PM_RNN2

November 30, 2017

In [1]:
```
import numpy as np
import pandas as pd
import os
import matplotlib.pyplot as plt
```

In [2]:
```
os.listdir('data')
```

Out[2]:
```
['Env_QH.csv',
 'micro_sud3.pkl',
 'AllPM_QH.csv',
 'micro_sud3_normalized.pkl',
 'AllNO2_QH.csv']
```

In [3]:
```
df = pd.read_pickle('data/micro_sud3_normalized.pkl')
df = df.reset_index()

def split_dataframe(dataframe, percent):
    nb_rows = int(np.floor(percent * len(dataframe)))
    return dataframe[:nb_rows], dataframe[nb_rows:]
def dataframe_to_xy(df):
    return (np.array(df[['PM_6182', 'PM_6179', 'PM_617B', 'PM25_6182', 'PM25_6179',\
                         'PM25_617B', 'temp', 'rh',\
                         'tgrad', 'pressure', 'pluvio']]),\
            np.array(df['PM_ref']))
def dataframe_to_xy(df, look_back):
    i = look_back
    while True:
        sequence = df.iloc[i - look_back:i]
        yield np.array(sequence[['PM_6182', 'PM_6179', 'PM_617B', 'PM25_6182', 'PM25_6
                         'PM25_617B', 'temp', 'rh',\
                         'tgrad', 'pressure', 'pluvio']]).reshape(look_back, 1, 11) , n
        i += 1
        if i == len(df):
            i = look_back

def dataframe_to_xy_test(df, look_back):
    X_test, y_test = [], []
    i = look_back
```

```
        while i < len(df):
            sequence = df.iloc[i - look_back:i]
            X_test.append(np.array(sequence[['PM_6182', 'PM_6179', 'PM_617B', 'PM25_6182',
                           'PM25_617B', 'temp', 'rh',\
                           'tgrad', 'pressure', 'pluvio']]).reshape(look_back, 1, 11))
            y_test.append(np.array(sequence['PM_ref']))
            i += 1
            if i == len(df):
                break

        return np.array(X_test), np.array(y_test)


    df_train, df_test = split_dataframe(df, 0.5)
    df_valid, df_test = split_dataframe(df_test, 0.5)

    X_train = dataframe_to_xy(df_train, 24)
    X_valid = dataframe_to_xy(df_valid, 24)
    X_test, y_test = dataframe_to_xy_test(df_test, 24)
```

In [4]:
```
a = next(X_train)
```

In [5]:
```
from keras.layers import SimpleRNN, Dense, LSTM, GRU
from keras.models import Sequential
from keras.callbacks import EarlyStopping

def simple_rnn_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
    model = Sequential()
    model.add(SimpleRNN(nb_units, input_shape=input_dim))#input_dim=input_dim[1], inpu
    model.add(Dense(1, kernel_initializer='normal'))
    model.compile(loss=loss, optimizer=optimizer)
    model.summary()
    return model

def lstm_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
    model = Sequential()
    model.add(LSTM(nb_units, input_shape=input_dim))#input_dim=input_dim[1], input_len
    model.add(Dense(1, kernel_initializer='normal'))
    model.compile(loss=loss, optimizer=optimizer)
    model.summary()
    return model

def gru_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
    model = Sequential()
    model.add(GRU(nb_units, input_shape=(input_dim)))#input_dim=input_dim[1], input_le
    model.add(Dense(1, kernel_initializer='normal'))
    model.compile(loss=loss, optimizer=optimizer)
    model.summary()
    return model
```

```
Using TensorFlow backend.
```

```
In [6]: model = simple_rnn_model(16, (1, 11))
        history = model.fit_generator(X_train, epochs=100, steps_per_epoch=16, validation_data=
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
simple_rnn_1 (SimpleRNN)     (None, 16)                448
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 17
=================================================================
Total params: 465
Trainable params: 465
Non-trainable params: 0
_________________________________________________________________
Epoch 1/100
16/16 [==============================] - 2s - loss: 240.7580 - val_loss: 87.9542
Epoch 2/100
16/16 [==============================] - 0s - loss: 324.0374 - val_loss: 68.8147
Epoch 3/100
16/16 [==============================] - 0s - loss: 722.3208 - val_loss: 115.7490
Epoch 4/100
16/16 [==============================] - 0s - loss: 887.9067 - val_loss: 148.4357
Epoch 5/100
16/16 [==============================] - 0s - loss: 556.8271 - val_loss: 241.9434
Epoch 6/100
16/16 [==============================] - 0s - loss: 572.5114 - val_loss: 266.4053
Epoch 7/100
16/16 [==============================] - 0s - loss: 281.3738 - val_loss: 411.8078
Epoch 8/100
16/16 [==============================] - 0s - loss: 301.7136 - val_loss: 695.6021
Epoch 9/100
16/16 [==============================] - 0s - loss: 576.8760 - val_loss: 1054.2417
Epoch 10/100
16/16 [==============================] - 0s - loss: 531.1208 - val_loss: 946.5771
Epoch 11/100
16/16 [==============================] - 0s - loss: 327.1745 - val_loss: 568.5938
Epoch 12/100
16/16 [==============================] - 0s - loss: 237.4413 - val_loss: 307.9957
Epoch 13/100
16/16 [==============================] - 0s - loss: 196.0601 - val_loss: 309.2304
Epoch 14/100
16/16 [==============================] - 0s - loss: 128.0434 - val_loss: 365.4593
Epoch 15/100
16/16 [==============================] - 0s - loss: 67.8009 - val_loss: 253.4262
Epoch 16/100
```

```
16/16 [==============================] - 0s - loss: 27.9748 - val_loss: 182.6272
Epoch 17/100
16/16 [==============================] - 0s - loss: 38.1709 - val_loss: 229.7312
Epoch 18/100
16/16 [==============================] - 0s - loss: 25.9472 - val_loss: 235.2564
Epoch 19/100
16/16 [==============================] - 0s - loss: 211.2942 - val_loss: 187.9289
Epoch 20/100
16/16 [==============================] - 0s - loss: 790.8387 - val_loss: 184.9477
Epoch 21/100
16/16 [==============================] - 0s - loss: 1035.6802 - val_loss: 198.1545
Epoch 22/100
16/16 [==============================] - 0s - loss: 534.7186 - val_loss: 935.7176
Epoch 23/100
16/16 [==============================] - 0s - loss: 109.3625 - val_loss: 1321.3749
Epoch 24/100
16/16 [==============================] - 0s - loss: 494.8283 - val_loss: 1248.7885
Epoch 25/100
16/16 [==============================] - 0s - loss: 997.8316 - val_loss: 856.1414
Epoch 26/100
16/16 [==============================] - 0s - loss: 1067.1632 - val_loss: 748.9677
Epoch 27/100
16/16 [==============================] - 0s - loss: 1037.0362 - val_loss: 750.6448
Epoch 28/100
16/16 [==============================] - 0s - loss: 692.2827 - val_loss: 535.2324
Epoch 29/100
16/16 [==============================] - 0s - loss: 374.7631 - val_loss: 279.8852
Epoch 30/100
16/16 [==============================] - 0s - loss: 482.7222 - val_loss: 410.7278
Epoch 31/100
16/16 [==============================] - 0s - loss: 781.5591 - val_loss: 1128.7974
Epoch 32/100
16/16 [==============================] - 0s - loss: 710.3910 - val_loss: 1751.6953
Epoch 33/100
16/16 [==============================] - 0s - loss: 617.5088 - val_loss: 1487.8668
Epoch 34/100
16/16 [==============================] - 0s - loss: 292.3167 - val_loss: 1233.0679
Epoch 35/100
16/16 [==============================] - 0s - loss: 160.6075 - val_loss: 1099.6998
Epoch 36/100
16/16 [==============================] - 0s - loss: 375.9030 - val_loss: 1142.9890
Epoch 37/100
16/16 [==============================] - 0s - loss: 329.4787 - val_loss: 906.2944
Epoch 38/100
16/16 [==============================] - 0s - loss: 734.3138 - val_loss: 558.0154
Epoch 39/100
16/16 [==============================] - 0s - loss: 859.1217 - val_loss: 446.4954
Epoch 40/100
```

```
16/16 [==============================] - 0s - loss: 460.0293 - val_loss: 555.8116
Epoch 41/100
16/16 [==============================] - 0s - loss: 640.5133 - val_loss: 762.4316
Epoch 42/100
16/16 [==============================] - 0s - loss: 884.8810 - val_loss: 792.2708
Epoch 43/100
16/16 [==============================] - 0s - loss: 575.1852 - val_loss: 695.9563
Epoch 44/100
16/16 [==============================] - 0s - loss: 503.8194 - val_loss: 768.1356
Epoch 45/100
16/16 [==============================] - 0s - loss: 756.6223 - val_loss: 646.8546
Epoch 46/100
16/16 [==============================] - 0s - loss: 488.9455 - val_loss: 406.5652
Epoch 47/100
16/16 [==============================] - 0s - loss: 107.7576 - val_loss: 283.9496
Epoch 48/100
16/16 [==============================] - 0s - loss: 84.8050 - val_loss: 686.2907
Epoch 49/100
16/16 [==============================] - 0s - loss: 91.3548 - val_loss: 1042.2042
Epoch 50/100
16/16 [==============================] - 0s - loss: 86.1029 - val_loss: 943.8293
Epoch 51/100
16/16 [==============================] - 0s - loss: 60.5776 - val_loss: 753.1616
Epoch 52/100
16/16 [==============================] - ETA: 0s - loss: 58.27 - 0s - loss: 69.5172 - val_loss
Epoch 53/100
16/16 [==============================] - 0s - loss: 111.9220 - val_loss: 1447.4707
Epoch 54/100
16/16 [==============================] - 0s - loss: 87.5344 - val_loss: 7.3697
Epoch 55/100
16/16 [==============================] - 0s - loss: 113.8763 - val_loss: 2.6711
Epoch 56/100
16/16 [==============================] - 0s - loss: 314.4716 - val_loss: 24.8013
Epoch 57/100
16/16 [==============================] - 0s - loss: 261.4240 - val_loss: 25.5419
Epoch 58/100
16/16 [==============================] - 0s - loss: 153.3576 - val_loss: 51.7447
Epoch 59/100
16/16 [==============================] - 0s - loss: 407.6840 - val_loss: 58.5026
Epoch 60/100
16/16 [==============================] - 0s - loss: 227.1043 - val_loss: 104.9177
Epoch 61/100
16/16 [==============================] - 0s - loss: 37.8130 - val_loss: 382.4667
Epoch 62/100
16/16 [==============================] - 0s - loss: 12.6714 - val_loss: 677.1978
Epoch 63/100
16/16 [==============================] - 0s - loss: 11.8061 - val_loss: 544.7205
Epoch 64/100
```

```
16/16 [==============================] - 0s - loss: 30.0816 - val_loss: 233.2806
Epoch 65/100
16/16 [==============================] - 0s - loss: 66.8729 - val_loss: 64.0773
Epoch 66/100
16/16 [==============================] - 0s - loss: 192.1836 - val_loss: 54.2251
Epoch 67/100
16/16 [==============================] - 0s - loss: 134.5015 - val_loss: 62.1392
Epoch 68/100
16/16 [==============================] - 0s - loss: 13.0585 - val_loss: 24.5777
Epoch 69/100
16/16 [==============================] - 0s - loss: 16.8562 - val_loss: 6.1316
Epoch 70/100
16/16 [==============================] - 0s - loss: 28.7296 - val_loss: 21.4031
Epoch 71/100
16/16 [==============================] - 0s - loss: 61.1252 - val_loss: 21.7075
Epoch 72/100
16/16 [==============================] - 0s - loss: 358.2624 - val_loss: 21.3097
Epoch 73/100
16/16 [==============================] - 0s - loss: 358.4501 - val_loss: 33.9087
Epoch 74/100
16/16 [==============================] - 0s - loss: 230.5919 - val_loss: 38.7211
Epoch 75/100
16/16 [==============================] - 0s - loss: 336.7031 - val_loss: 444.4774
Epoch 76/100
16/16 [==============================] - 0s - loss: 66.0822 - val_loss: 598.1645
Epoch 77/100
16/16 [==============================] - 0s - loss: 93.3342 - val_loss: 373.6503
Epoch 78/100
16/16 [==============================] - 0s - loss: 160.7178 - val_loss: 211.0065
Epoch 79/100
16/16 [==============================] - 0s - loss: 104.7269 - val_loss: 211.4937
Epoch 80/100
16/16 [==============================] - 0s - loss: 36.2358 - val_loss: 207.9099
Epoch 81/100
16/16 [==============================] - 0s - loss: 15.0308 - val_loss: 136.2351
Epoch 82/100
16/16 [==============================] - 0s - loss: 5.1211 - val_loss: 24.9182
Epoch 83/100
16/16 [==============================] - 0s - loss: 2.9345 - val_loss: 298.5112
Epoch 84/100
16/16 [==============================] - 0s - loss: 13.5083 - val_loss: 584.0840
Epoch 85/100
16/16 [==============================] - 0s - loss: 17.7164 - val_loss: 834.3745
Epoch 86/100
16/16 [==============================] - 0s - loss: 3.4599 - val_loss: 585.6539
Epoch 87/100
16/16 [==============================] - 0s - loss: 2.3528 - val_loss: 411.6891
Epoch 88/100
```

```
16/16 [==============================] - 0s - loss: 61.1653 - val_loss: 476.1581
Epoch 89/100
16/16 [==============================] - 0s - loss: 316.3557 - val_loss: 519.9321
Epoch 90/100
16/16 [==============================] - 0s - loss: 380.3658 - val_loss: 391.0831
Epoch 91/100
16/16 [==============================] - 0s - loss: 145.4739 - val_loss: 204.1142
Epoch 92/100
16/16 [==============================] - 0s - loss: 24.0692 - val_loss: 181.7808
Epoch 93/100
16/16 [==============================] - 0s - loss: 182.5140 - val_loss: 269.5009
Epoch 94/100
16/16 [==============================] - 0s - loss: 356.9468 - val_loss: 352.2679
Epoch 95/100
16/16 [==============================] - 0s - loss: 389.2575 - val_loss: 355.8195
Epoch 96/100
16/16 [==============================] - 0s - loss: 315.1099 - val_loss: 331.2967
Epoch 97/100
16/16 [==============================] - 0s - loss: 118.4962 - val_loss: 398.8660
Epoch 98/100
16/16 [==============================] - 0s - loss: 29.5482 - val_loss: 315.4416
Epoch 99/100
16/16 [==============================] - 0s - loss: 131.4496 - val_loss: 137.8734
Epoch 100/100
16/16 [==============================] - 0s - loss: 254.3669 - val_loss: 139.7797
```

```
In [7]: df = pd.read_pickle('data/micro_sud3_normalized.pkl')
        df = df.reset_index()

        def dataframe_to_xy_no_generator(df, look_back):
            X, y = [], []
            i = look_back
            while i < len(df):
                sequence = df.iloc[i - look_back:i]
                X.append(np.array(sequence[['PM_6182', 'PM_6179', 'PM_617B', 'PM25_6182', 'PM25
                                 'PM25_617B', 'temp', 'rh',\
                                 'tgrad', 'pressure', 'pluvio']]).reshape(look_back, 1, 11))
                y.append(np.array(df.iloc[i]['PM_ref']))
                i += 1
                if i == len(df):
                    break
            X = np.array(X)
            y = np.array(y)
            X = X.reshape((X.shape[0], X.shape[1], X.shape[3]))
            return X, y

In [8]: X_train, y_train = dataframe_to_xy_no_generator(df_train, 24)
```

```
        X_valid, y_valid = dataframe_to_xy_no_generator(df_valid, 24)
        X_test, y_test = dataframe_to_xy_no_generator(df_test, 24)
```

```
In [9]: from keras.layers import SimpleRNN, Dense, LSTM, GRU
        from keras.models import Sequential
        from keras.callbacks import EarlyStopping

        def simple_rnn_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
            model = Sequential()
            model.add(SimpleRNN(nb_units, input_shape=input_dim))#input_dim=input_dim[1], inpu
            model.add(Dense(1, kernel_initializer='normal'))
            model.compile(loss=loss, optimizer=optimizer)
            model.summary()
            return model

        def lstm_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
            model = Sequential()
            model.add(LSTM(nb_units, input_shape=input_dim))#input_dim=input_dim[1], input_leng
            model.add(Dense(1, kernel_initializer='normal'))
            model.compile(loss=loss, optimizer=optimizer)
            model.summary()
            return model

        def gru_model(nb_units, input_dim, loss='mean_squared_error', optimizer='adam'):
            model = Sequential()
            model.add(GRU(nb_units, input_shape=(input_dim)))#input_dim=input_dim[1], input_le
            model.add(Dense(1, kernel_initializer='normal'))
            model.compile(loss=loss, optimizer=optimizer)
            model.summary()
            return model
```

```
In [10]: model = simple_rnn_model(16, X_train.shape[1:])
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
simple_rnn_2 (SimpleRNN)     (None, 16)                448
_________________________________________________________________
dense_2 (Dense)              (None, 1)                 17
=================================================================
Total params: 465
Trainable params: 465
Non-trainable params: 0
_________________________________________________________________
```

```
In [11]: early_stopping = EarlyStopping(monitor='val_loss', verbose=1, mode='auto', patience=10
         history = model.fit(X_train, y_train, batch_size=16, epochs=5000, validation_data=(X_v
```

```
Train on 1102 samples, validate on 539 samples
Epoch 1/5000
1102/1102 [==============================] - 5s - loss: 527.0749 - val_loss: 807.4887
Epoch 2/5000
1102/1102 [==============================] - 2s - loss: 469.7450 - val_loss: 706.0692
Epoch 3/5000
1102/1102 [==============================] - 2s - loss: 408.0203 - val_loss: 649.5457
Epoch 4/5000
1102/1102 [==============================] - 2s - loss: 360.8012 - val_loss: 603.0961
Epoch 5/5000
1102/1102 [==============================] - 2s - loss: 323.8026 - val_loss: 563.2627
Epoch 6/5000
1102/1102 [==============================] - 2s - loss: 292.5147 - val_loss: 528.8296
Epoch 7/5000
1102/1102 [==============================] - 2s - loss: 267.6393 - val_loss: 501.9558
Epoch 8/5000
1102/1102 [==============================] - 2s - loss: 247.1418 - val_loss: 476.7355
Epoch 9/5000
1102/1102 [==============================] - 2s - loss: 227.1555 - val_loss: 455.9925
Epoch 10/5000
1102/1102 [==============================] - 2s - loss: 211.2327 - val_loss: 437.1987
Epoch 11/5000
1102/1102 [==============================] - 2s - loss: 198.4454 - val_loss: 423.8323
Epoch 12/5000
1102/1102 [==============================] - 2s - loss: 194.4419 - val_loss: 423.7073
Epoch 13/5000
1102/1102 [==============================] - 2s - loss: 202.1624 - val_loss: 498.0546
Epoch 14/5000
1102/1102 [==============================] - 2s - loss: 196.4690 - val_loss: 422.1432
Epoch 15/5000
1102/1102 [==============================] - 1s - loss: 159.6144 - val_loss: 419.8415
Epoch 16/5000
1102/1102 [==============================] - 2s - loss: 152.1385 - val_loss: 401.3974
Epoch 17/5000
1102/1102 [==============================] - 2s - loss: 143.3382 - val_loss: 400.8988
Epoch 18/5000
1102/1102 [==============================] - 2s - loss: 136.8376 - val_loss: 384.0385
Epoch 19/5000
1102/1102 [==============================] - 2s - loss: 130.0231 - val_loss: 351.6395
Epoch 20/5000
1102/1102 [==============================] - 2s - loss: 121.3023 - val_loss: 323.3844
Epoch 21/5000
1102/1102 [==============================] - 2s - loss: 116.1092 - val_loss: 314.6127
Epoch 22/5000
1102/1102 [==============================] - 2s - loss: 114.7906 - val_loss: 293.4391
Epoch 23/5000
1102/1102 [==============================] - 2s - loss: 104.3403 - val_loss: 259.9770
Epoch 24/5000
```

```
1102/1102 [==============================] - 2s - loss: 94.1509 - val_loss: 231.4640
Epoch 25/5000
1102/1102 [==============================] - 2s - loss: 86.0002 - val_loss: 204.9567
Epoch 26/5000
1102/1102 [==============================] - 2s - loss: 73.6349 - val_loss: 178.4162
Epoch 27/5000
1102/1102 [==============================] - 2s - loss: 67.8861 - val_loss: 167.1449
Epoch 28/5000
1102/1102 [==============================] - 2s - loss: 65.5396 - val_loss: 157.5228
Epoch 29/5000
1102/1102 [==============================] - 2s - loss: 62.5925 - val_loss: 152.5049
Epoch 30/5000
1102/1102 [==============================] - 2s - loss: 60.3707 - val_loss: 144.4430
Epoch 31/5000
1102/1102 [==============================] - 2s - loss: 57.2923 - val_loss: 141.0146
Epoch 32/5000
1102/1102 [==============================] - 1s - loss: 54.8828 - val_loss: 137.5693
Epoch 33/5000
1102/1102 [==============================] - 2s - loss: 53.2424 - val_loss: 134.4946
Epoch 34/5000
1102/1102 [==============================] - 1s - loss: 51.3395 - val_loss: 131.1894
Epoch 35/5000
1102/1102 [==============================] - 2s - loss: 49.7778 - val_loss: 129.4128
Epoch 36/5000
1102/1102 [==============================] - 2s - loss: 48.9717 - val_loss: 126.4665
Epoch 37/5000
1102/1102 [==============================] - 2s - loss: 47.0920 - val_loss: 123.2214
Epoch 38/5000
1102/1102 [==============================] - 2s - loss: 46.0874 - val_loss: 121.0335
Epoch 39/5000
1102/1102 [==============================] - 2s - loss: 45.4140 - val_loss: 118.1595
Epoch 40/5000
1102/1102 [==============================] - 2s - loss: 44.4730 - val_loss: 116.1078
Epoch 41/5000
1102/1102 [==============================] - 2s - loss: 43.6942 - val_loss: 114.5601
Epoch 42/5000
1102/1102 [==============================] - 2s - loss: 42.7652 - val_loss: 113.4401
Epoch 43/5000
1102/1102 [==============================] - 2s - loss: 42.1480 - val_loss: 112.6848
Epoch 44/5000
1102/1102 [==============================] - 2s - loss: 41.4055 - val_loss: 125.6808
Epoch 45/5000
1102/1102 [==============================] - 2s - loss: 40.8842 - val_loss: 115.0624
Epoch 46/5000
1102/1102 [==============================] - 2s - loss: 40.0833 - val_loss: 116.3303
Epoch 47/5000
1102/1102 [==============================] - 2s - loss: 39.4862 - val_loss: 110.0112
Epoch 48/5000
```

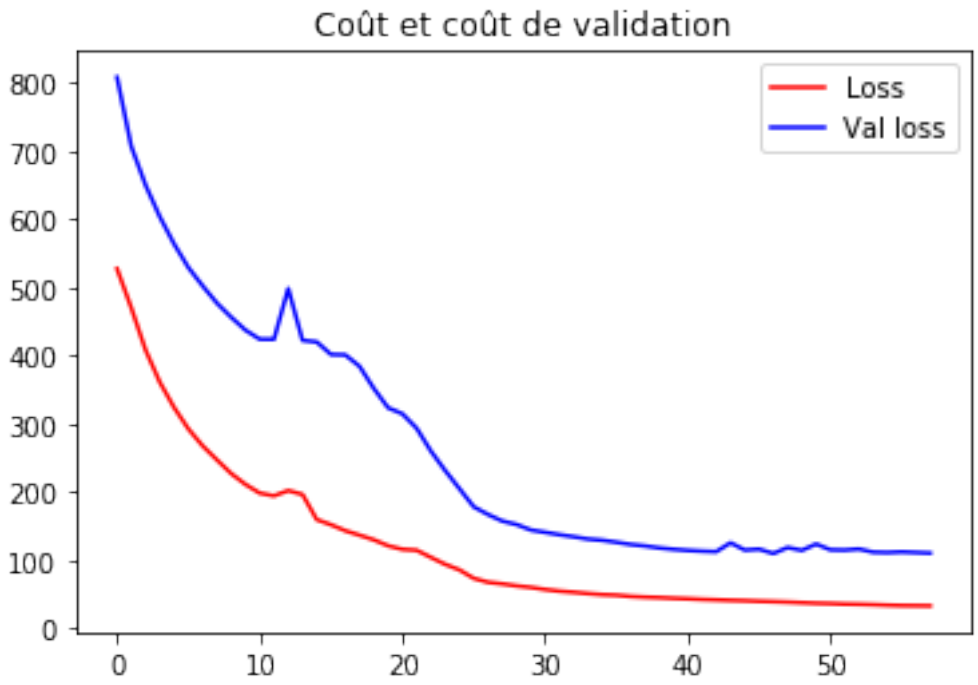
```
1102/1102 [==============================] - 2s - loss: 38.8208 - val_loss: 118.7489
Epoch 49/5000
1102/1102 [==============================] - 2s - loss: 37.9822 - val_loss: 114.6038
Epoch 50/5000
1102/1102 [==============================] - 2s - loss: 37.1508 - val_loss: 123.8460
Epoch 51/5000
1102/1102 [==============================] - 2s - loss: 36.7018 - val_loss: 115.4303
Epoch 52/5000
1102/1102 [==============================] - 2s - loss: 35.9483 - val_loss: 115.0432
Epoch 53/5000
1102/1102 [==============================] - 2s - loss: 35.6104 - val_loss: 116.5304
Epoch 54/5000
1102/1102 [==============================] - 1s - loss: 35.0622 - val_loss: 111.9174
Epoch 55/5000
1102/1102 [==============================] - 2s - loss: 34.3291 - val_loss: 111.4187
Epoch 56/5000
1102/1102 [==============================] - 2s - loss: 33.7745 - val_loss: 112.2768
Epoch 57/5000
1102/1102 [==============================] - 2s - loss: 33.5983 - val_loss: 111.4616
Epoch 58/5000
1102/1102 [==============================] - 2s - loss: 33.3538 - val_loss: 110.6437
Epoch 00057: early stopping
```

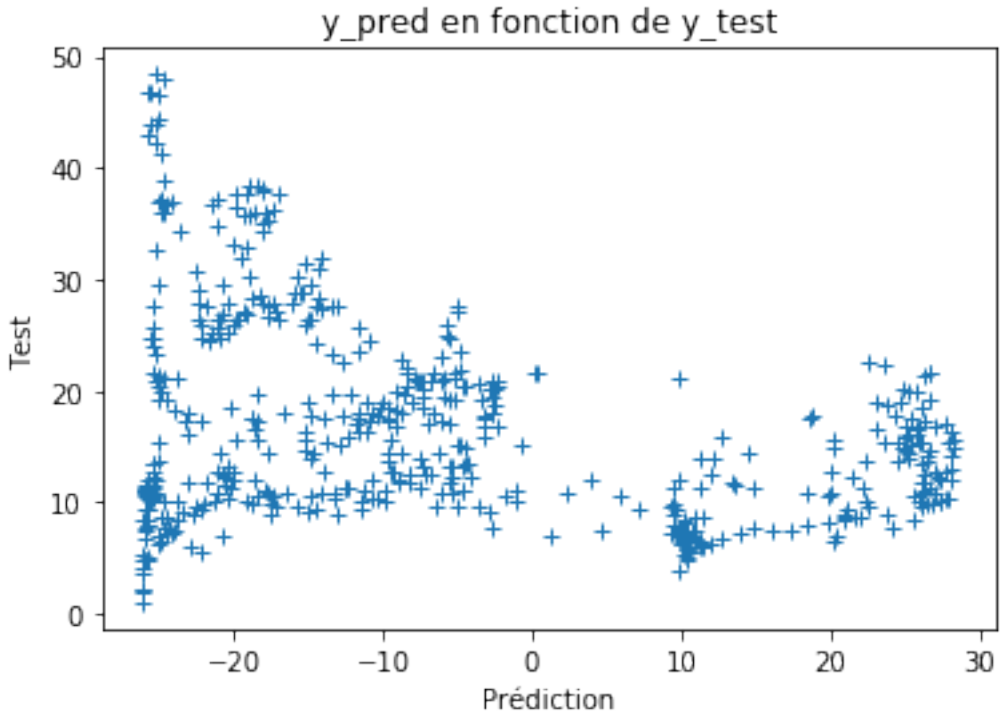
```
In [12]: y_pred = model.predict(X_test)
         plt.title('Coût et coût de validation')
         line1,=plt.plot(history.history['loss'], label="Loss", linestyle='-', color='r')
         line2,=plt.plot(history.history['val_loss'], label="Val loss", linestyle='-', color='
         first_legend = plt.legend(handles=[line1, line2], loc=1)

         plt.show()

         plt.title('y_pred en fonction de y_test')

         plt.plot(y_pred[:], y_test[:], '+')
         plt.ylabel('Test')
         plt.xlabel('Prédiction')
         plt.show()
```






```
In [15]: model = lstm_model(16, X_train.shape[1:])
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm_2 (LSTM)                (None, 16)                1792
_________________________________________________________________
dense_4 (Dense)              (None, 1)                 17
=================================================================
Total params: 1,809
Trainable params: 1,809
Non-trainable params: 0
_________________________________________________________________
```

```
In [16]: early_stopping = EarlyStopping(monitor='val_loss', verbose=1, mode='auto', patience=1
         history = model.fit(X_train, y_train, batch_size=16, epochs=5000, validation_data=(X_
```

```
Train on 1102 samples, validate on 539 samples
Epoch 1/5000
1102/1102 [==============================] - 7s - loss: 525.9527 - val_loss: 794.4789
Epoch 2/5000
1102/1102 [==============================] - 6s - loss: 455.9805 - val_loss: 666.3283
Epoch 3/5000
1102/1102 [==============================] - 6s - loss: 379.9015 - val_loss: 594.2004
Epoch 4/5000
1102/1102 [==============================] - 6s - loss: 333.5245 - val_loss: 541.6576
Epoch 5/5000
1102/1102 [==============================] - 6s - loss: 297.0443 - val_loss: 496.5548
Epoch 6/5000
1102/1102 [==============================] - 6s - loss: 266.1631 - val_loss: 457.7730
Epoch 7/5000
1102/1102 [==============================] - 7s - loss: 239.6944 - val_loss: 423.2032
Epoch 8/5000
1102/1102 [==============================] - 7s - loss: 216.7445 - val_loss: 392.7829
Epoch 9/5000
1102/1102 [==============================] - 6s - loss: 196.8508 - val_loss: 366.0180
Epoch 10/5000
1102/1102 [==============================] - 6s - loss: 179.5627 - val_loss: 342.4233
Epoch 11/5000
1102/1102 [==============================] - 6s - loss: 164.2624 - val_loss: 321.8017
Epoch 12/5000
1102/1102 [==============================] - 6s - loss: 148.9892 - val_loss: 295.6469
Epoch 13/5000
1102/1102 [==============================] - 6s - loss: 135.4541 - val_loss: 283.9435
Epoch 14/5000
1102/1102 [==============================] - 5s - loss: 124.2149 - val_loss: 264.2125
Epoch 15/5000
1102/1102 [==============================] - 5s - loss: 114.3340 - val_loss: 248.9804
Epoch 16/5000
```

```
1102/1102 [==============================] - 6s - loss: 105.7816 - val_loss: 233.1060
Epoch 17/5000
1102/1102 [==============================] - 6s - loss: 98.1762 - val_loss: 219.4082
Epoch 18/5000
1102/1102 [==============================] - 5s - loss: 91.5489 - val_loss: 206.2718
Epoch 19/5000
1102/1102 [==============================] - 5s - loss: 85.8181 - val_loss: 193.1227
Epoch 20/5000
1102/1102 [==============================] - 5s - loss: 80.8190 - val_loss: 181.6276
Epoch 21/5000
1102/1102 [==============================] - 6s - loss: 76.5421 - val_loss: 173.6322
Epoch 22/5000
1102/1102 [==============================] - 6s - loss: 72.9824 - val_loss: 166.4704
Epoch 23/5000
1102/1102 [==============================] - 6s - loss: 69.7123 - val_loss: 160.6751
Epoch 24/5000
1102/1102 [==============================] - 5s - loss: 66.8409 - val_loss: 155.3220
Epoch 25/5000
1102/1102 [==============================] - 5s - loss: 63.9353 - val_loss: 150.3917
Epoch 26/5000
1102/1102 [==============================] - 6s - loss: 61.0666 - val_loss: 145.7173
Epoch 27/5000
1102/1102 [==============================] - 6s - loss: 58.6379 - val_loss: 141.5781
Epoch 28/5000
1102/1102 [==============================] - 5s - loss: 56.4952 - val_loss: 137.8245
Epoch 29/5000
1102/1102 [==============================] - 6s - loss: 54.5231 - val_loss: 134.6476
Epoch 30/5000
1102/1102 [==============================] - 6s - loss: 52.7692 - val_loss: 131.5441
Epoch 31/5000
1102/1102 [==============================] - 6s - loss: 51.2755 - val_loss: 128.9769
Epoch 32/5000
1102/1102 [==============================] - 6s - loss: 49.7033 - val_loss: 125.2808
Epoch 33/5000
1102/1102 [==============================] - 6s - loss: 48.1018 - val_loss: 124.9437
Epoch 34/5000
1102/1102 [==============================] - 6s - loss: 47.8783 - val_loss: 136.8487
Epoch 35/5000
1102/1102 [==============================] - 5s - loss: 45.2687 - val_loss: 163.5622
Epoch 36/5000
1102/1102 [==============================] - 5s - loss: 44.1317 - val_loss: 170.5034
Epoch 37/5000
1102/1102 [==============================] - 5s - loss: 43.5503 - val_loss: 129.3420
Epoch 38/5000
1102/1102 [==============================] - 6s - loss: 42.3178 - val_loss: 151.6787
Epoch 39/5000
1102/1102 [==============================] - 6s - loss: 41.5507 - val_loss: 151.8013
Epoch 40/5000
```

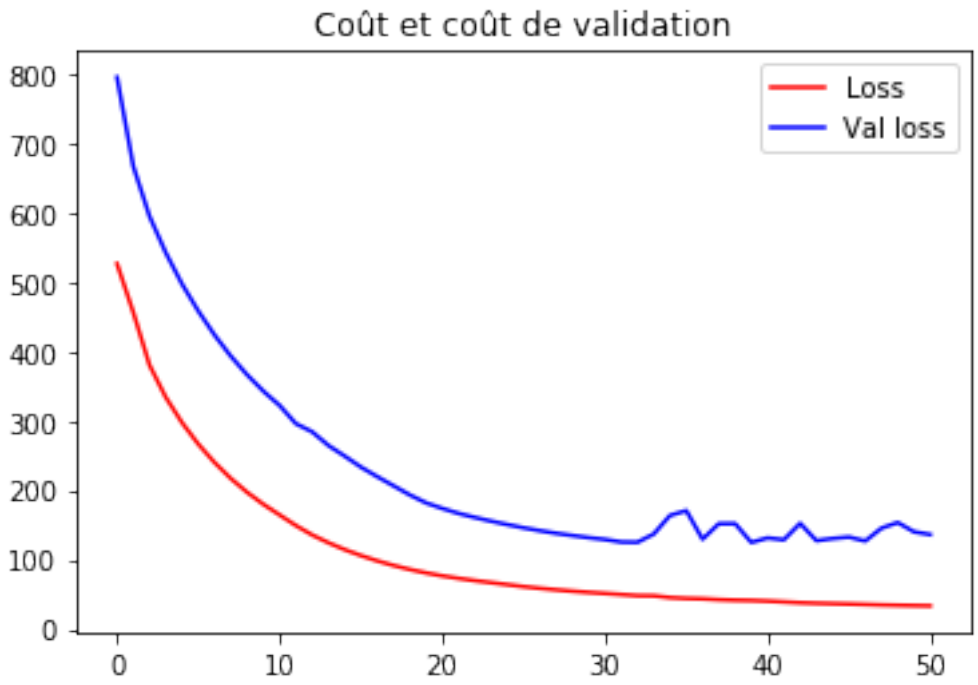
```
1102/1102 [==============================] - 6s - loss: 41.1240 - val_loss: 124.7012
Epoch 41/5000
1102/1102 [==============================] - 6s - loss: 40.2595 - val_loss: 131.2113
Epoch 42/5000
1102/1102 [==============================] - 6s - loss: 39.0661 - val_loss: 128.5480
Epoch 43/5000
1102/1102 [==============================] - 6s - loss: 37.8808 - val_loss: 152.2595
Epoch 44/5000
1102/1102 [==============================] - 6s - loss: 37.1280 - val_loss: 127.2384
Epoch 45/5000
1102/1102 [==============================] - 6s - loss: 36.5754 - val_loss: 130.3641
Epoch 46/5000
1102/1102 [==============================] - 6s - loss: 36.0274 - val_loss: 132.4484
Epoch 47/5000
1102/1102 [==============================] - 6s - loss: 35.3988 - val_loss: 126.7132
Epoch 48/5000
1102/1102 [==============================] - 6s - loss: 34.6974 - val_loss: 145.2465
Epoch 49/5000
1102/1102 [==============================] - 6s - loss: 34.2348 - val_loss: 153.3759
Epoch 50/5000
1102/1102 [==============================] - 6s - loss: 33.7965 - val_loss: 139.9571
Epoch 51/5000
1102/1102 [==============================] - 6s - loss: 33.4164 - val_loss: 136.0671
Epoch 00050: early stopping
```

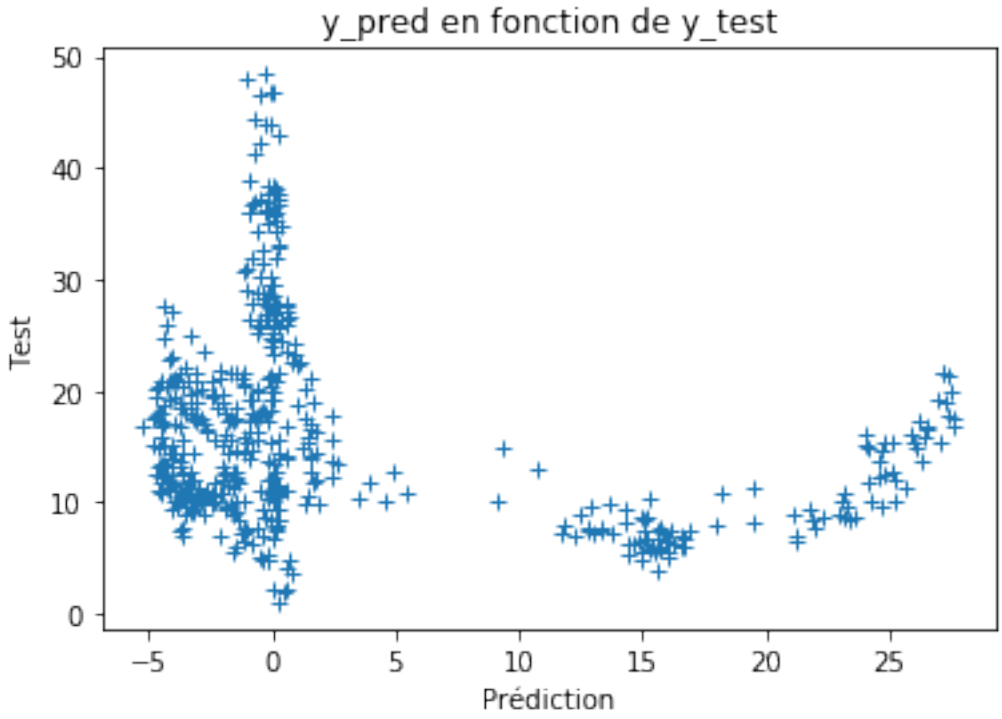
```
In [17]: y_pred = model.predict(X_test)
         plt.title('Coût et coût de validation')
         line1,=plt.plot(history.history['loss'], label="Loss", linestyle='-', color='r')
         line2,=plt.plot(history.history['val_loss'], label="Val loss", linestyle='-', color='
         first_legend = plt.legend(handles=[line1, line2], loc=1)

         plt.show()

         plt.title('y_pred en fonction de y_test')

         plt.plot(y_pred[:], y_test[:], '+')
         plt.ylabel('Test')
         plt.xlabel('Prédiction')
         plt.show()
```






```
In [18]: model = gru_model(16, X_train.shape[1:])
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
gru_1 (GRU)                  (None, 16)                1344
_________________________________________________________________
dense_5 (Dense)              (None, 1)                 17
=================================================================
Total params: 1,361
Trainable params: 1,361
Non-trainable params: 0
_________________________________________________________________
```

```
In [19]: early_stopping = EarlyStopping(monitor='val_loss', verbose=1, mode='auto', patience=1
         history = model.fit(X_train, y_train, batch_size=16, epochs=5000, validation_data=(X_
```

```
Train on 1102 samples, validate on 539 samples
Epoch 1/5000
1102/1102 [==============================] - 6s - loss: 530.6202 - val_loss: 799.1553
Epoch 2/5000
1102/1102 [==============================] - 5s - loss: 468.9815 - val_loss: 674.3885
Epoch 3/5000
1102/1102 [==============================] - 5s - loss: 388.8781 - val_loss: 599.2855
Epoch 4/5000
1102/1102 [==============================] - 5s - loss: 340.7207 - val_loss: 543.0146
Epoch 5/5000
1102/1102 [==============================] - 5s - loss: 302.8017 - val_loss: 495.5599
Epoch 6/5000
1102/1102 [==============================] - 5s - loss: 270.9833 - val_loss: 454.5212
Epoch 7/5000
1102/1102 [==============================] - 4s - loss: 243.7336 - val_loss: 418.4116
Epoch 8/5000
1102/1102 [==============================] - 5s - loss: 220.1970 - val_loss: 386.5818
Epoch 9/5000
1102/1102 [==============================] - 5s - loss: 199.9488 - val_loss: 358.0916
Epoch 10/5000
1102/1102 [==============================] - 5s - loss: 182.5502 - val_loss: 332.5489
Epoch 11/5000
1102/1102 [==============================] - 5s - loss: 167.5274 - val_loss: 310.3220
Epoch 12/5000
1102/1102 [==============================] - 5s - loss: 154.1284 - val_loss: 290.1904
Epoch 13/5000
1102/1102 [==============================] - 5s - loss: 142.7857 - val_loss: 272.2143
Epoch 14/5000
1102/1102 [==============================] - 5s - loss: 132.4009 - val_loss: 256.1573
Epoch 15/5000
1102/1102 [==============================] - 5s - loss: 122.8490 - val_loss: 241.6169
Epoch 16/5000
```

```
1102/1102 [==============================] - 5s - loss: 114.5017 - val_loss: 230.5329
Epoch 17/5000
1102/1102 [==============================] - 5s - loss: 105.2380 - val_loss: 217.6737
Epoch 18/5000
1102/1102 [==============================] - 4s - loss: 97.6586 - val_loss: 206.1693
Epoch 19/5000
1102/1102 [==============================] - 5s - loss: 91.0629 - val_loss: 197.8518
Epoch 20/5000
1102/1102 [==============================] - 5s - loss: 85.1404 - val_loss: 187.6728
Epoch 21/5000
1102/1102 [==============================] - 4s - loss: 80.0305 - val_loss: 178.7226
Epoch 22/5000
1102/1102 [==============================] - 5s - loss: 75.8718 - val_loss: 170.7395
Epoch 23/5000
1102/1102 [==============================] - 4s - loss: 72.3692 - val_loss: 164.5891
Epoch 24/5000
1102/1102 [==============================] - 5s - loss: 69.3779 - val_loss: 158.8511
Epoch 25/5000
1102/1102 [==============================] - 4s - loss: 66.7624 - val_loss: 153.6193
Epoch 26/5000
1102/1102 [==============================] - 5s - loss: 64.5583 - val_loss: 149.7699
Epoch 27/5000
1102/1102 [==============================] - 5s - loss: 62.8176 - val_loss: 145.6799
Epoch 28/5000
1102/1102 [==============================] - 5s - loss: 61.2254 - val_loss: 142.1507
Epoch 29/5000
1102/1102 [==============================] - 5s - loss: 59.5873 - val_loss: 139.0310
Epoch 30/5000
1102/1102 [==============================] - 5s - loss: 56.7189 - val_loss: 136.6372
Epoch 31/5000
1102/1102 [==============================] - 5s - loss: 54.5830 - val_loss: 133.6476
Epoch 32/5000
1102/1102 [==============================] - 5s - loss: 52.3597 - val_loss: 130.8558
Epoch 33/5000
1102/1102 [==============================] - 5s - loss: 50.3291 - val_loss: 128.2079
Epoch 34/5000
1102/1102 [==============================] - 5s - loss: 48.6399 - val_loss: 125.8929
Epoch 35/5000
1102/1102 [==============================] - 4s - loss: 47.0761 - val_loss: 123.8873
Epoch 36/5000
1102/1102 [==============================] - 5s - loss: 45.6684 - val_loss: 121.7471
Epoch 37/5000
1102/1102 [==============================] - 4s - loss: 44.7356 - val_loss: 120.5168
Epoch 38/5000
1102/1102 [==============================] - 6s - loss: 43.6540 - val_loss: 118.5536
Epoch 39/5000
1102/1102 [==============================] - 5s - loss: 42.6699 - val_loss: 116.6065
Epoch 40/5000
```

```
1102/1102 [==============================] - 6s - loss: 41.7768 - val_loss: 114.9546
Epoch 41/5000
1102/1102 [==============================] - 5s - loss: 41.1256 - val_loss: 113.4166
Epoch 42/5000
1102/1102 [==============================] - 5s - loss: 40.4532 - val_loss: 112.7673
Epoch 43/5000
1102/1102 [==============================] - 5s - loss: 39.9949 - val_loss: 111.6265
Epoch 44/5000
1102/1102 [==============================] - 5s - loss: 39.5221 - val_loss: 111.2361
Epoch 45/5000
1102/1102 [==============================] - 4s - loss: 39.1721 - val_loss: 110.3374
Epoch 46/5000
1102/1102 [==============================] - 4s - loss: 38.5954 - val_loss: 109.5077
Epoch 47/5000
1102/1102 [==============================] - 5s - loss: 38.3006 - val_loss: 108.4158
Epoch 48/5000
1102/1102 [==============================] - 5s - loss: 37.9301 - val_loss: 108.5040
Epoch 49/5000
1102/1102 [==============================] - 5s - loss: 37.4489 - val_loss: 107.3587
Epoch 50/5000
1102/1102 [==============================] - 5s - loss: 37.0400 - val_loss: 106.9844
Epoch 51/5000
1102/1102 [==============================] - 5s - loss: 36.5829 - val_loss: 108.7554
Epoch 52/5000
1102/1102 [==============================] - 4s - loss: 36.2046 - val_loss: 107.4035
Epoch 53/5000
1102/1102 [==============================] - 5s - loss: 35.7804 - val_loss: 107.3623
Epoch 54/5000
1102/1102 [==============================] - 5s - loss: 35.3279 - val_loss: 108.6652
Epoch 55/5000
1102/1102 [==============================] - 5s - loss: 34.8934 - val_loss: 105.6952
Epoch 56/5000
1102/1102 [==============================] - 5s - loss: 34.3829 - val_loss: 107.0279
Epoch 57/5000
1102/1102 [==============================] - 4s - loss: 34.1068 - val_loss: 103.9202
Epoch 58/5000
1102/1102 [==============================] - 4s - loss: 33.7141 - val_loss: 106.6317
Epoch 59/5000
1102/1102 [==============================] - 4s - loss: 33.1730 - val_loss: 108.1802
Epoch 60/5000
1102/1102 [==============================] - 4s - loss: 32.7570 - val_loss: 107.5572
Epoch 61/5000
1102/1102 [==============================] - 5s - loss: 32.4268 - val_loss: 108.5661
Epoch 62/5000
1102/1102 [==============================] - 4s - loss: 32.0747 - val_loss: 104.8484
Epoch 63/5000
1102/1102 [==============================] - 4s - loss: 31.7861 - val_loss: 105.3999
Epoch 64/5000
```

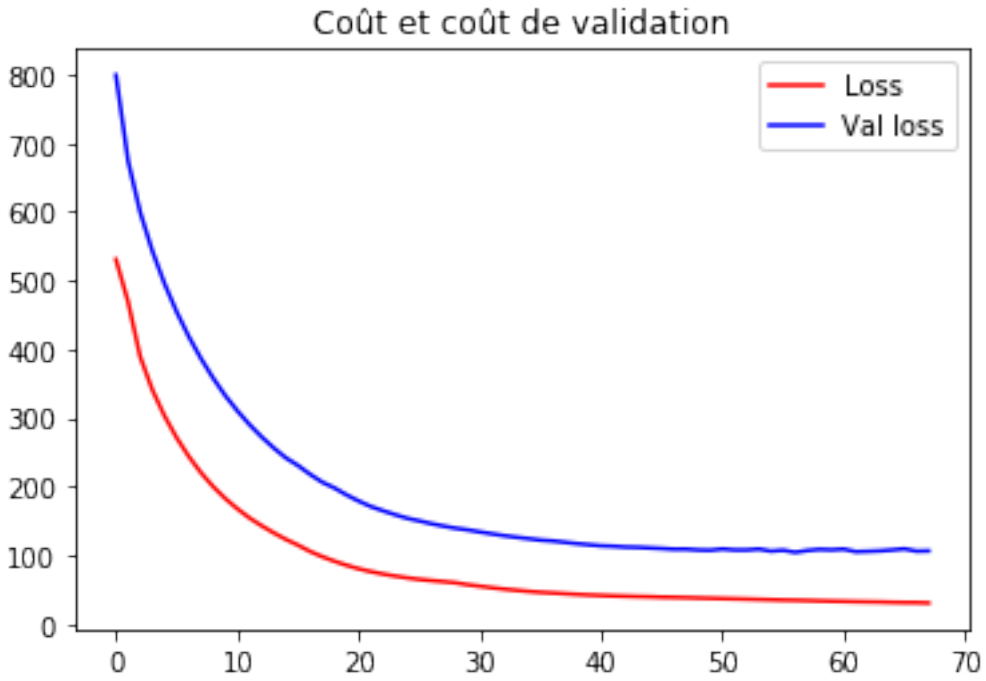
```
1102/1102 [==============================] - 5s - loss: 31.5543 - val_loss: 106.0969
Epoch 65/5000
1102/1102 [==============================] - 4s - loss: 31.1010 - val_loss: 107.3881
Epoch 66/5000
1102/1102 [==============================] - 4s - loss: 30.8105 - val_loss: 109.0295
Epoch 67/5000
1102/1102 [==============================] - 4s - loss: 30.7301 - val_loss: 105.6396
Epoch 68/5000
1102/1102 [==============================] - 4s - loss: 30.1593 - val_loss: 106.0621
Epoch 00067: early stopping
```

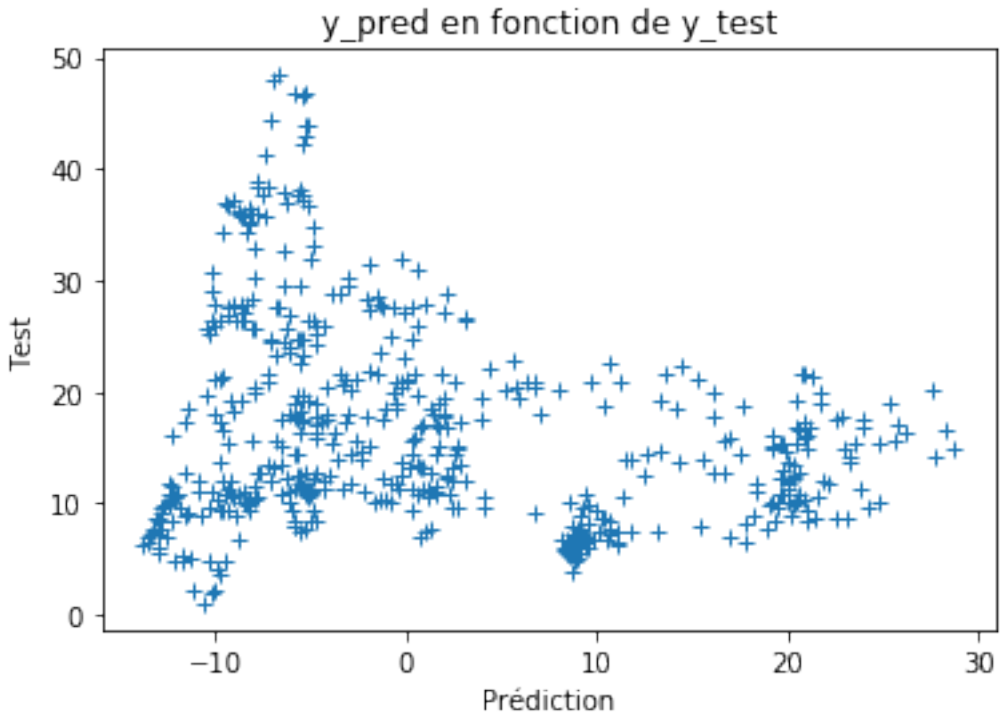
In [20]:
```
y_pred = model.predict(X_test)
plt.title('Coût et coût de validation')
line1,=plt.plot(history.history['loss'], label="Loss", linestyle='-', color='r')
line2,=plt.plot(history.history['val_loss'], label="Val loss", linestyle='-', color='
first_legend = plt.legend(handles=[line1, line2], loc=1)

plt.show()

plt.title('y_pred en fonction de y_test')

plt.plot(y_pred[:], y_test[:], '+')
plt.ylabel('Test')
plt.xlabel('Prédiction')
plt.show()
```




y_pred en fonction de y_test
Test
Prédiction
50
40
30
20
10
0
−10
0
10
20
30

In [ ]: