in the name of Allah

Description:

The article was about heart rate prediction. I got 3 minutes as input in this code and predict 5 minutes as output. We have the heart rate for every 0.5 seconds in the data set. So for getting 3 minutes as input, our input shape will be like this: 60(60 seconds per minute) * 3(minutes) * 2(for 1 second) = 360, and for output shape(predict 5 minutes), it will be : 60 * 5 * 2 = 600.

- Before starting to work with our data, we have to check if our data is stationary or not. For this part, I checked it in three ways:
    1. Histogram plot to check if we have normal distribution data or not.
    2. calculate mean and variance in parts of data to understand whether our mean or variance in our data is alike or not.
    3. Dickey-Fuller test

    If our data wasn't stationary, we had to make it stationary (It was stationary.)
- After that, we have to scale our data between [-1,1]
- There are some functions that I will describe here:
    - to_supervised : this function will take our dataset, make windows and predictions, and make an array containing two columns (3 minutes input, 5minutes output). And the next window and prediction will be in the next row.
    - split_dataset: It will take our dataset, supervise data via the to_supervised function, and split it to train and test.

These parts of code were about preparing data for building a model.

The next step is about building a model.
(first, I made my model without Keras tuner. and then I used Keras tuner)

- Functions:
    - build_model: it takes one argument name hp and prepares a model to tune model parameters. number of neurons is in the range (10, 500), and the dropout value is in the range (0.1, 0.9)
    - tune: it defines parameters(train, test, model name, and directory address, where our result will save). It will find the best parameters and build a model with the parameters.

The next part is about evaluation.we used rmse for evaluation mertric.

- Functions:
    - rmse: it calculates rmse score.
    - evaluate_model: first, it runs the build_model function, then tune parameters and build model, and at last calculates rmse score.

Report

In the following, I have reported the values calculated in the code by different models.

RNN Report

No. of layers	No. of neurons	Dropout	RMSE
1	410	0.5	0.506
2	[394,346]	[0.7,0.2]	0.515
3	[362,90,138]	[0.4,0.2,0.5]	0.510

LSTM Report

No. of layers	No. of neurons	Dropout	RMSE
1	74	0.7	0.481
2	[106,378]	[0.7,0.9]	0.508
3	[282,90,346]	[0.5,0.7,0.5]	0.438

GRU Report

No. of layers	No. of neurons	Dropout	RMSE
1	122	0.7	0.482
2	[74,58]	[0.8,0.4]	0.428
3	[90,42,490]	[0.2,0.6,0.1]	0.451

BI-LSTM Report

No. of layers	No. of neurons	Dropout	RMSE
1	154	0.3	0.452
2	[74,58]	[0.8,0.4]	0.466
3	[346,106,394]	[0.2,0.6,0.7]	0.501

Import libraries

```
import numpy as np
import pandas as pd
import time
import math
import matplotlib.pyplot as plt
from statsmodels.tsa.stattools import adfuller
from sklearn.preprocessing import MinMaxScaler

from keras.metrics import RootMeanSquaredError
from keras.metrics import mean_squared_error
from keras.models import Sequential
from keras.models import load_model
from keras.layers import (SimpleRNN, Dense, LSTM, GRU, Flatten, Dropout, Bidirecti

!pip install keras-tuner --upgrade
import keras_tuner as kt
```

Preprocessing

```
df = pd.read_csv("/content/heart-rate-time-series.csv",header=None)
```

```
df.head()
```

	0
0	91.4634
1	91.4634
2	91.1834
3	91.8788
4	91.1772

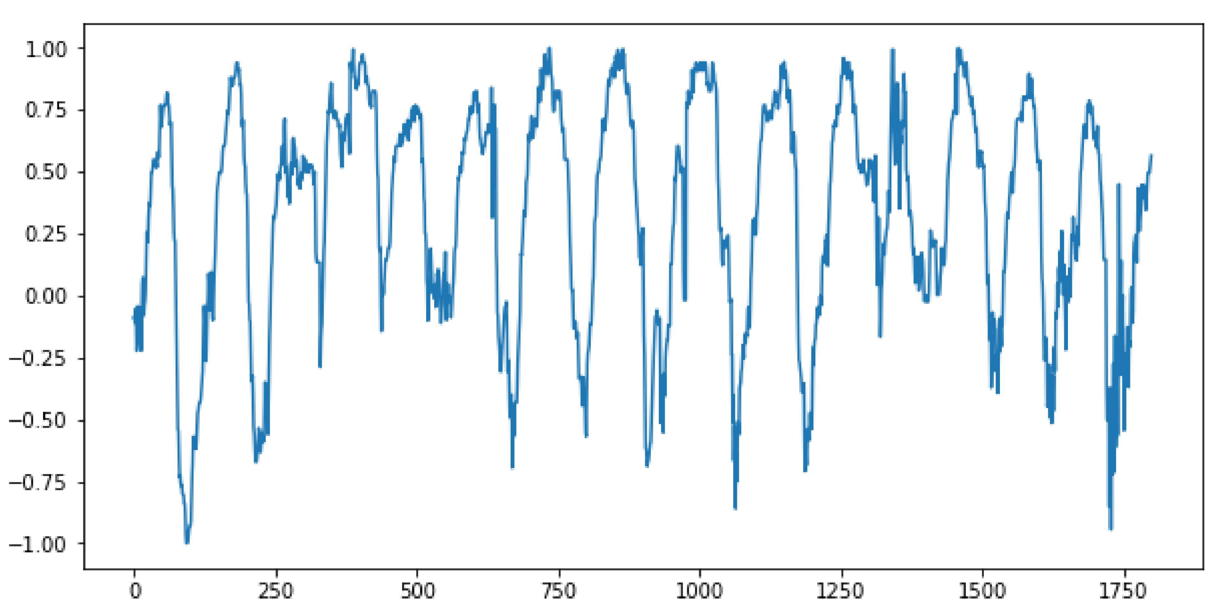
```
df.describe()
```

	0
count	1800.000000
mean	96.637474
std	5.687179
min	80.213900
25%	92.418925
50%	98.238450
75%	101.362750
max	104.895000

Statistical tests

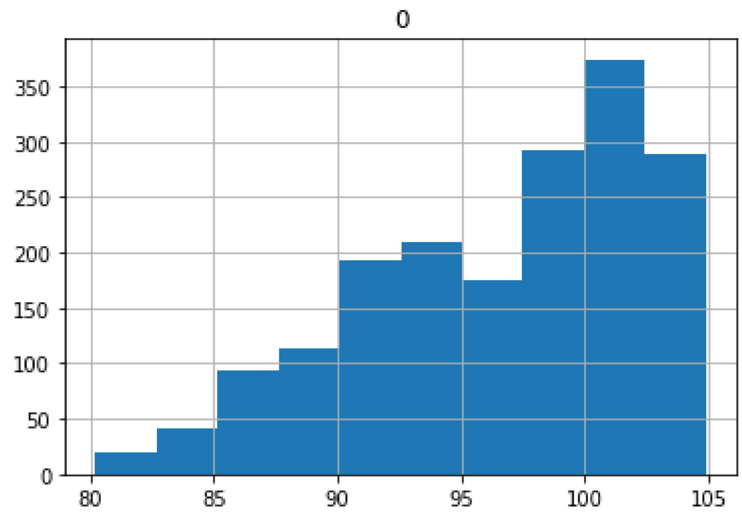
plot dataset

```
plt.figure(figsize=(10,5))
plt.plot(df)
plt.show()
```



Histogram plot.

```
df.hist()
plt.show()
```



calculate mean and variance in parts of data, to undrestand that our mean or variance in our data is alike or not.

in this data we have the same mean and variance,So it looks stationary.

```
x = df.values
split = round(len(x)/2)
x1, x2 = x[:split], x[split:]
mean1, mean2 = x1.mean(), x2.mean()
var1, var2 = x1.var(), x2.var()
print("mean1=%f, mean2=%f" % (mean1,mean2))
print("var1=%f, var2=%f" % (var1,var2))
```

```
mean1=96.890504, mean2=96.384444
var1=33.904997, var2=30.619018
```

Dickey-Fuller test

We interpret this result using the p-value from the test. If the p_value is more significant than 0.05, this test fails. And if the p_value is less than 0.05, the test is successful, and our data is stationary.

```
x = df.values
x = x.reshape((1800))
result = adfuller(x)
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])
print('Critical Values:')
for key, value in result[4].items():
    print('\t%s: %.3f' % (key, value))
```

```
ADF Statistic: -7.455368
p-value: 0.000000
Critical Values:
	1%: -3.434
	5%: -2.863
	10%: -2.568
```

Scale and supervised data

```
# scale our data between [-1, 1]
s = MinMaxScaler(feature_range=(-1,1))
df = s.fit_transform(df[[0]])


# convert list of minutes into inputs and outputs,input
# n_input, outputs:number of time steps returns the data in
# the overlapping moving window format(3 minutes, 5minutes)

def to_supervised(data, n_input, n_out):
    X, y = list(), list()
    in_start = 0
    for _ in range(len(data)):
        in_end = in_start + n_input
        out_end = in_end + n_out
        if out_end <= len(data):
            x_input = data[in_start:in_end, 0]
            x_input = x_input.reshape((len(x_input), 1))
            X.append(x_input)
            y.append(data[in_end:out_end, 0])
        # move along one time step
        in_start += 1
    return np.array(X),np.array(y)


# split a univariate dataset into train/test sets
def split_dataset(data,n_input,n_out,percent):
    # supervised dataset
    x, y = to_supervised(data,n_input,n_out)
  # split dataset into train and test
    n = int(len(x)*percent)
    train = [x[:n,:], y[:n]]
    test = [x[n:,:], y[n:]]
    return train, test
```

Build model

```
# build model function
# number of neurons is in range (10, 500)
# and dropout value is in range (0.1, 0.9)

def build_model(hp):  #prepare model for tuner
    n_timesteps, n_features, n_out = 360, 1, 600
    # define model
    model = Sequential()

    model.add(Bidirectional(LSTM(
            units=hp.Int("BILSTM1 units",min_value=10, max_value=500,step=16),
            # return_sequences=True
            )
            ,input_shape=(n_timesteps, n_features)))

    model.add(Dropout(
            rate=hp.Float("dropout1",min_value=0.1,max_value=0.9,step=0.1)
     ))

    # model.add(Bidirectional(LSTM(
    #       units=hp.Int("BILSTM2 units",min_value=10,max_value=500,step=16),
```

```
    #       return_sequences=True
    #   )))
    # model.add(Dropout(
    #       rate=hp.Float("dropout2",min_value=0.1,max_value=0.9,step=0.1)
    # ))

    # model.add(Bidirectional(LSTM(
    #       units=hp.Int("BILSTM3 units",min_value=10,max_value=500,step=16),
    #   )))
    # model.add(Dropout(
    #       rate=hp.Float("dropout3",min_value=0.1,max_value=0.9,step=0.1)
    # ))

    model.add(Dense(n_out, activation="relu"))
    model.compile(loss='mse', optimizer='adam',metrics=['accuracy',RootMeanSquarec
    return model
```

Tune parameters and build model model with theme.

```
# find the best parameters and build model with theme
# print scores and save results.
def tune(train,test,name,dir):
  #prepare data
  x_train, y_train = train[0], train[1]
  x_test, y_test = test[0], test[1]
  project_name, directory = name , dir

  #define parameters
  verbose, epochs, batch_size = 0, 5, 16
  n_timesteps, n_features, n_outputs = x_train.shape[1], x_train.shape[2], y_trair

  #configure tuner
  tuner = kt.RandomSearch(
    hypermodel=build_model,
    objective="val_accuracy",
    max_trials=3,
    executions_per_trial=2,
    overwrite=True,
    directory=directory,
    project_name=project_name
  )

  #search for best parameters
  tuner.search(x_train, y_train, epochs=epochs, validation_data=(x_test, y_test))

  #build best model
  models = tuner.get_best_models(num_models=2)
  best_model = models[0]
  best_model.build(input_shape=(n_timesteps, n_features))

  #summery results
  best_model.summary()
  tuner.results_summary()

  return best_model
```

Evaluation

```
# evaluate a single model
def evaluate_model(train, test,name,dir):
    # compile model
    build_model(kt.HyperParameters())

    # tune and fit model
    model = tune(train,test,name,dir)

    # predict test set
    predict = model.predict(test[0])
    xtest = test[0].reshape((test[0].shape[0],test[0].shape[1]))
    predictions = predict
    observation = test[1]

  #calculate rmse and scores
    score, scores = rmse(observation,predictions)
    return predict,score, scores


#calculate rmse for every single prediction
#and calculate rmse overall
def rmse(actual, predicted):
    scores = list()
    # calculate an RMSE score for each day
    for i in range(len(actual)):
        # calculate rmse
        mse = mean_squared_error(actual[i], predicted[i])
        rmse = math.sqrt(mse)

        scores.append(rmse)
    # calculate overall RMSE
    s = 0
    for row in range(actual.shape[0]):
        for col in range(actual.shape[1]):
            s += (actual[row, col] - predicted[row, col])**2
    score = math.sqrt(s / (actual.shape[0] * actual.shape[1]))
    return score, scores
```

RUN and report results

```
n_input = 360
n_out = 600
name = "BI-LSTM(1 layer)"
dir = "/content"
# split into train and test
train ,test = split_dataset(df,n_input,n_out,0.7)

# evaluate model
t1 = time.time()
predict, score, scores = evaluate_model(train, test ,name ,dir)
t2 = time.time()
#print score
print('running time : %.2f min'%((t2-t1)/60))
print('%s RMSE : [%.3f]' %(name, score))
```

```
Trial 3 Complete [00h 00m 44s]
val_accuracy: 0.0
```

```
Best val_accuracy So Far: 0.0
Total elapsed time: 00h 02m 54s
INFO:tensorflow:Oracle triggered exit
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 bidirectional (Bidirectiona  (None, 308)              192192
 l)

 dropout (Dropout)           (None, 308)               0

 dense (Dense)               (None, 600)               185400

=================================================================
Total params: 377,592
Trainable params: 377,592
Non-trainable params: 0
_________________________________________________________________
Results summary
Results in /content/BI-LSTM(1 layer)
Showing 10 best trials
<keras_tuner.engine.objective.Objective object at 0x7fedbcf31b90>
Trial summary
Hyperparameters:
BILSTM1 units: 154
dropout1: 0.30000000000000004
Score: 0.0
Trial summary
Hyperparameters:
BILSTM1 units: 442
dropout1: 0.7000000000000001
Score: 0.0
Trial summary
Hyperparameters:
BILSTM1 units: 154
dropout1: 0.6
Score: 0.0
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is being de]
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root)
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root)
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root)
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root)
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root)
running time : 3.00 min
BI-LSTM(1 layer) RMSE : [0.452]
```

Report results

RNN Report

No. of layers	No. of neurons	Dropout	RMSE
1	410	0.5	0.506
2	[394,346]	[0.7,0.2]	0.515
3	[362,90,138]	[0.4,0.2,0.5]	0.510

```
def build_model(hp):  #prepare model for tuner
    n_timesteps, n_features, n_out = 360, 1, 600
    # define model
    model = Sequential()
```

```
    model.add(SimpleRNN(
            units=hp.Int("RNN1 units",min_value=10, max_value=500,step=16),
            input_shape=(n_timesteps, n_features),
            return_sequences=True
        ))
    model.add(Dropout(
            rate=hp.Float("dropout1",min_value=0.1,max_value=0.9,step=0.1)
     ))

    model.add(SimpleRNN(
            units=hp.Int("RNN2 units",min_value=10,max_value=500,step=16),
            return_sequences=True
     ))
    model.add(Dropout(
            rate=hp.Float("dropout2",min_value=0.1,max_value=0.9,step=0.1)
    ))

    model.add(SimpleRNN(
            units=hp.Int("RNN3 units",min_value=10,max_value=500,step=16),
     ))
    model.add(Dropout(
            rate=hp.Float("dropout3",min_value=0.1,max_value=0.9,step=0.1)
    ))

    model.add(Dense(n_out, activation="relu"))
    model.compile(loss='mse', optimizer='adam',metrics=['accuracy',RootMeanSquaredError()])
    return model
```

LSTM Report

No. of layers	No. of neurons	Dropout	RMSE
1	74	0.7	0.481
2	[106,378]	[0.7,0.9]	0.508
3	[282,90,346]	[0.5,0.7,0.5]	0.438

```
def build_model(hp):  #prepare model for tuner
    n_timesteps, n_features, n_out = 360, 1, 600
    # define model
    model = Sequential()

    model.add(LSTM(
            units=hp.Int("lstm1 units",min_value=10, max_value=500,step=16),
            input_shape=(n_timesteps, n_features),
            return_sequences=True
        ))
    model.add(Dropout(
            rate=hp.Float("dropout1",min_value=0.1,max_value=0.9,step=0.1)
     ))

    model.add(LSTM(
```

```
        units=hp.Int("lstm2 units",min_value=10,max_value=500,step=16),
        return_sequences=True
 ))
model.add(Dropout(
        rate=hp.Float("dropout2",min_value=0.1,max_value=0.9,step=0.1)
))

model.add(LSTM(
        units=hp.Int("lstm3 units",min_value=10,max_value=500,step=16),
 ))
model.add(Dropout(
        rate=hp.Float("dropout3",min_value=0.1,max_value=0.9,step=0.1)
))

model.add(Dense(n_out, activation="relu"))
model.compile(loss='mse', optimizer='adam',metrics=['accuracy',RootMeanSquaredError()])
return model
```

GRU Report

No. of layers	No. of neurons	Dropout	RMSE
1	122	0.7	0.482
2	[74,58]	[0.8,0.4]	0.428
3	[90,42,490]	[0.2,0.6,0.1]	0.451

```
def build_model(hp):  #prepare model for tuner
    n_timesteps, n_features, n_out = 360, 1, 600
    # define model
    model = Sequential()

    model.add(GRU(
            units=hp.Int("GRU1 units",min_value=10, max_value=500,step=16),
            input_shape=(n_timesteps, n_features),
            return_sequences=True
        ))
    model.add(Dropout(
            rate=hp.Float("dropout1",min_value=0.1,max_value=0.9,step=0.1)
     ))

    model.add(GRU(
            units=hp.Int("GRU2 units",min_value=10,max_value=500,step=16),
            return_sequences=True
     ))
    model.add(Dropout(
            rate=hp.Float("dropout2",min_value=0.1,max_value=0.9,step=0.1)
    ))

    model.add(GRU(
            units=hp.Int("GRU3 units",min_value=10,max_value=500,step=16),
     ))
    model.add(Dropout(
            rate=hp.Float("dropout3",min_value=0.1,max_value=0.9,step=0.1)
```

```
    ))

    model.add(Dense(n_out, activation="relu"))
    model.compile(loss='mse', optimizer='adam',metrics=['accuracy',RootMeanSquaredError()])
    return model
```

BI-LSTM Report

```
  No. of layers  |   No. of neurons   |     Dropout     |   RMSE
       1         |         154        |       0.3       |   0.452
       2         |       [74,58]      |    [0.8,0.4]    |   0.466
       3         |    [346,106,394]   |  [0.2,0.6,0.7]  |   0.501
```

```
def build_model(hp):  #prepare model for tuner
    n_timesteps, n_features, n_out = 360, 1, 600
    # define model
    model = Sequential()

    model.add(Bidirectional(LSTM(
            units=hp.Int("BILSTM1 units",min_value=10, max_value=500,step=16),
            return_sequences=True
            )
            ,input_shape=(n_timesteps, n_features)))

    model.add(Dropout(
            rate=hp.Float("dropout1",min_value=0.1,max_value=0.9,step=0.1)
     ))

    model.add(Bidirectional(LSTM(
            units=hp.Int("BILSTM2 units",min_value=10,max_value=500,step=16),
            return_sequences=True
     )))
    model.add(Dropout(
            rate=hp.Float("dropout2",min_value=0.1,max_value=0.9,step=0.1)
    ))

    model.add(Bidirectional(LSTM(
            units=hp.Int("BILSTM3 units",min_value=10,max_value=500,step=16),
     )))
    model.add(Dropout(
            rate=hp.Float("dropout3",min_value=0.1,max_value=0.9,step=0.1)
    ))

    model.add(Dense(n_out, activation="relu"))
    model.compile(loss='mse', optimizer='adam',metrics=['accuracy',RootMeanSquaredError()])
    return model
```