west_o[288:]
for iter in range (35):
    data_west_o = np.concatenate([data_west_o,array_to_concatinate])

# #SCALE AND RESHAPE DATA
scaler = MinMaxScaler()
array = data_west_o.reshape(-1, 1)
array_scaled = scaler.fit_transform(array)
flow_reshaped = array_scaled[:(len(array_scaled) - (len(array_scaled) % (n_steps+forecast
print(flow_reshaped.shape)

# #TRAIN SET, VALIDATION SET, TEST SET
test = int(0.7 * flow_reshaped.shape[0])
valid = int(0.9 * flow_reshaped.shape[0])

X_train= flow_reshaped[:test, :n_steps] #first 50, last 10
X_valid = flow_reshaped[test:valid, :n_steps]
X_test = flow_reshaped[valid:, :n_steps]

#prepare targets
Y = np.empty((flow_reshaped.shape[0], n_steps, forecast))
for step_ahead in range(1, forecast + 1):
    Y[:, :, step_ahead - 1] = flow_reshaped[:, step_ahead:step_ahead + n_steps, 0]

y_train = Y[:test]
y_valid = Y[test:valid]
y_test = Y[valid:]

# # NEW MODEL TO FIT HYPERPARAMETERS
model = keras.models.Sequential([
    keras.layers.SimpleRNN(20, return_sequences=True, input_shape=[None, 1]),
    keras.layers.SimpleRNN(20, return_sequences=True),
    keras.layers.TimeDistributed(keras.layers.Dense(forecast))
])

def last_time_step_mse(Y_true, Y_pred):
    return keras.metrics.mean_squared_error(Y_true[:, -1], Y_pred[:, -1])

model.compile(loss="mse", optimizer="adam",  metrics=[last_time_step_mse])
```

```
early_stopping_cb = keras.callbacks.EarlyStopping(patience=10, restore_best_weights=True)
history = model.fit(X_train, y_train, epochs=700,
                    validation_data=(X_valid, y_valid), callbacks=[early_stopping_cb])

model.save("rnn_1014_south.h5")
plot_learning_curves(history.history["loss"], history.history["val_loss"])


#50 minutes forecast
flow_unscaled = array[:(len(array) - (len(array) % (n_steps + forecast)))].reshape(-1, (n
y_test_unscaled = flow_unscaled[valid:, n_steps:, 0]
y_real_rescaled = y_test_unscaled[-1, :].reshape(-1, 1)
print(y_real_rescaled.shape)

flow_not_reshaped = array[:(len(array) - (len(array) % (n_steps+forecast)))]

#flow prediction
y_pred = model.predict(X_test[-1, :].reshape(-1, n_steps, 1)) #shape (1, 50, 10)
y_pred = y_pred[-1,-1,:].reshape(-1,1)
y_pred_rescaled = scaler.inverse_transform(y_pred).reshape(-1, 1) #shape (10, 1)
print(y_pred_rescaled.shape)

#time
time_not_reshaped = np.array(data_west['TIME'][:(len(data_west['TIME']) - (len(data_west[
time_reshaped = np.array(data_west['TIME'][:(len(data_west['TIME']) - (len(data_west['TIM
    reshape(-1, (n_steps+forecast), 1)

valid_time = int(0.9 * time_reshaped.shape[0])
y_time_test = time_reshaped[valid_time:, n_steps:, 0]
print(y_time_test[-1, :].shape)

def plot_prediction(y_real_resacled, y_pred_rescaled, flow_not_reshaped, time_not_reshape
    plt.figure()
    plt.title("50 minutes prediction", fontsize=14)
    plt.plot(time_not_reshaped[-300:-forecast], flow_not_reshaped[-300:-forecast], 'b-')
    plt.plot(y_time_test[-1, :], y_real_resacled, 'ro-', label = 'Real values')
    plt.plot(y_time_test[-1, :], y_pred_rescaled, 'gx-', label = 'Predicted values')
    plt.legend(loc="upper left")
    plt.xlabel("Time")
    plt.ylabel('Volume')

plot_prediction(y_real_rescaled, y_pred_rescaled, flow_not_reshaped, time_not_reshaped, y

plt.show()
```

```
(10132, 60, 1)
Train on 7092 samples, validate on 2026 samples
Epoch 1/700
7092/7092 [==============================] - 4s 536us/sample - loss: 0.0487 - l
Epoch 2/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0103 - l
Epoch 3/700
7092/7092 [==============================] - 3s 488us/sample - loss: 0.0085 - l
Epoch 4/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0078 - l
Epoch 5/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0075 - l
Epoch 6/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0074 - l
Epoch 7/700
7092/7092 [==============================] - 4s 496us/sample - loss: 0.0073 - l
Epoch 8/700
7092/7092 [==============================] - 4s 503us/sample - loss: 0.0072 - l
Epoch 9/700
7092/7092 [==============================] - 4s 505us/sample - loss: 0.0072 - l
Epoch 10/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0071 - l
Epoch 11/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0071 - l
Epoch 12/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0071 - l
Epoch 13/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0071 - l
Epoch 14/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0071 - l
Epoch 15/700
7092/7092 [==============================] - 3s 477us/sample - loss: 0.0071 - l
Epoch 16/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0071 - l
Epoch 17/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0070 - l
Epoch 18/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0070 - l
Epoch 19/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0070 - l
Epoch 20/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0070 - l
Epoch 21/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0070 - l
Epoch 22/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0070 - l
Epoch 23/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0069 - l
Epoch 24/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0069 - l
Epoch 25/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0070 - l
Epoch 26/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0069 - l
Epoch 27/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0069 - l
Epoch 28/700
7092/7092 [==============================] - 4s 501us/sample - loss: 0.0069 - l
Epoch 29/700
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Epoch 29/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0069 - l
Epoch 30/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0069 - l
Epoch 31/700
7092/7092 [==============================] - 3s 470us/sample - loss: 0.0069 - l
Epoch 32/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0069 - l
Epoch 33/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0068 - l
Epoch 34/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0068 - l
Epoch 35/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0069 - l
Epoch 36/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0068 - l
Epoch 37/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0068 - l
Epoch 38/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0067 - l
Epoch 39/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0067 - l
Epoch 40/700
7092/7092 [==============================] - 4s 498us/sample - loss: 0.0066 - l
Epoch 41/700
7092/7092 [==============================] - 4s 507us/sample - loss: 0.0066 - l
Epoch 42/700
7092/7092 [==============================] - 4s 516us/sample - loss: 0.0066 - l
Epoch 43/700
7092/7092 [==============================] - 4s 507us/sample - loss: 0.0066 - l
Epoch 44/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0065 - l
Epoch 45/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0065 - l
Epoch 46/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0066 - l
Epoch 47/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0065 - l
Epoch 48/700
7092/7092 [==============================] - 3s 470us/sample - loss: 0.0065 - l
Epoch 49/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0065 - l
Epoch 50/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0065 - l
Epoch 51/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0064 - l
Epoch 52/700
7092/7092 [==============================] - 3s 472us/sample - loss: 0.0064 - l
Epoch 53/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0064 - l
Epoch 54/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0064 - l
Epoch 55/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0064 - l
Epoch 56/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0064 - l
Epoch 57/700
7092/7092 [==============================] - 4s 501us/sample - loss: 0.0064 - l
Epoch 58/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0063 - l
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Epoch 59/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0064 - l
Epoch 60/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0063 - l
Epoch 61/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0063 - l
Epoch 62/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0063 - l
Epoch 63/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0063 - l
Epoch 64/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0063 - l
Epoch 65/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0063 - l
Epoch 66/700
7092/7092 [==============================] - 3s 467us/sample - loss: 0.0063 - l
Epoch 67/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0063 - l
Epoch 68/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0063 - l
Epoch 69/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0063 - l
Epoch 70/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0062 - l
Epoch 71/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0063 - l
Epoch 72/700
7092/7092 [==============================] - 3s 472us/sample - loss: 0.0062 - l
Epoch 73/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0062 - l
Epoch 74/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0063 - l
Epoch 75/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0062 - l
Epoch 76/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0062 - l
Epoch 77/700
7092/7092 [==============================] - 4s 513us/sample - loss: 0.0062 - l
Epoch 78/700
7092/7092 [==============================] - 4s 511us/sample - loss: 0.0062 - l
Epoch 79/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0062 - l
Epoch 80/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0062 - l
Epoch 81/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0062 - l
Epoch 82/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0062 - l
Epoch 83/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0062 - l
Epoch 84/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0062 - l
Epoch 85/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0062 - l
Epoch 86/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0062 - l
Epoch 87/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0062 - l
Epoch 88/700
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7092/7092 [==============================] - 3s 470us/sample - loss: 0.0062 - l
Epoch 89/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0062 - l
Epoch 90/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0062 - l
Epoch 91/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0062 - l
Epoch 92/700
7092/7092 [==============================] - 4s 501us/sample - loss: 0.0061 - l
Epoch 93/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0062 - l
Epoch 94/700
7092/7092 [==============================] - 4s 497us/sample - loss: 0.0061 - l
Epoch 95/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0062 - l
Epoch 96/700
7092/7092 [==============================] - 4s 495us/sample - loss: 0.0062 - l
Epoch 97/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0062 - l
Epoch 98/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0061 - l
(10, 1)
(10, 1)
(10,)
```