#Projeto 2 - Redes Neurais

###Professor: Germano Vasconselos

Alunos: Felipe Jun Ting Lin - fjtl2@cin.ufpe.br João Gabriel Vasconcelos - jgav@cin.ufpe.br Maria Eduarda Mota - mebm@cin.ufpe.br Rafael Bernardo Nunes Neto - rbnn@cin.ufpe.br

Previsão do comportamento de preço do Bitcoin

Neste projeto faremos a implementação de um LSTM para previsão do preço do Bitcoin de dezembro de 2014 a maio de 2018. Para isso, utilizaremos Tensorflow e Keras, além da biblioteca Numpy para operações matemáticas e Scikit-Learn para funções de métricas de avaliação.

Importação das Bibliotecas

```
%pip install tensorflow
```

```
Looking in indexes: https://pypi.org/simple, https://us-
python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: tensorflow in
/usr/local/lib/python3.9/dist-packages (2.11.0)
Requirement already satisfied: tensorflow-estimator<2.12,>=2.11.0
in /usr/local/lib/python3.9/dist-packages (from tensorflow) (2.11.0)
Requirement already satisfied: gast<=0.4.0,>=0.2.1 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (0.4.0)
Requirement already satisfied: six>=1.12.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.15.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.51.3)
Requirement already satisfied: libclang>=13.0.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (15.0.6.1)
Requirement already satisfied: wrapt>=1.11.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.15.0)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (0.31.0)
Requirement already satisfied: typing-extensions>=3.6.6 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (4.5.0)
Requirement already satisfied: flatbuffers>=2.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (23.3.3)
Requirement already satisfied: protobuf<3.20,>=3.9.2 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (3.19.6)
Requirement already satisfied: tensorboard<2.12,>=2.11 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (2.11.2)
Requirement already satisfied: keras<2.12,>=2.11.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (2.11.0)
Requirement already satisfied: termcolor>=1.1.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (2.2.0)
Requirement already satisfied: absl-py>=1.0.0 in
```

```
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.4.0)
Requirement already satisfied: packaging in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (23.0)
Requirement already satisfied: astunparse>=1.6.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: h5py>=2.9.0 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (3.1.0)
Requirement already satisfied: setuptools in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (57.4.0)
Requirement already satisfied: opt-einsum>=2.3.2 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (3.3.0)
Requirement already satisfied: google-pasta>=0.1.1 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: numpy>=1.20 in
/usr/local/lib/python3.9/dist-packages (from tensorflow) (1.22.4)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/usr/local/lib/python3.9/dist-packages (from astunparse>=1.6.0-
>tensorflow) (0.38.4)
Requirement already satisfied: werkzeug>=1.0.1 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (2.2.3)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (0.4.6)
Requirement already satisfied: requests<3,>=2.21.0 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (2.25.1)
Requirement already satisfied: tensorboard-data-server<0.7.0,>=0.6.0
in /usr/local/lib/python3.9/dist-packages (from
tensorboard<2.12,>=2.11->tensorflow) (0.6.1)
Requirement already satisfied: google-auth<3,>=1.6.3 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (2.16.2)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (1.8.1)
Requirement already satisfied: markdown>=2.6.8 in
/usr/local/lib/python3.9/dist-packages (from tensorboard<2.12,>=2.11-
>tensorflow) (3.4.1)
Requirement already satisfied: rsa<5,>=3.1.4 in
/usr/local/lib/python3.9/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.12,>=2.11->tensorflow) (4.9)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in
/usr/local/lib/python3.9/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.12,>=2.11->tensorflow) (5.3.0)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/usr/local/lib/python3.9/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.12,>=2.11->tensorflow) (0.2.8)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
/usr/local/lib/python3.9/dist-packages (from google-auth-
```

```
oauthlib<0.5,>=0.4.1->tensorboard<2.12,>=2.11->tensorflow) (1.3.1)
Requirement already satisfied: importlib-metadata>=4.4 in
/usr/local/lib/python3.9/dist-packages (from markdown>=2.6.8-
>tensorboard<2.12,>=2.11->tensorflow) (6.0.0)
Requirement already satisfied: chardet<5,>=3.0.2 in
/usr/local/lib/python3.9/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.12,>=2.11->tensorflow) (4.0.0)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.9/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.12,>=2.11->tensorflow) (2022.12.7)
Requirement already satisfied: idna<3,>=2.5 in
/usr/local/lib/python3.9/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.12,>=2.11->tensorflow) (2.10)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in
/usr/local/lib/python3.9/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.12,>=2.11->tensorflow) (1.26.14)
Requirement already satisfied: MarkupSafe>=2.1.1 in
/usr/local/lib/python3.9/dist-packages (from werkzeug>=1.0.1-
>tensorboard<2.12,>=2.11->tensorflow) (2.1.2)
Requirement already satisfied: zipp>=0.5 in
/usr/local/lib/python3.9/dist-packages (from importlib-metadata>=4.4-
>markdown>=2.6.8->tensorboard<2.12,>=2.11->tensorflow) (3.15.0)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in
/usr/local/lib/python3.9/dist-packages (from pyasn1-modules>=0.2.1-
>google-auth<3,>=1.6.3->tensorboard<2.12,>=2.11->tensorflow) (0.4.8)
Requirement already satisfied: oauthlib>=3.0.0 in
/usr/local/lib/python3.9/dist-packages (from requests-oauthlib>=0.7.0-
>google-auth-oauthlib<0.5,>=0.4.1->tensorboard<2.12,>=2.11-
>tensorflow) (3.2.2)
```

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.preprocessing import StandardScaler
from sklearn.preprocessing import MinMaxScaler
import tensorflow as tf
import io
import math
%matplotlib inline
```

```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, LSTM
from sklearn.metrics import mean_squared_error
```

A fim de trabalharmos com valores determinísticos, instanciamos uma seed manual.

```python
np.random.seed(10)
tf.random.set_seed(10)
```

```
url = 'https://raw.githubusercontent.com/brianmwangy/predicting-
bitcoin-prices-using-LSTM/master/btc.csv'
df = pd.read_csv(url)
df = df.iloc[::-1].reset_index(drop=True)
```

Análise 1 (Configuração Base)

Anállise de Dados

A partir do banco de preços fornecido no arquivo .csv , vamos fazer a análise dos dados informativos:

```
df.head(5)
```

```
        Date  Symbol   Open   High     Low  Close  Volume From  Volume 
To
0  12/1/2014  BTCUSD  300.0  370.0  300.00  370.0      0.05656    
19.53
1  12/2/2014  BTCUSD  370.0  378.0  370.00  378.0     15.01000  
5675.07
2  12/3/2014  BTCUSD  378.0  378.0  377.01  378.0      0.54660   
206.52
3  12/4/2014  BTCUSD  378.0  378.0  377.10  377.1      0.01000     
3.77
4  12/5/2014  BTCUSD  377.1  377.1  377.10  377.1      0.00000     
0.00
```

```
df.describe()
```

```
               Open          High           Low         Close  
Volume From  \
count   1273.000000   1273.000000   1273.000000   1273.000000    
1273.000000   
mean    2498.589018   2594.908704   2382.982019   2504.256002   
10256.954990   
std     3786.446583   3959.166670   3560.430575   3788.559184    
9940.038576   
min      120.000000    184.000000      0.060000    120.000000       
0.000000   
25%      340.000000    340.000000    340.000000    340.000000    
4932.600000   
50%      630.870000    639.990000    620.590000    634.970000    
7405.230000   
75%     2657.450000   2776.950000   2551.060000   2664.990000   
12878.030000   
max    19650.000000  19891.990000  19010.000000  19650.000000  
160540.990000   

          Volume To  
count  1.273000e+03  
mean   4.454886e+07  
```

```
std    1.055807e+08
min    0.000000e+00
25%    2.042181e+06
50%    3.532958e+06
75%    3.532348e+07
max    1.237771e+09
```

Acima, temos estatísticas descritivas dos dados trabalhados.

```
df.info()
```

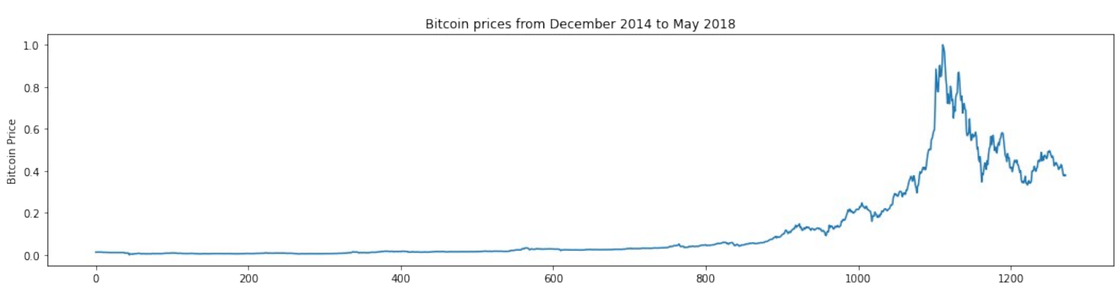
```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1273 entries, 0 to 1272
Data columns (total 8 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   Date         1273 non-null   object
 1   Symbol       1273 non-null   object
 2   Open         1273 non-null   float64
 3   High         1273 non-null   float64
 4   Low          1273 non-null   float64
 5   Close        1273 non-null   float64
 6   Volume From  1273 non-null   float64
 7   Volume To    1273 non-null   float64
dtypes: float64(6), object(2)
memory usage: 79.7+ KB
```

Normalização e Plot

Como os dados possuem valor absoluto alto, faremos uma normalização dos dados, a fim de evitar que alguns parâmetros se sobressaiam a outros no processo de treinamento.

```
df_to_use = df['Close'].values
scaler = MinMaxScaler()
scaled_df = scaler.fit_transform(df_to_use.reshape(-1,1))
```

```
figure = plt.figure(figsize=(18,4))
sns.lineplot(data=scaled_df, legend=None)
plt.xlabel('Days')
plt.ylabel('Bitcoin Price')
plt.title('Bitcoin prices from December 2014 to May 2018')
plt.show()
```



Funções Auxiliares

Trabalharemos com uma função para fazer a separação de treino e teste.

Usaremos a função `create_x_y`, que possui a finalidade de instanciar janelas de treinamento em sequências de dados.

```
def create_x_y(data, time_steps=1):
    x, y = [], []
    for i in range(len(data) - time_steps):
        v = data[i:(i + time_steps), 0] # pega todos os dias antes do 
dia que queremos prever
        x.append(v)
        y.append(data[i + time_steps, 0]) # pega o dia que queremos 
prever
    return np.array(x), np.array(y)
```

A fim de separar o dataset base, a função split_data é chamada.

```
# 818 instâncias para treino e 205 para teste, com um test_size de 20%
def split_data(data, test_size, time_steps):
    X, y = create_x_y(data, time_steps)

    length = X.shape[0]
    split = int(length * (1 - test_size))
    X_train, y_train = X[:split], y[:split]
    X_test, y_test = X[split:], y[split:]
    return X_train, y_train, X_test, y_test

time_steps = 250 # primeiramente, vamos treinar olhando para os 250 
dias anteriores
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2, 
time_steps)
print(X_train.shape)
print(y_train.shape)
print(X_test.shape)
print(y_test.shape)
```

```
(818, 250)
(818,)
(205, 250)
(205,)
```

Aqui, instanciaremos a função que implementará o algoritmo de Early Stopping em cada um dos modelos manipulados.

```
callback = tf.keras.callbacks.EarlyStopping(
    monitor="loss",
    min_delta=0,
    patience=10,
    verbose=1,
```

```
    mode="auto",
    baseline=None,
    restore_best_weights=False,
    start_from_epoch=0,
)
```

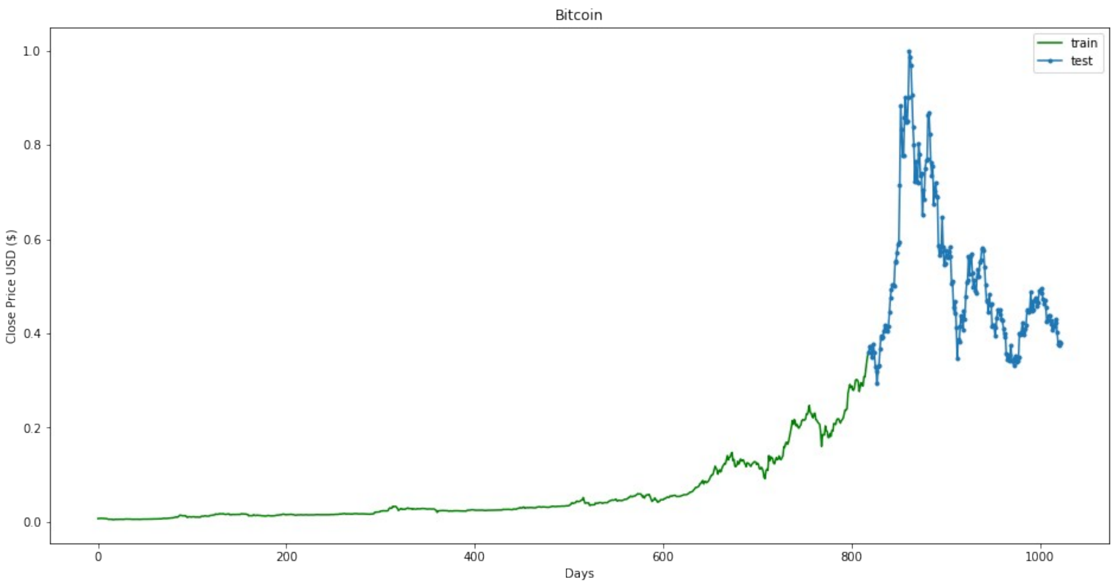
Treino e Teste

```
X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

print(X_train.shape)
print(y_train.shape)
print(X_test.shape)
print(y_test.shape)
```

```
(818, 250, 1)
(818, 1)
(205, 250, 1)
(205, 1)
```

Abaixo, temos o plot do nosso dataset segmentado

```
plt.figure(figsize=(16,8))
plt.plot(np.arange(0, len(y_train)), y_train, 'g', label='train')
plt.plot(np.arange(len(y_train), len(y_train) + len(y_test)), y_test,
marker='.', label='test')
plt.title('Bitcoin')
plt.xlabel('Days')
plt.ylabel('Close Price USD ($)')
plt.legend()
plt.show()
```



Arquitetura da Rede e Configuração dos Parâmetros

Nessa etapa, configuramos os parâmetros a serem utilizados e manipulados no treino.

```
EPOCHS = 30
BATCH_SIZE = 16
LEARNING_RATE = 0.001
DROPOUT = 0.1
VERBOSE = 1
OPT = tf.keras.optimizers.Adam
```

Instanciando o modelo de LSTM:

```
model_LSTM = tf.keras.Sequential()
model_LSTM.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT))
model_LSTM.add(Dense(1, activation='linear'))
model_LSTM.compile(
    optimizer=OPT(learning_rate = LEARNING_RATE),
    loss="mse")

model_LSTM.summary()

Model: "sequential_37"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_74 (LSTM)              (None, 250)               252000

 dense_33 (Dense)            (None, 1)                 251

=================================================================
Total params: 252,251
```

```
Trainable params: 252,251
Non-trainable params: 0
_________________________________________________________________
```

Agora, faremos o treinamento do modelo sem a manipulação de parâmetros.

```
history_LSTM = model_LSTM.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback])
```

```
Epoch 1/30
41/41 [==============================] - 6s 35ms/step - loss: 1.7033e-
04 - val_loss: 3.9778e-04
Epoch 2/30
41/41 [==============================] - 1s 22ms/step - loss: 2.3947e-
05 - val_loss: 2.8530e-04
Epoch 3/30
41/41 [==============================] - 1s 21ms/step - loss: 2.1933e-
05 - val_loss: 4.8413e-04
Epoch 4/30
41/41 [==============================] - 1s 21ms/step - loss: 2.0495e-
05 - val_loss: 3.6000e-04
Epoch 5/30
41/41 [==============================] - 1s 21ms/step - loss: 1.7605e-
05 - val_loss: 3.2969e-04
Epoch 6/30
41/41 [==============================] - 1s 21ms/step - loss: 1.4153e-
05 - val_loss: 4.2462e-04
Epoch 7/30
41/41 [==============================] - 1s 20ms/step - loss: 1.6891e-
05 - val_loss: 2.9256e-04
Epoch 8/30
41/41 [==============================] - 1s 34ms/step - loss: 2.1075e-
05 - val_loss: 3.1680e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8566e-
05 - val_loss: 3.0901e-04
Epoch 10/30
41/41 [==============================] - 1s 19ms/step - loss: 1.6285e-
05 - val_loss: 4.5046e-04
Epoch 11/30
41/41 [==============================] - 1s 20ms/step - loss: 2.2211e-
05 - val_loss: 0.0016
Epoch 12/30
41/41 [==============================] - 1s 19ms/step - loss: 2.5923e-
05 - val_loss: 6.1398e-04
```

```
Epoch 13/30
41/41 [==============================] - 1s 24ms/step - loss: 1.7538e-
05 - val_loss: 2.4083e-04
Epoch 14/30
41/41 [==============================] - 1s 19ms/step - loss: 1.7914e-
05 - val_loss: 3.7126e-04
Epoch 15/30
41/41 [==============================] - 1s 20ms/step - loss: 2.0646e-
05 - val_loss: 2.6833e-04
Epoch 16/30
41/41 [==============================] - 1s 20ms/step - loss: 1.3269e-
05 - val_loss: 2.9398e-04
Epoch 17/30
41/41 [==============================] - 1s 18ms/step - loss: 2.1581e-
05 - val_loss: 2.8929e-04
Epoch 18/30
41/41 [==============================] - 1s 22ms/step - loss: 1.8439e-
05 - val_loss: 3.4406e-04
Epoch 19/30
41/41 [==============================] - 1s 23ms/step - loss: 2.1559e-
05 - val_loss: 3.0061e-04
Epoch 20/30
41/41 [==============================] - 1s 23ms/step - loss: 1.7140e-
05 - val_loss: 5.2023e-04
Epoch 21/30
41/41 [==============================] - 1s 21ms/step - loss: 1.7218e-
05 - val_loss: 5.0141e-04
Epoch 22/30
41/41 [==============================] - 1s 33ms/step - loss: 2.2196e-
05 - val_loss: 3.2105e-04
Epoch 23/30
41/41 [==============================] - 1s 36ms/step - loss: 2.1434e-
05 - val_loss: 2.8393e-04
Epoch 24/30
41/41 [==============================] - 1s 23ms/step - loss: 1.5713e-
05 - val_loss: 2.8673e-04
Epoch 25/30
41/41 [==============================] - 1s 21ms/step - loss: 1.8066e-
05 - val_loss: 3.4262e-04
Epoch 26/30
41/41 [==============================] - 1s 17ms/step - loss: 2.5457e-
05 - val_loss: 7.5304e-04
Epoch 26: early stopping
```

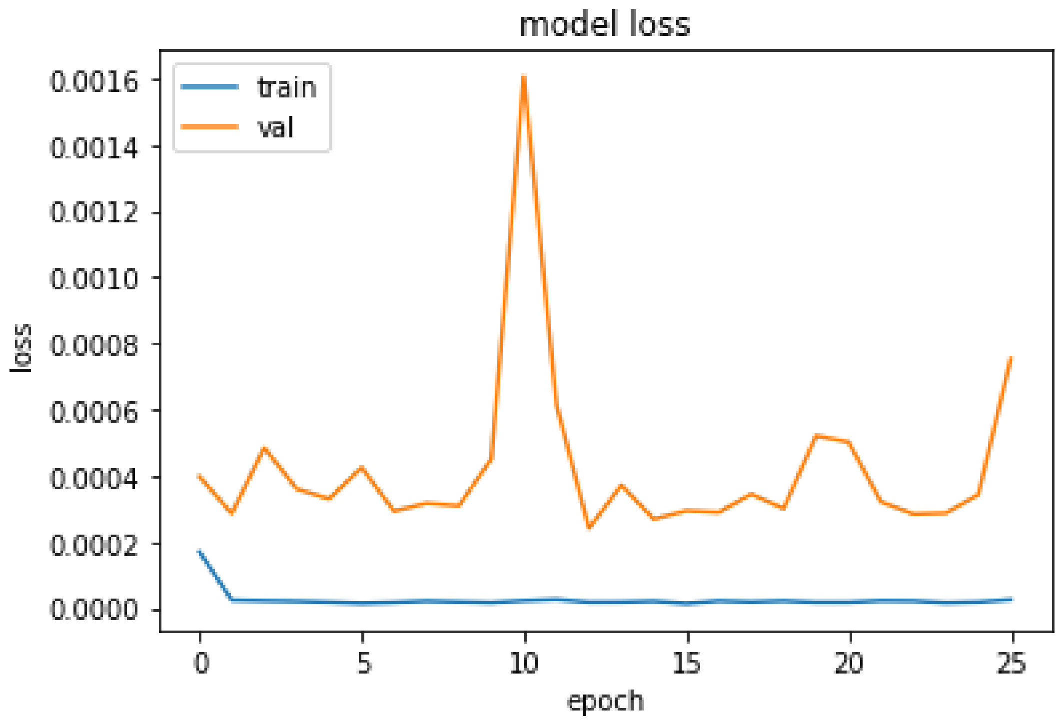
A fim de facilitar o processo de avaliação dos modelos referentes no documento, usaremos a função model_evaluation abaixo:

```
def model_evaluation(history, model, scaler, X_test, X_train, y_train,
y_test):
  plt.plot(history.history['loss'])
```

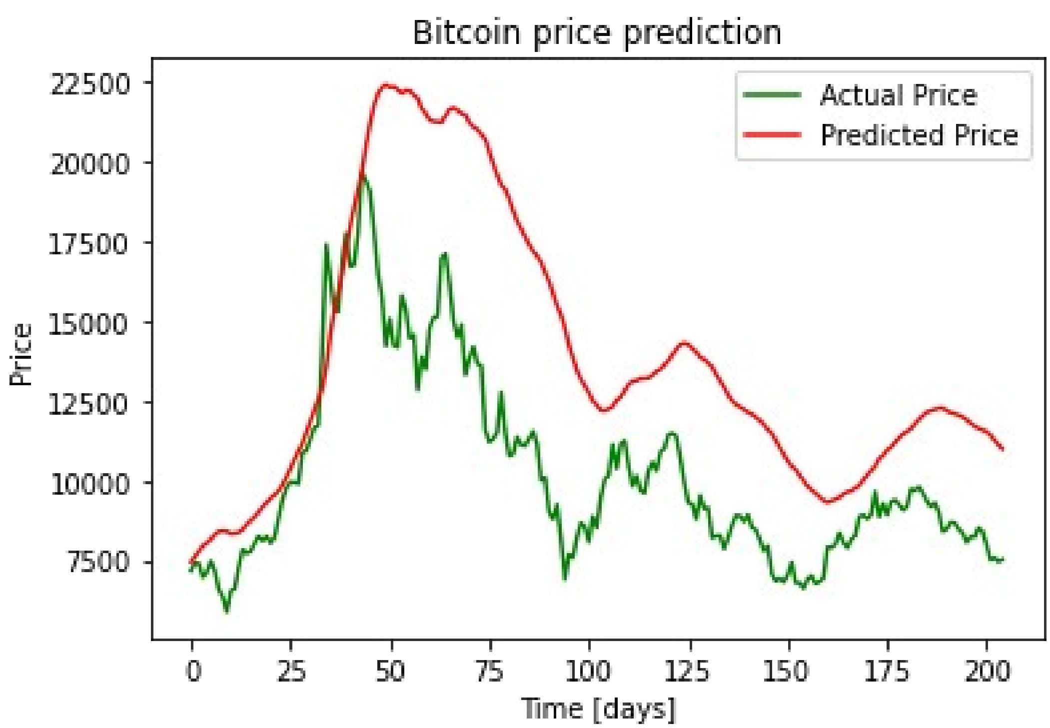
```
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc = 'upper left')
plt.show()

y_hat = model.predict(X_test)
y_t = model.predict(X_train)

y_test_inverse = scaler.inverse_transform(y_test)
y_hat_inverse = scaler.inverse_transform(y_hat)

plt.plot(y_test_inverse, label='Actual Price', color = 'green')
plt.plot(y_hat_inverse, label='Predicted Price', color = 'red')

plt.title('Bitcoin price prediction')
plt.xlabel('Time [days]')
plt.ylabel('Price')
plt.legend(['Actual Price', 'Predicted Price'], loc = 'upper right')
## adicionar legenda com os parametros atuais

trainScore = math.sqrt(mean_squared_error(y_train[0], y_t[0]))
print('Train Score: %.4f RMSE' % (trainScore))
testScore = math.sqrt(mean_squared_error(y_test[0], y_hat[0]))
print('Test Score: %.4f RMSE' % (testScore))

plt.show()
```

Com o plot dos dados, conseguimos ter uma avaliação mais palpável do treinamento. Assim, faremos esse processo a seguir:

```
model_evaluation(history_LSTM, model_LSTM, scaler, X_test, X_train,
y_train, y_test)
```




```
7/7 [==============================] - 0s 11ms/step
26/26 [==============================] - 0s 10ms/step
Train Score: 0.0010 RMSE
Test Score: 0.0144 RMSE
```



Análise de Resultados

A partir dos dados obtidos, observamos um comportamento similar (no quesito de aumento ou diminuição do valor do Bitcoin ao longo do tempo) do conjunto de treino e teste. Apesar de as magnitudes se encontrarem na ordem de grandeza, suas valorações ainda divergem. Por fim, obtivemos um test score de 0.0244 RMSE.

Análise 2 (Número de Camadas LSTM)

Nessa etapa, faremos testes com diferentes números de camadas LSTM, a fim de analisar e encontrar a melhor estrutura a ser aplicada no projeto

2 camadas de LSTM

Usando 2 camadas de LSTM:

```
model_LSTM_2 = tf.keras.Sequential()
model_LSTM_2.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2.add(Dense(1, activation='linear'))
model_LSTM_2.compile(
    optimizer=OPT(learning_rate = LEARNING_RATE),
    loss="mse"
)

model_LSTM_2.summary()
```

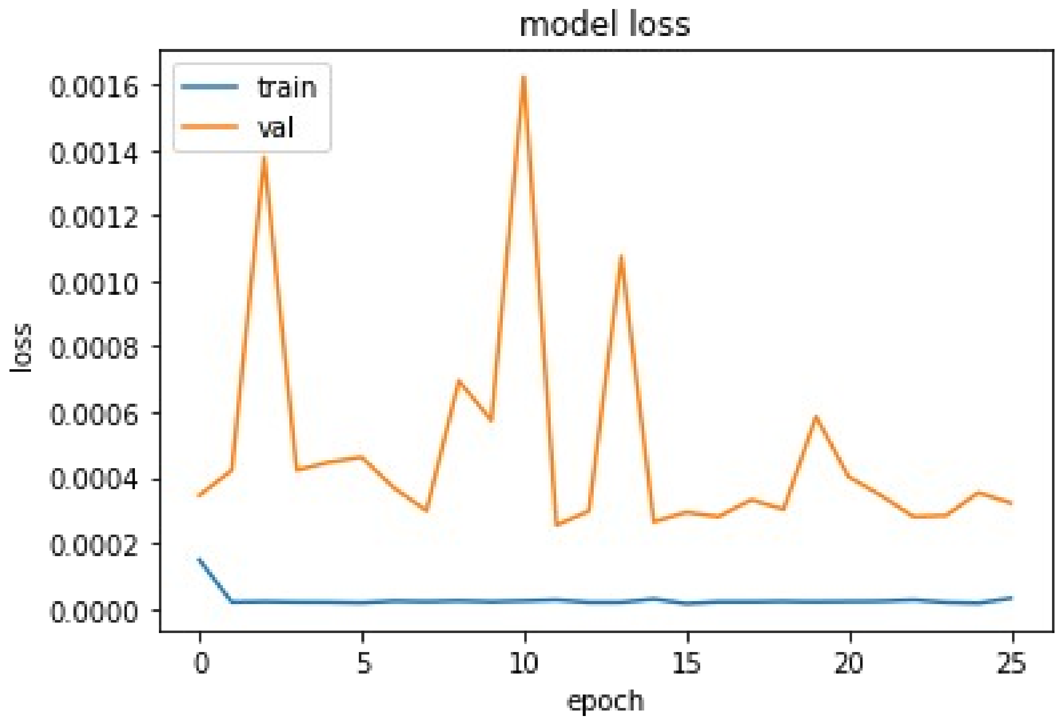
```
Model: "sequential_38"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_75 (LSTM)              (None, 250, 250)          252000

 lstm_76 (LSTM)              (None, 250)               501000

 dense_34 (Dense)            (None, 1)                 251

=================================================================
Total params: 753,251
Trainable params: 753,251
Non-trainable params: 0
_________________________________________________________________
```

```
history_LSTM_2 = model_LSTM_2.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
```

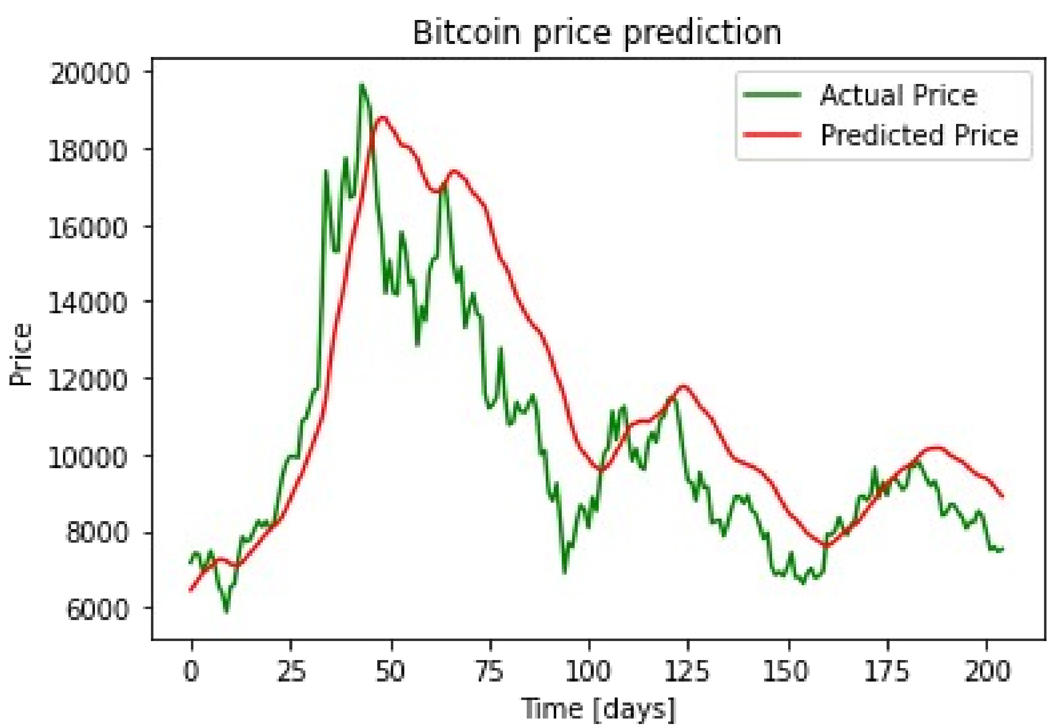
```
    callbacks=[callback]
)

Epoch 1/30
41/41 [==============================] - 6s 48ms/step - loss: 1.4881e-
04 - val_loss: 3.4576e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9332e-
05 - val_loss: 4.2218e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0926e-
05 - val_loss: 0.0014
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9416e-
05 - val_loss: 4.2291e-04
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9198e-
05 - val_loss: 4.4707e-04
Epoch 6/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7398e-
05 - val_loss: 4.6208e-04
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2809e-
05 - val_loss: 3.6850e-04
Epoch 8/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1086e-
05 - val_loss: 2.9873e-04
Epoch 9/30
41/41 [==============================] - 1s 32ms/step - loss: 2.3554e-
05 - val_loss: 6.9500e-04
Epoch 10/30
41/41 [==============================] - 1s 34ms/step - loss: 2.0763e-
05 - val_loss: 5.7406e-04
Epoch 11/30
41/41 [==============================] - 1s 29ms/step - loss: 2.3167e-
05 - val_loss: 0.0016
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6473e-
05 - val_loss: 2.5451e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8670e-
05 - val_loss: 2.9780e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8744e-
05 - val_loss: 0.0011
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9051e-
05 - val_loss: 2.6506e-04
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 1.4718e-
```

```
05 - val_loss: 2.9392e-04
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0427e-
05 - val_loss: 2.8058e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0400e-
05 - val_loss: 3.3208e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1768e-
05 - val_loss: 3.0290e-04
Epoch 20/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0523e-
05 - val_loss: 5.8555e-04
Epoch 21/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1439e-
05 - val_loss: 4.0280e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2121e-
05 - val_loss: 3.4561e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6358e-
05 - val_loss: 2.8047e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8713e-
05 - val_loss: 2.8364e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6307e-
05 - val_loss: 3.5396e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.1260e-
05 - val_loss: 3.2242e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2, model_LSTM_2, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 12ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0023 RMSE
Test Score: 0.0368 RMSE
```



Análise de Resultados

A partir dos resultados obtidos, nota-se uma perfomance superior ao teste com uma camada.

3 camadas de LSTM

Usando 3 camadas de LSTM, temos:

```
model_LSTM_3 = tf.keras.Sequential()
model_LSTM_3.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_3.add(LSTM(time_steps, dropout=DROPOUT,
return_sequences=True))
model_LSTM_3.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_3.add(Dense(1, activation='linear'))
model_LSTM_3.compile(
    optimizer=OPT(learning_rate = LEARNING_RATE),
    loss="mse"
)
```

```
history_LSTM_3 = model_LSTM_3.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 8s 68ms/step - loss: 1.2745e-
04 - val_loss: 4.8255e-04
Epoch 2/30
41/41 [==============================] - 2s 43ms/step - loss: 3.3104e-
05 - val_loss: 4.7518e-04
Epoch 3/30
41/41 [==============================] - 2s 39ms/step - loss: 2.2133e-
05 - val_loss: 5.8620e-04
Epoch 4/30
41/41 [==============================] - 2s 39ms/step - loss: 2.5639e-
05 - val_loss: 0.0012
Epoch 5/30
41/41 [==============================] - 2s 40ms/step - loss: 2.3655e-
05 - val_loss: 5.1182e-04
Epoch 6/30
41/41 [==============================] - 2s 41ms/step - loss: 1.7995e-
05 - val_loss: 4.1045e-04
Epoch 7/30
41/41 [==============================] - 2s 40ms/step - loss: 2.5105e-
```

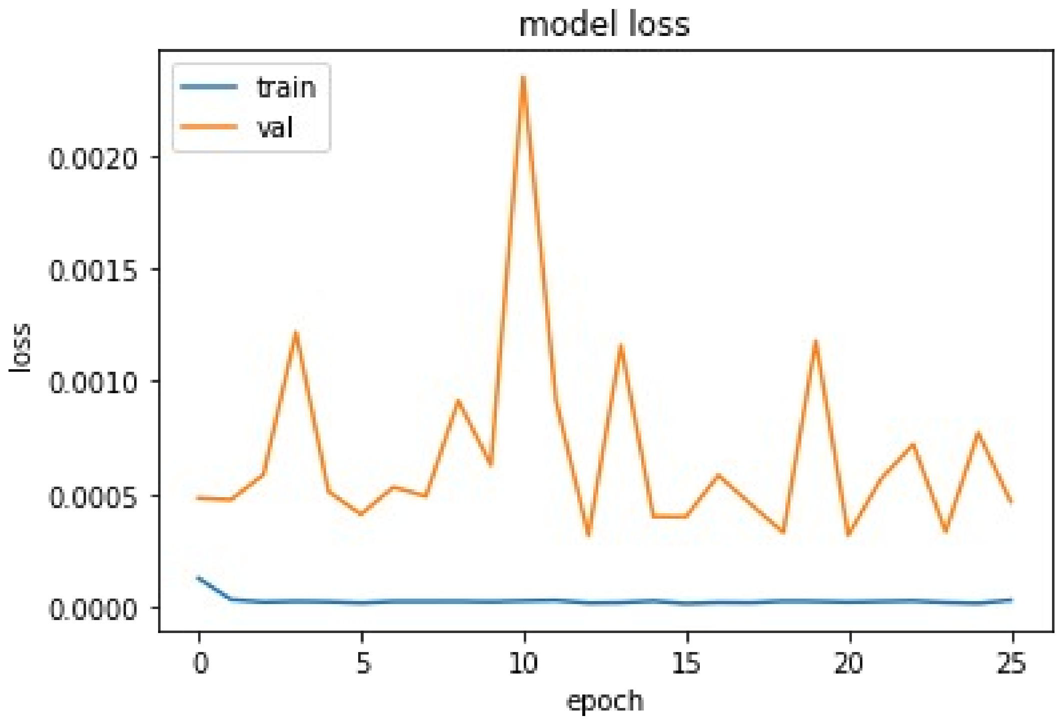
```
05 - val_loss: 5.3114e-04
Epoch 8/30
41/41 [==============================] - 2s 40ms/step - loss: 2.5148e-
05 - val_loss: 4.9065e-04
Epoch 9/30
41/41 [==============================] - 2s 40ms/step - loss: 2.5595e-
05 - val_loss: 9.1324e-04
Epoch 10/30
41/41 [==============================] - 2s 40ms/step - loss: 2.3486e-
05 - val_loss: 6.2901e-04
Epoch 11/30
41/41 [==============================] - 2s 40ms/step - loss: 2.7207e-
05 - val_loss: 0.0023
Epoch 12/30
41/41 [==============================] - 2s 40ms/step - loss: 2.9875e-
05 - val_loss: 9.1474e-04
Epoch 13/30
41/41 [==============================] - 2s 41ms/step - loss: 1.7821e-
05 - val_loss: 3.1582e-04
Epoch 14/30
41/41 [==============================] - 2s 40ms/step - loss: 1.9739e-
05 - val_loss: 0.0012
Epoch 15/30
41/41 [==============================] - 2s 40ms/step - loss: 2.7015e-
05 - val_loss: 4.0100e-04
Epoch 16/30
41/41 [==============================] - 2s 39ms/step - loss: 1.4856e-
05 - val_loss: 3.9951e-04
Epoch 17/30
41/41 [==============================] - 2s 41ms/step - loss: 2.0470e-
05 - val_loss: 5.8313e-04
Epoch 18/30
41/41 [==============================] - 2s 41ms/step - loss: 1.9104e-
05 - val_loss: 4.5544e-04
Epoch 19/30
41/41 [==============================] - 2s 40ms/step - loss: 2.6432e-
05 - val_loss: 3.2992e-04
Epoch 20/30
41/41 [==============================] - 2s 40ms/step - loss: 2.5497e-
05 - val_loss: 0.0012
Epoch 21/30
41/41 [==============================] - 2s 41ms/step - loss: 2.1761e-
05 - val_loss: 3.1777e-04
Epoch 22/30
41/41 [==============================] - 2s 40ms/step - loss: 2.4835e-
05 - val_loss: 5.6612e-04
Epoch 23/30
41/41 [==============================] - 2s 46ms/step - loss: 2.7405e-
05 - val_loss: 7.1961e-04
Epoch 24/30
```

```
41/41 [==============================] - 2s 40ms/step - loss: 2.0231e-
05 - val_loss: 3.3351e-04
Epoch 25/30
41/41 [==============================] - 2s 40ms/step - loss: 1.6236e-
05 - val_loss: 7.7180e-04
Epoch 26/30
41/41 [==============================] - 2s 39ms/step - loss: 3.0793e-
05 - val_loss: 4.6664e-04
Epoch 26: early stopping
```

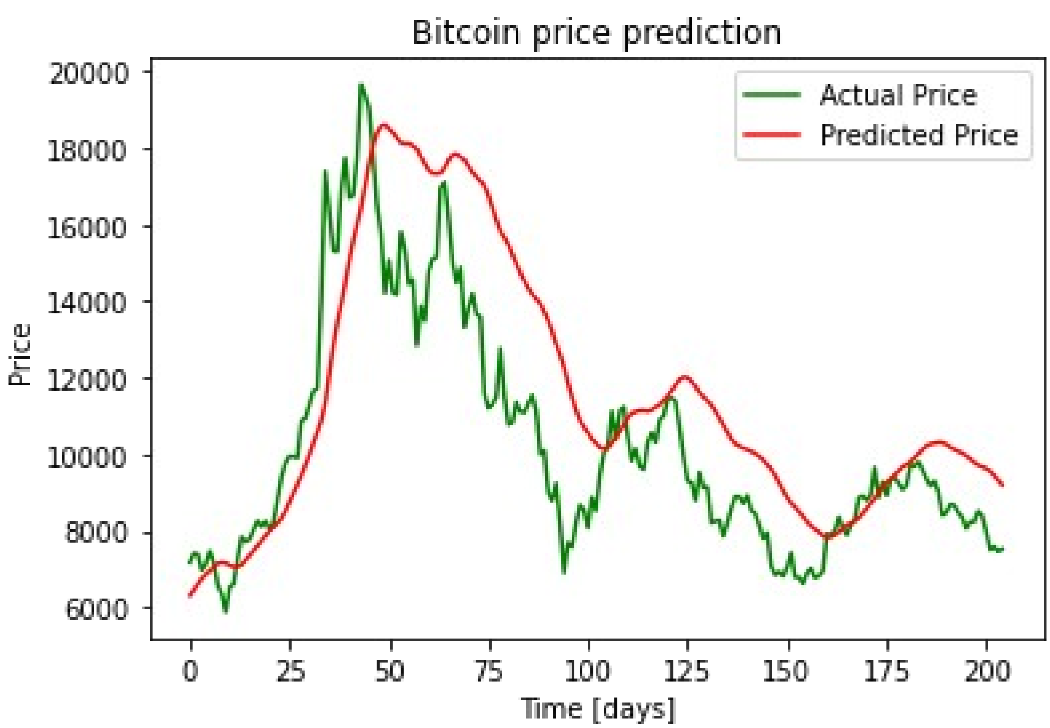
```
model_LSTM_3.summary()
```

```
Model: "sequential_39"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_77 (LSTM)              (None, 250, 250)          252000

 lstm_78 (LSTM)              (None, 250, 250)          501000

 lstm_79 (LSTM)              (None, 250)               501000

 dense_35 (Dense)            (None, 1)                 251

=================================================================
Total params: 1,254,251
Trainable params: 1,254,251
Non-trainable params: 0
_________________________________________________________________
```

```
model_evaluation(history_LSTM_3, model_LSTM_3, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 31ms/step
26/26 [==============================] - 0s 18ms/step
Train Score: 0.0029 RMSE
Test Score: 0.0443 RMSE
```



Análise de Resultados

A partir dos resultados obtidos, nota-se uma performance inferior ao teste com duas camadas. Sendo assim, até o momento, duas camadas aparenta ser a estrutura mais coerente.

4 camadas de LSTM

Usando 4 camadas de LSTM:

```
model_LSTM_4 = tf.keras.Sequential()
model_LSTM_4.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_4.add(LSTM(time_steps, dropout=DROPOUT,
return_sequences=True))
model_LSTM_4.add(LSTM(time_steps, dropout=DROPOUT,
return_sequences=True))
model_LSTM_4.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_4.add(Dense(1, activation='linear'))
model_LSTM_4.compile(
    optimizer=OPT(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_4 = model_LSTM_4.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 12s 86ms/step - loss:
1.6856e-04 - val_loss: 8.2629e-04
Epoch 2/30
41/41 [==============================] - 2s 52ms/step - loss: 2.9660e-
05 - val_loss: 8.0060e-04
Epoch 3/30
41/41 [==============================] - 2s 52ms/step - loss: 2.8684e-
05 - val_loss: 0.0012
Epoch 4/30
41/41 [==============================] - 2s 52ms/step - loss: 4.2996e-
05 - val_loss: 0.0048
Epoch 5/30
41/41 [==============================] - 2s 52ms/step - loss: 3.6049e-
05 - val_loss: 7.9948e-04
Epoch 6/30
41/41 [==============================] - 2s 52ms/step - loss: 2.1492e-
```

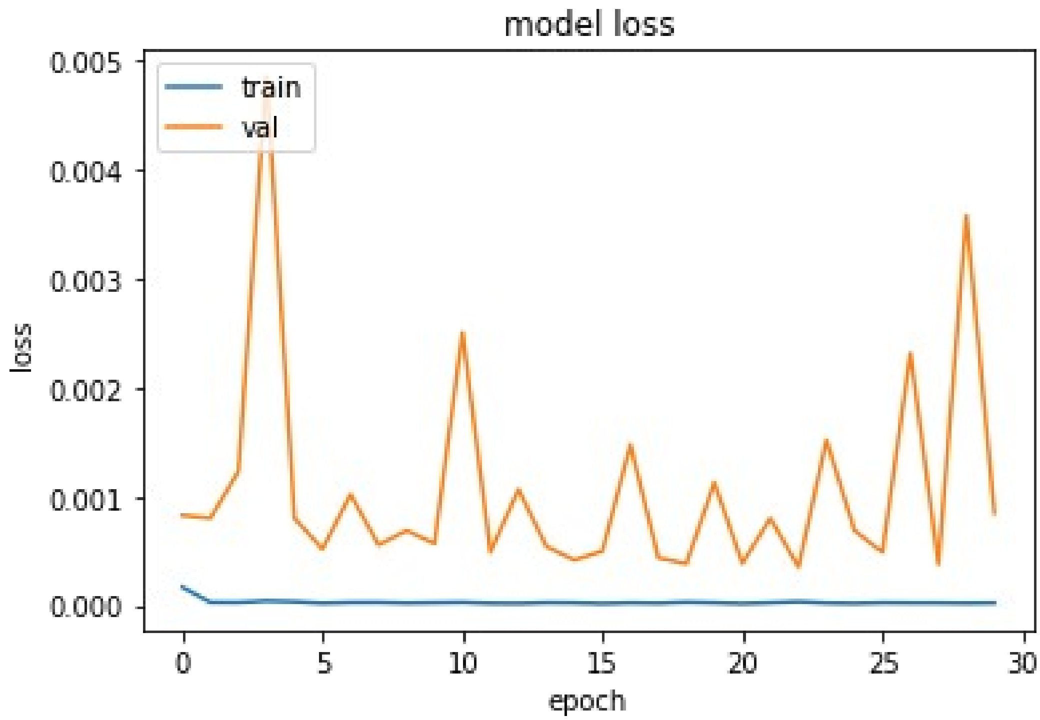
```
05 - val_loss: 5.1834e-04
Epoch 7/30
41/41 [==============================] - 2s 53ms/step - loss: 2.8540e-
05 - val_loss: 0.0010
Epoch 8/30
41/41 [==============================] - 2s 53ms/step - loss: 2.9215e-
05 - val_loss: 5.5652e-04
Epoch 9/30
41/41 [==============================] - 2s 53ms/step - loss: 2.3326e-
05 - val_loss: 6.8680e-04
Epoch 10/30
41/41 [==============================] - 2s 54ms/step - loss: 2.6586e-
05 - val_loss: 5.6907e-04
Epoch 11/30
41/41 [==============================] - 2s 53ms/step - loss: 2.9868e-
05 - val_loss: 0.0025
Epoch 12/30
41/41 [==============================] - 2s 53ms/step - loss: 2.0566e-
05 - val_loss: 4.9168e-04
Epoch 13/30
41/41 [==============================] - 2s 53ms/step - loss: 1.8587e-
05 - val_loss: 0.0011
Epoch 14/30
41/41 [==============================] - 2s 53ms/step - loss: 2.6805e-
05 - val_loss: 5.4134e-04
Epoch 15/30
41/41 [==============================] - 2s 53ms/step - loss: 2.5014e-
05 - val_loss: 4.1717e-04
Epoch 16/30
41/41 [==============================] - 2s 52ms/step - loss: 1.7677e-
05 - val_loss: 4.9970e-04
Epoch 17/30
41/41 [==============================] - 2s 53ms/step - loss: 2.5255e-
05 - val_loss: 0.0015
Epoch 18/30
41/41 [==============================] - 2s 53ms/step - loss: 2.1679e-
05 - val_loss: 4.3720e-04
Epoch 19/30
41/41 [==============================] - 2s 53ms/step - loss: 3.1652e-
05 - val_loss: 3.8467e-04
Epoch 20/30
41/41 [==============================] - 2s 52ms/step - loss: 2.6174e-
05 - val_loss: 0.0011
Epoch 21/30
41/41 [==============================] - 2s 53ms/step - loss: 1.7626e-
05 - val_loss: 3.8716e-04
Epoch 22/30
41/41 [==============================] - 2s 57ms/step - loss: 2.6249e-
05 - val_loss: 8.0057e-04
Epoch 23/30
```

```
41/41 [==============================] - 2s 53ms/step - loss: 3.6124e-
05 - val_loss: 3.5449e-04
Epoch 24/30
41/41 [==============================] - 2s 60ms/step - loss: 2.3373e-
05 - val_loss: 0.0015
Epoch 25/30
41/41 [==============================] - 2s 52ms/step - loss: 1.9258e-
05 - val_loss: 6.8908e-04
Epoch 26/30
41/41 [==============================] - 2s 52ms/step - loss: 2.5948e-
05 - val_loss: 4.8835e-04
Epoch 27/30
41/41 [==============================] - 2s 52ms/step - loss: 2.4322e-
05 - val_loss: 0.0023
Epoch 28/30
41/41 [==============================] - 2s 52ms/step - loss: 2.4337e-
05 - val_loss: 3.8022e-04
Epoch 29/30
41/41 [==============================] - 2s 52ms/step - loss: 2.1663e-
05 - val_loss: 0.0036
Epoch 30/30
41/41 [==============================] - 2s 52ms/step - loss: 2.4402e-
05 - val_loss: 8.4763e-04
```

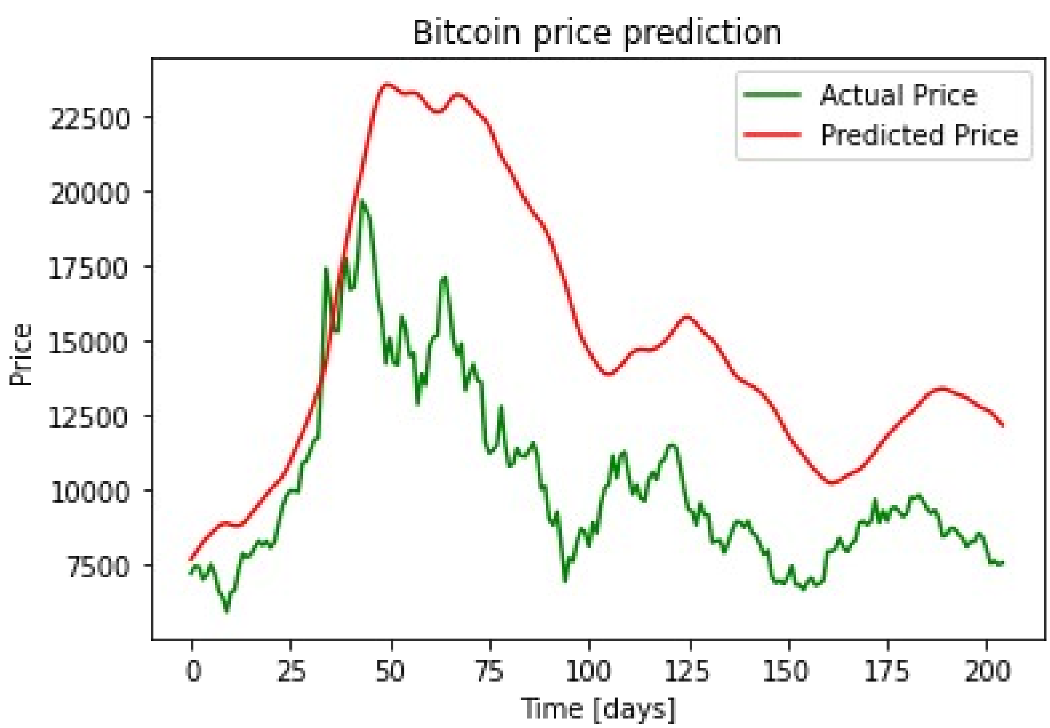
```
model_LSTM_4.summary()
```

```
Model: "sequential_40"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_80 (LSTM)              (None, 250, 250)          252000

 lstm_81 (LSTM)              (None, 250, 250)          501000

 lstm_82 (LSTM)              (None, 250, 250)          501000

 lstm_83 (LSTM)              (None, 250)               501000

 dense_36 (Dense)            (None, 1)                 251

=================================================================
Total params: 1,755,251
Trainable params: 1,755,251
Non-trainable params: 0
_________________________________________________________________
```

```
model_evaluation(history_LSTM_4, model_LSTM_4, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 39ms/step
26/26 [==============================] - 1s 22ms/step
Train Score: 0.0032 RMSE
Test Score: 0.0241 RMSE
```



Análise de Resultados

A partir dos resultados obtidos, nota-se uma performance inferior ao teste com duas camadas.

Continuidade

Em virtude dos resultados encontrados, utilizaremos a partir de agora a rede com 2 camadas LSTM.

Análise 3 (Algoritmo de Otimização)

Agora, vamos analisar a influência dos diferentes algoritmos de otimização aplicados na rede com 2 LSTMs.

ADAM Optmizer

Aplicando o ADAM Optimizer:

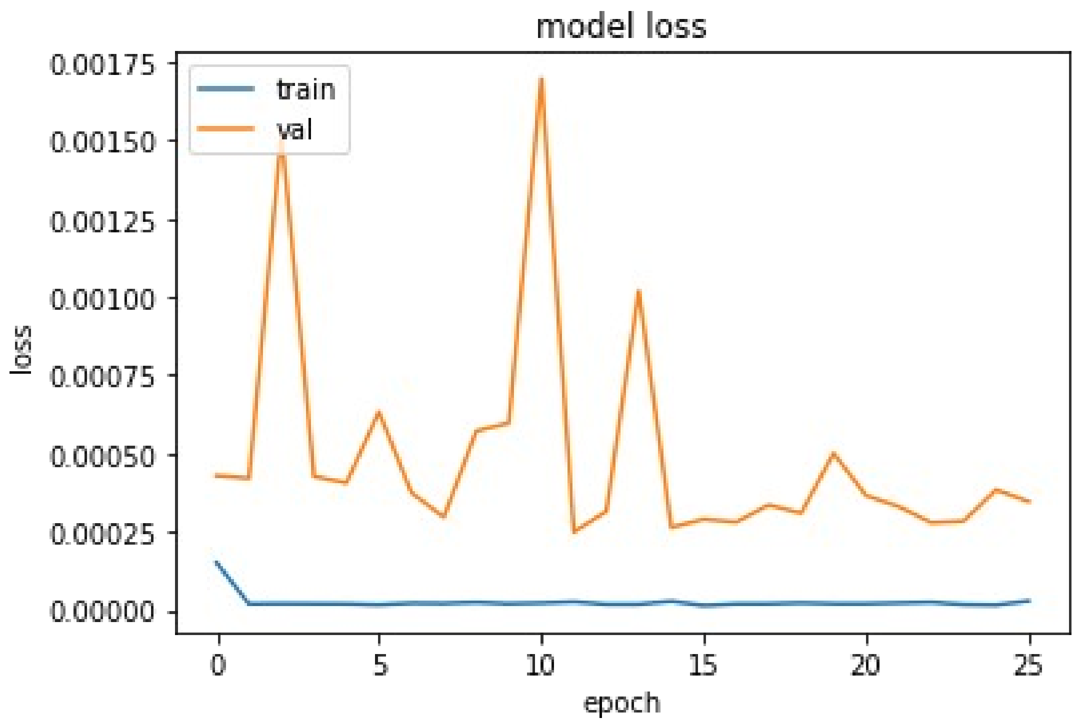
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps, 
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 6s 47ms/step - loss: 1.5160e-
04 - val_loss: 4.2931e-04
Epoch 2/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9866e-
05 - val_loss: 4.2122e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0802e-
05 - val_loss: 0.0015
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0191e-
05 - val_loss: 4.2688e-04
```

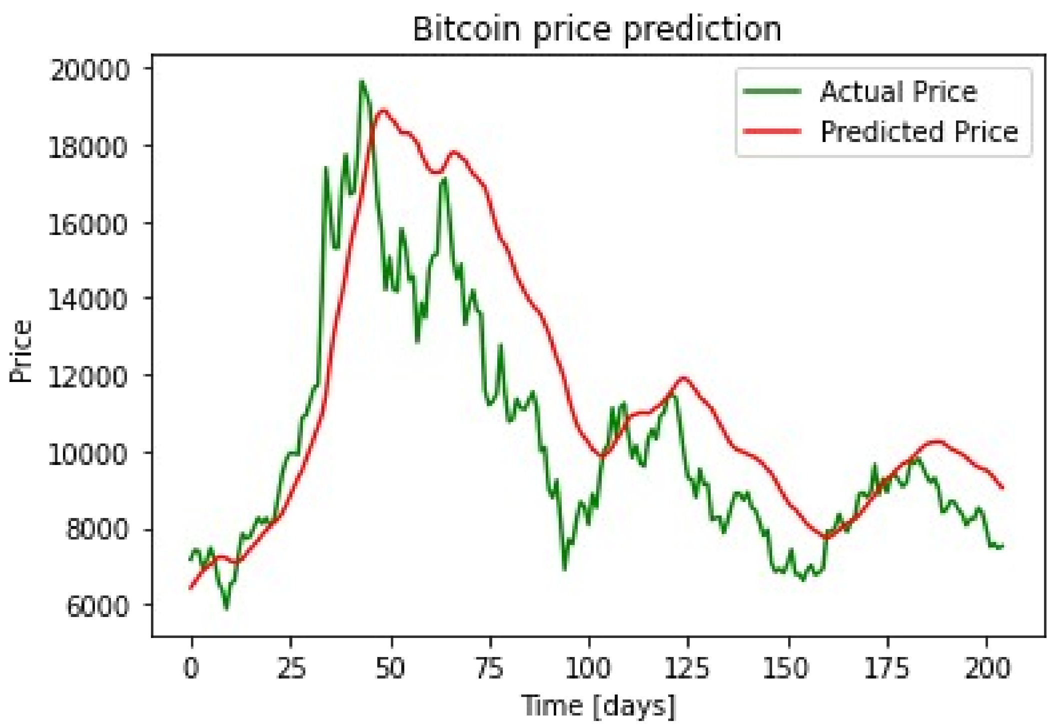
```
Epoch 5/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9951e-
05 - val_loss: 4.0646e-04
Epoch 6/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7097e-
05 - val_loss: 6.3256e-04
Epoch 7/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2474e-
05 - val_loss: 3.7542e-04
Epoch 8/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1556e-
05 - val_loss: 2.9706e-04
Epoch 9/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5216e-
05 - val_loss: 5.7168e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0711e-
05 - val_loss: 5.9683e-04
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2877e-
05 - val_loss: 0.0017
Epoch 12/30
41/41 [==============================] - 1s 28ms/step - loss: 2.6827e-
05 - val_loss: 2.4947e-04
Epoch 13/30
41/41 [==============================] - 1s 28ms/step - loss: 1.8640e-
05 - val_loss: 3.1591e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8658e-
05 - val_loss: 0.0010
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 2.8843e-
05 - val_loss: 2.6422e-04
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 1.4507e-
05 - val_loss: 2.9046e-04
Epoch 17/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0006e-
05 - val_loss: 2.8112e-04
Epoch 18/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0147e-
05 - val_loss: 3.3595e-04
Epoch 19/30
41/41 [==============================] - 1s 29ms/step - loss: 2.3196e-
05 - val_loss: 3.0983e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0574e-
05 - val_loss: 5.0080e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0609e-
```

```
05 - val_loss: 3.6597e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2934e-
05 - val_loss: 3.3112e-04
Epoch 23/30
41/41 [==============================] - 1s 26ms/step - loss: 2.5608e-
05 - val_loss: 2.7964e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7827e-
05 - val_loss: 2.8455e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6404e-
05 - val_loss: 3.8437e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9514e-
05 - val_loss: 3.4706e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 21ms/step
26/26 [==============================] - 0s 13ms/step
Train Score: 0.0020 RMSE
Test Score: 0.0379 RMSE
```



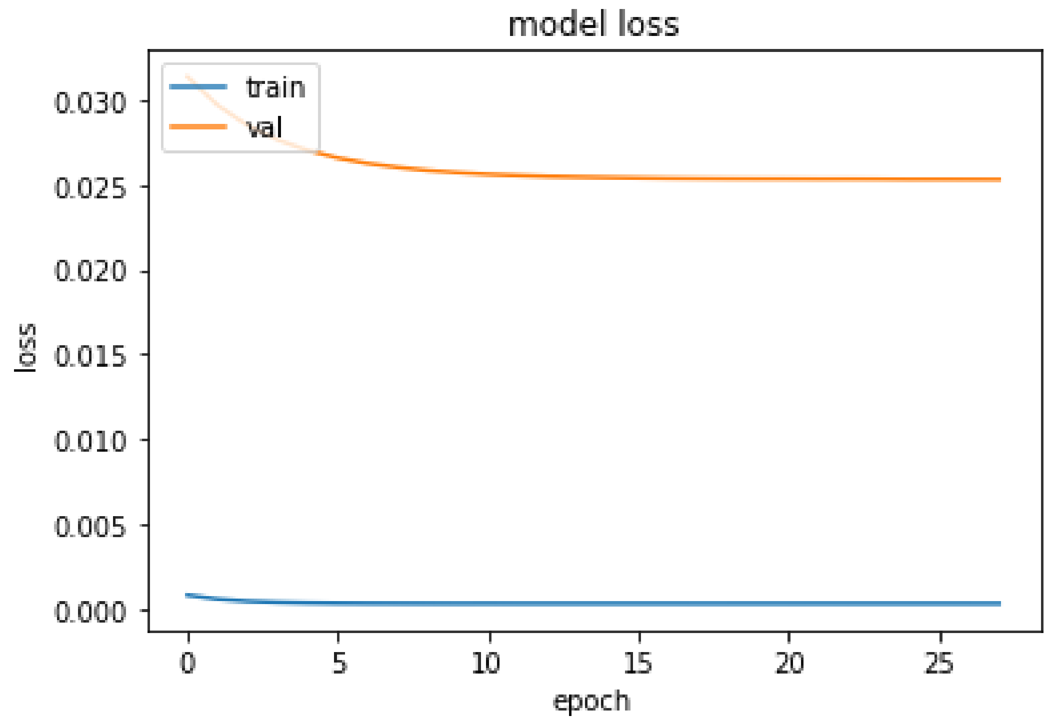
Stochastic Gradient Descent

```
model_LSTM_2_sgd = tf.keras.Sequential()
model_LSTM_2_sgd.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_sgd.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_sgd.add(Dense(1, activation='linear'))
model_LSTM_2_sgd.compile(
    optimizer=tf.keras.optimizers.SGD(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_sgd = model_LSTM_2_sgd.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)

Epoch 1/30
41/41 [==============================] - 6s 51ms/step - loss: 7.9524e-
04 - val_loss: 0.0314
Epoch 2/30
41/41 [==============================] - 1s 26ms/step - loss: 5.6293e-
04 - val_loss: 0.0297
Epoch 3/30
```

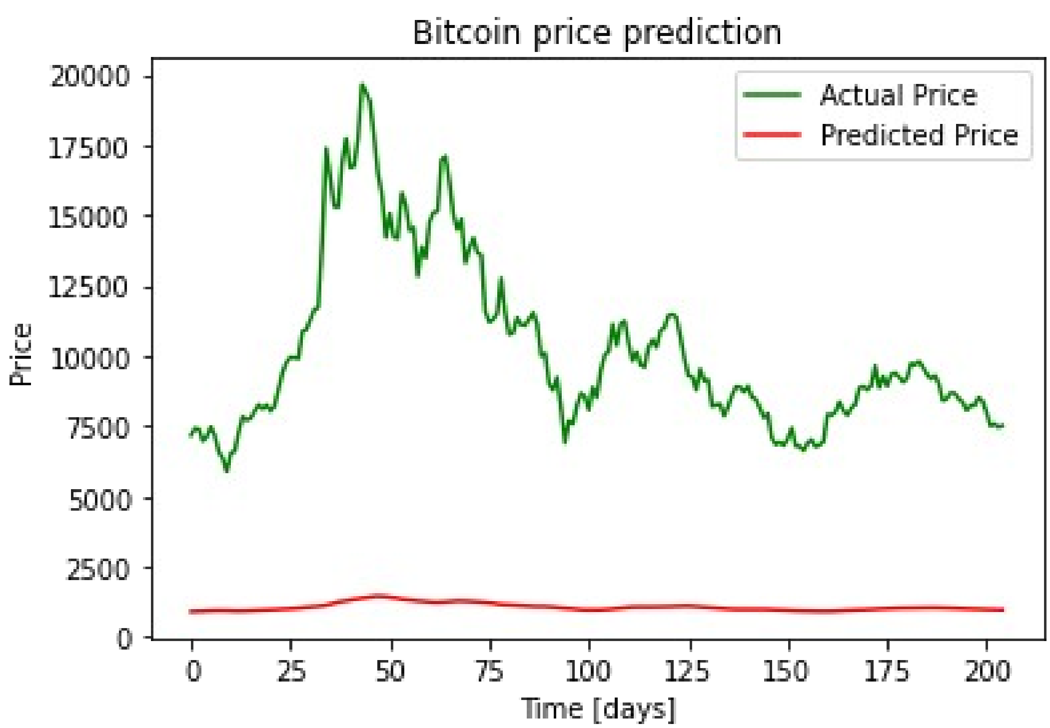
```
41/41 [==============================] - 1s 26ms/step - loss: 4.3823e-
04 - val_loss: 0.0285
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 3.7158e-
04 - val_loss: 0.0277
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 3.3553e-
04 - val_loss: 0.0270
Epoch 6/30
41/41 [==============================] - 1s 26ms/step - loss: 3.1682e-
04 - val_loss: 0.0266
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 3.0637e-
04 - val_loss: 0.0263
Epoch 8/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0190e-
04 - val_loss: 0.0260
Epoch 9/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9867e-
04 - val_loss: 0.0258
Epoch 10/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9608e-
04 - val_loss: 0.0257
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9724e-
04 - val_loss: 0.0256
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9456e-
04 - val_loss: 0.0255
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9499e-
04 - val_loss: 0.0255
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9450e-
04 - val_loss: 0.0255
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9556e-
04 - val_loss: 0.0254
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9453e-
04 - val_loss: 0.0254
Epoch 17/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9524e-
04 - val_loss: 0.0254
Epoch 18/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9377e-
04 - val_loss: 0.0254
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9442e-
04 - val_loss: 0.0254
```

```
Epoch 20/30
41/41 [==============================] - 1s 29ms/step - loss: 2.9465e-
04 - val_loss: 0.0254
Epoch 21/30
41/41 [==============================] - 1s 33ms/step - loss: 2.9430e-
04 - val_loss: 0.0253
Epoch 22/30
41/41 [==============================] - 2s 51ms/step - loss: 2.9545e-
04 - val_loss: 0.0253
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9398e-
04 - val_loss: 0.0253
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9446e-
04 - val_loss: 0.0253
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9456e-
04 - val_loss: 0.0253
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9510e-
04 - val_loss: 0.0253
Epoch 27/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9412e-
04 - val_loss: 0.0253
Epoch 28/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9385e-
04 - val_loss: 0.0253
Epoch 28: early stopping
```

```
model_evaluation(history_LSTM_2_sgd, model_LSTM_2_sgd, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0188 RMSE
Test Score: 0.3211 RMSE
```



RMSprop

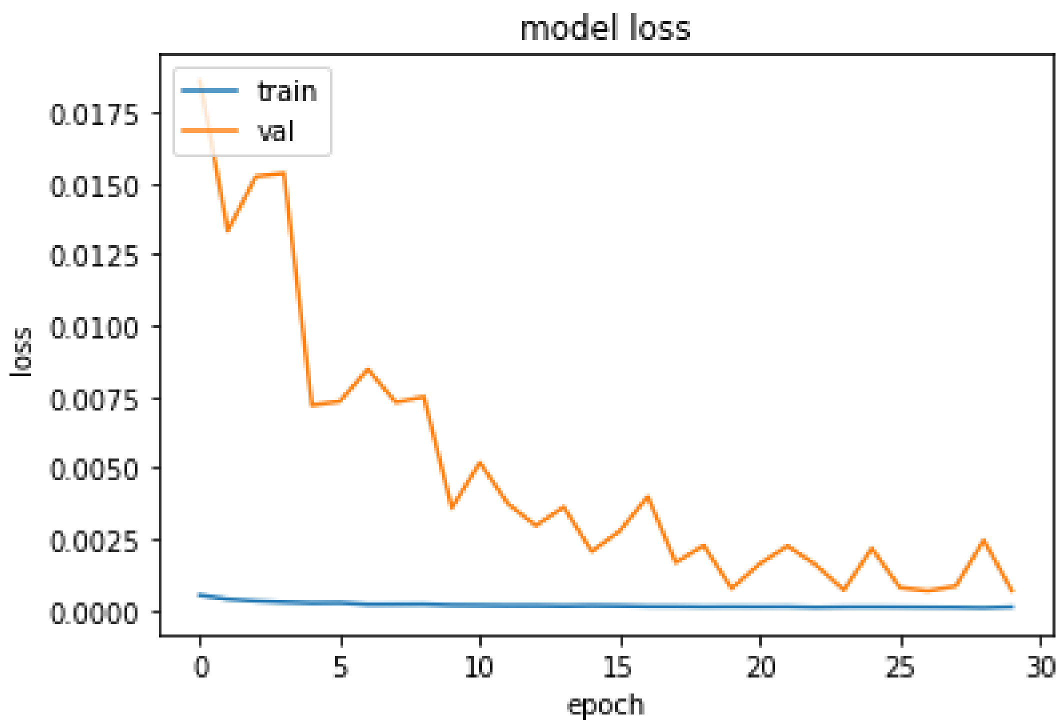
```
model_LSTM_2_rms = tf.keras.Sequential()
model_LSTM_2_rms.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_rms.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_rms.add(Dense(1, activation='linear'))
model_LSTM_2_rms.compile(
    optimizer=tf.keras.optimizers.RMSprop(learning_rate =
LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_rms = model_LSTM_2_rms.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 5s 48ms/step - loss: 5.2908e-
04 - val_loss: 0.0186
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 3.8596e-
04 - val_loss: 0.0133
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 3.2288e-
04 - val_loss: 0.0152
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 2.8215e-
04 - val_loss: 0.0153
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 2.5111e-
04 - val_loss: 0.0072
Epoch 6/30
41/41 [==============================] - 1s 28ms/step - loss: 2.5865e-
04 - val_loss: 0.0073
Epoch 7/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0172e-
04 - val_loss: 0.0085
Epoch 8/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0459e-
04 - val_loss: 0.0073
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0832e-
04 - val_loss: 0.0075
Epoch 10/30
```

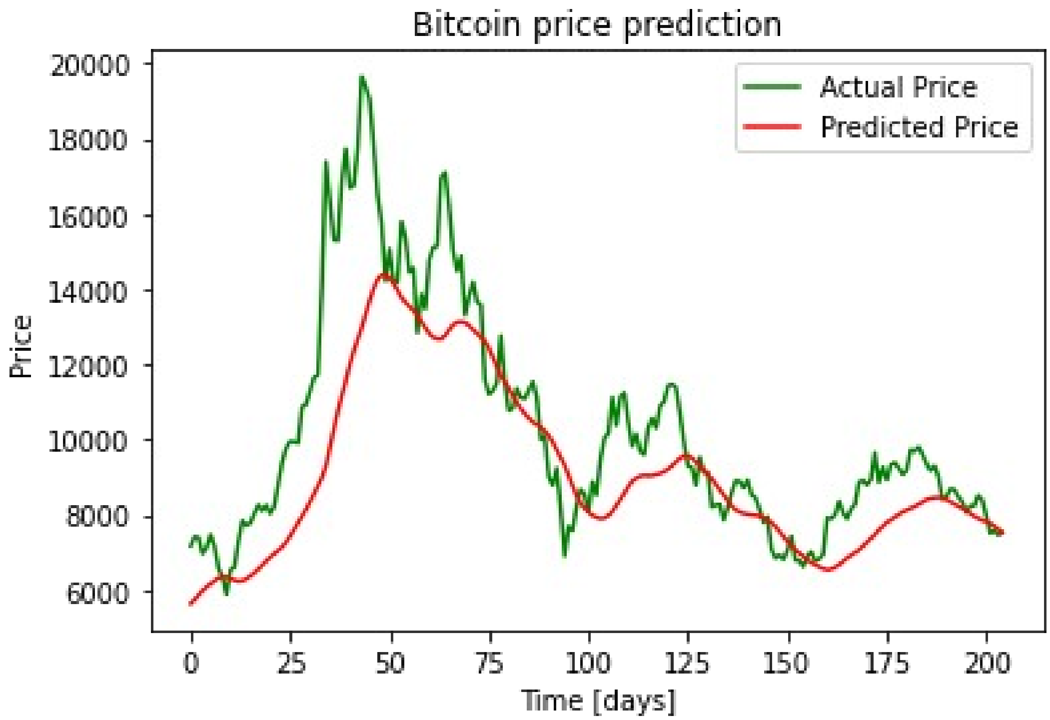
```
41/41 [==============================] - 1s 27ms/step - loss: 1.7798e-
04 - val_loss: 0.0036
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7205e-
04 - val_loss: 0.0052
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6335e-
04 - val_loss: 0.0037
Epoch 13/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6431e-
04 - val_loss: 0.0030
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 1.5114e-
04 - val_loss: 0.0036
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6243e-
04 - val_loss: 0.0021
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 1.5313e-
04 - val_loss: 0.0028
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 1.3322e-
04 - val_loss: 0.0040
Epoch 18/30
41/41 [==============================] - 1s 28ms/step - loss: 1.3147e-
04 - val_loss: 0.0017
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 1.2022e-
04 - val_loss: 0.0023
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 1.2426e-
04 - val_loss: 7.6359e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 1.1930e-
04 - val_loss: 0.0016
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 1.2236e-
04 - val_loss: 0.0023
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 1.0006e-
04 - val_loss: 0.0016
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.1277e-
04 - val_loss: 7.0944e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.1483e-
04 - val_loss: 0.0022
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 1.1018e-
04 - val_loss: 7.9747e-04
```

```
Epoch 27/30
41/41 [==============================] - 1s 26ms/step - loss: 1.0452e-
04 - val_loss: 6.7964e-04
Epoch 28/30
41/41 [==============================] - 1s 28ms/step - loss: 9.7999e-
05 - val_loss: 8.4660e-04
Epoch 29/30
41/41 [==============================] - 1s 27ms/step - loss: 8.4348e-
05 - val_loss: 0.0025
Epoch 30/30
41/41 [==============================] - 1s 27ms/step - loss: 1.1406e-
04 - val_loss: 6.8991e-04
```

```
model_evaluation(history_LSTM_2_rms, model_LSTM_2_rms, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0120 RMSE
Test Score: 0.0787 RMSE
```



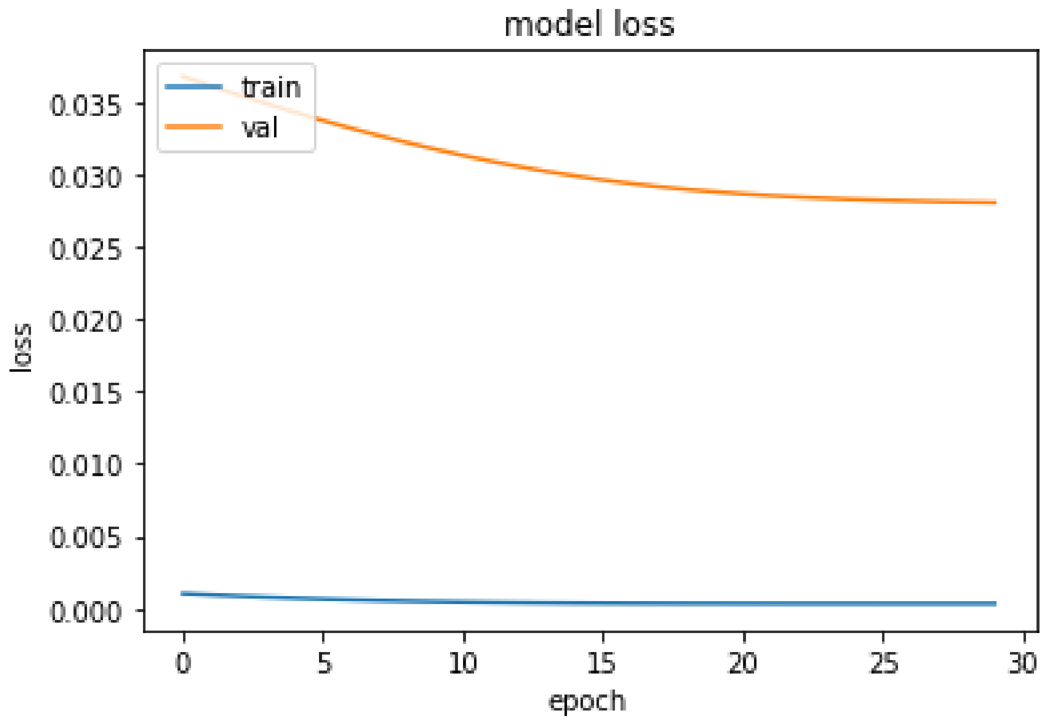
Adadelta

```
model_LSTM_2_ada = tf.keras.Sequential()
model_LSTM_2_ada.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_ada.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_ada.add(Dense(1, activation='linear'))
model_LSTM_2_ada.compile(
    optimizer=tf.keras.optimizers.Adadelta(learning_rate =
LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_ada = model_LSTM_2_ada.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)

Epoch 1/30
41/41 [==============================] - 6s 48ms/step - loss: 0.0010 -
val_loss: 0.0368
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 9.3167e-
04 - val_loss: 0.0361
```

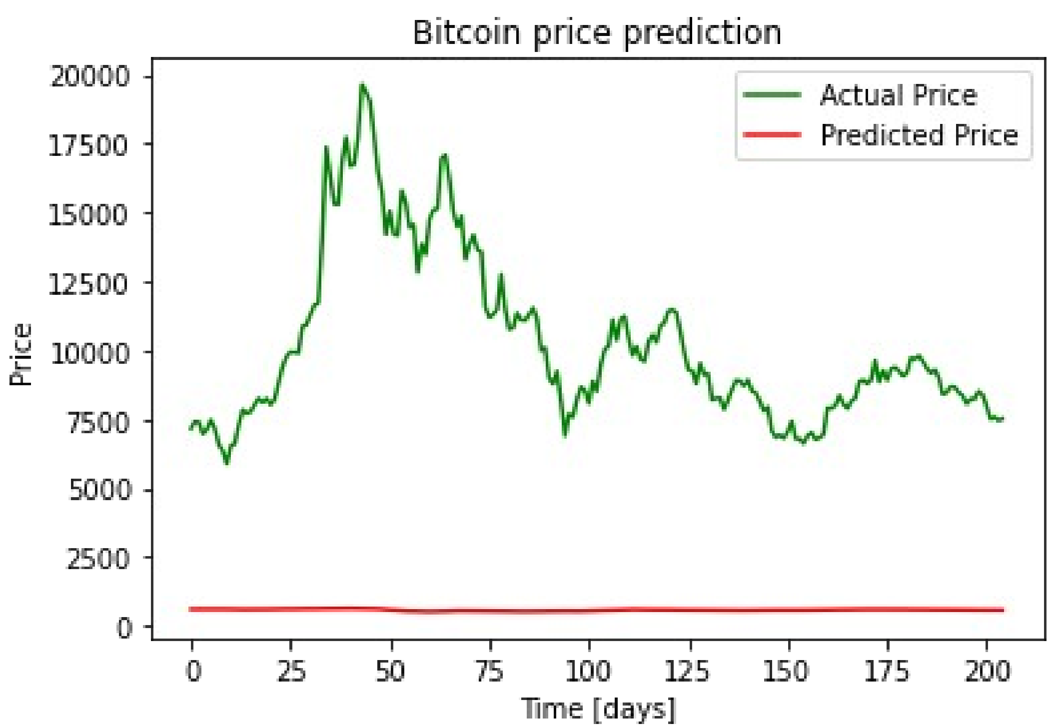
```
Epoch 3/30
41/41 [==============================] - 1s 28ms/step - loss: 8.4838e-
04 - val_loss: 0.0355
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 7.7498e-
04 - val_loss: 0.0349
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 7.0716e-
04 - val_loss: 0.0343
Epoch 6/30
41/41 [==============================] - 1s 26ms/step - loss: 6.4638e-
04 - val_loss: 0.0337
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 5.9325e-
04 - val_loss: 0.0332
Epoch 8/30
41/41 [==============================] - 1s 26ms/step - loss: 5.4582e-
04 - val_loss: 0.0327
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 5.0538e-
04 - val_loss: 0.0322
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 4.7124e-
04 - val_loss: 0.0317
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 4.4011e-
04 - val_loss: 0.0313
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 4.1563e-
04 - val_loss: 0.0309
Epoch 13/30
41/41 [==============================] - 1s 26ms/step - loss: 3.9638e-
04 - val_loss: 0.0305
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 3.7892e-
04 - val_loss: 0.0302
Epoch 15/30
41/41 [==============================] - 1s 28ms/step - loss: 3.6616e-
04 - val_loss: 0.0299
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 3.5630e-
04 - val_loss: 0.0296
Epoch 17/30
41/41 [==============================] - 1s 26ms/step - loss: 3.4714e-
04 - val_loss: 0.0294
Epoch 18/30
41/41 [==============================] - 1s 26ms/step - loss: 3.3995e-
04 - val_loss: 0.0291
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 3.3634e-
```

```
04 - val_loss: 0.0290
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 3.3324e-
04 - val_loss: 0.0288
Epoch 21/30
41/41 [==============================] - 1s 26ms/step - loss: 3.3048e-
04 - val_loss: 0.0287
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2808e-
04 - val_loss: 0.0285
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2625e-
04 - val_loss: 0.0284
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2579e-
04 - val_loss: 0.0283
Epoch 25/30
41/41 [==============================] - 1s 28ms/step - loss: 3.2610e-
04 - val_loss: 0.0283
Epoch 26/30
41/41 [==============================] - 1s 28ms/step - loss: 3.2507e-
04 - val_loss: 0.0282
Epoch 27/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2478e-
04 - val_loss: 0.0282
Epoch 28/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2502e-
04 - val_loss: 0.0281
Epoch 29/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2435e-
04 - val_loss: 0.0281
Epoch 30/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2465e-
04 - val_loss: 0.0281
```

```
model_evaluation(history_LSTM_2_ada, model_LSTM_2_ada, scaler, X_test,
X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 22ms/step
26/26 [==============================] - 0s 15ms/step
Train Score: 0.0194 RMSE
Test Score: 0.3360 RMSE
```



Continuidade

Observando o RMSE dos algoritmos testados, notamos que obtemos uma menor raiz quadrada média do erro com o otimizador ADAM na rede com 2 camadas. Dessa forma, seguiremos utilizando esse modelo para as próximas análises.

Análise 4 (Taxa de Aprendizagem)

Taxa de Aprendizado: 0.001

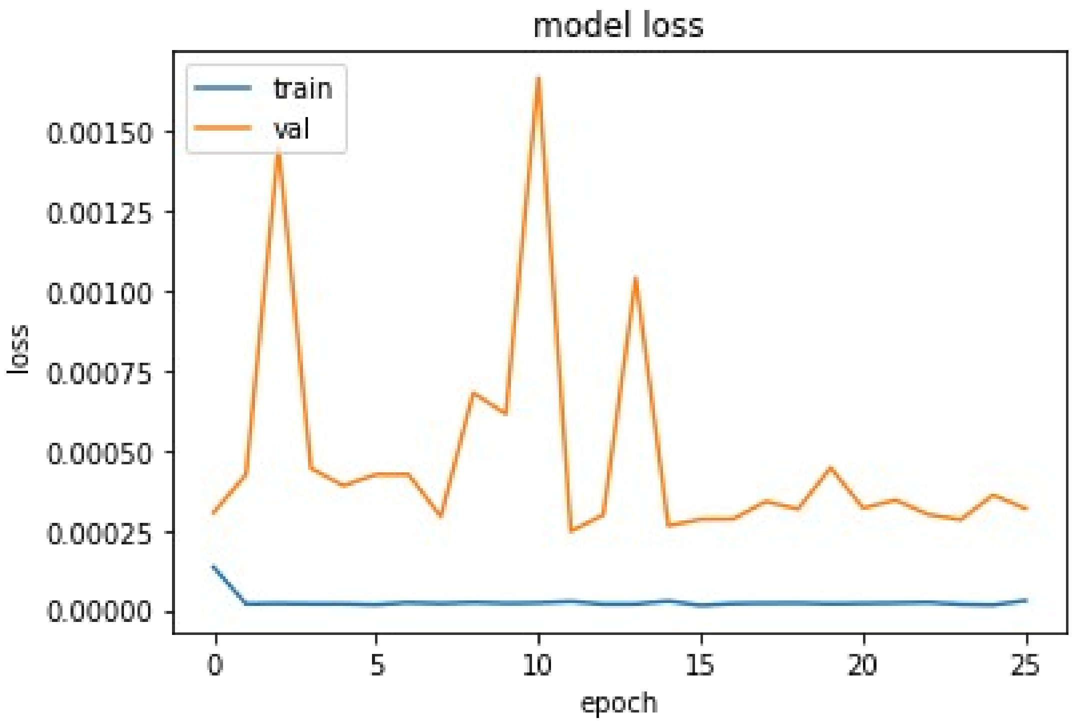
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 5s 47ms/step - loss: 1.3493e-
04 - val_loss: 3.0589e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9596e-
05 - val_loss: 4.2482e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0957e-
05 - val_loss: 0.0015
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9518e-
05 - val_loss: 4.4432e-04
Epoch 5/30
41/41 [==============================] - 1s 29ms/step - loss: 1.9673e-
05 - val_loss: 3.8975e-04
Epoch 6/30
41/41 [==============================] - 1s 31ms/step - loss: 1.6987e-
05 - val_loss: 4.2484e-04
Epoch 7/30
41/41 [==============================] - 1s 31ms/step - loss: 2.3838e-
05 - val_loss: 4.2534e-04
Epoch 8/30
```

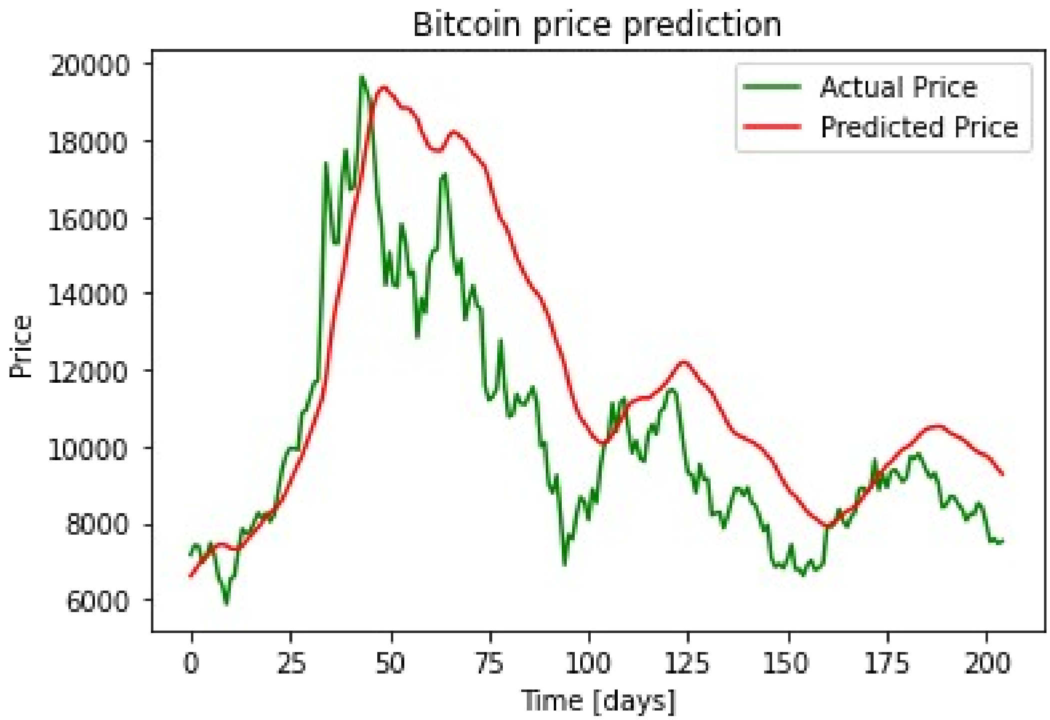
```
41/41 [==============================] - 1s 27ms/step - loss: 2.0860e-
05 - val_loss: 2.9327e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.4452e-
05 - val_loss: 6.8013e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1487e-
05 - val_loss: 6.1389e-04
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2771e-
05 - val_loss: 0.0017
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 2.7492e-
05 - val_loss: 2.4704e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8789e-
05 - val_loss: 2.9859e-04
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9013e-
05 - val_loss: 0.0010
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 2.8886e-
05 - val_loss: 2.6419e-04
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 1.4519e-
05 - val_loss: 2.8456e-04
Epoch 17/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0841e-
05 - val_loss: 2.8540e-04
Epoch 18/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1853e-
05 - val_loss: 3.4035e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2428e-
05 - val_loss: 3.1666e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0013e-
05 - val_loss: 4.4616e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1293e-
05 - val_loss: 3.1974e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2536e-
05 - val_loss: 3.4482e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.4530e-
05 - val_loss: 2.9991e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8198e-
05 - val_loss: 2.8306e-04
```

```
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6215e-
05 - val_loss: 3.6062e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0032e-
05 - val_loss: 3.1808e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 22ms/step
26/26 [==============================] - 0s 13ms/step
Train Score: 0.0020 RMSE
Test Score: 0.0288 RMSE
```



Taxa de Aprendizado: 0.00075

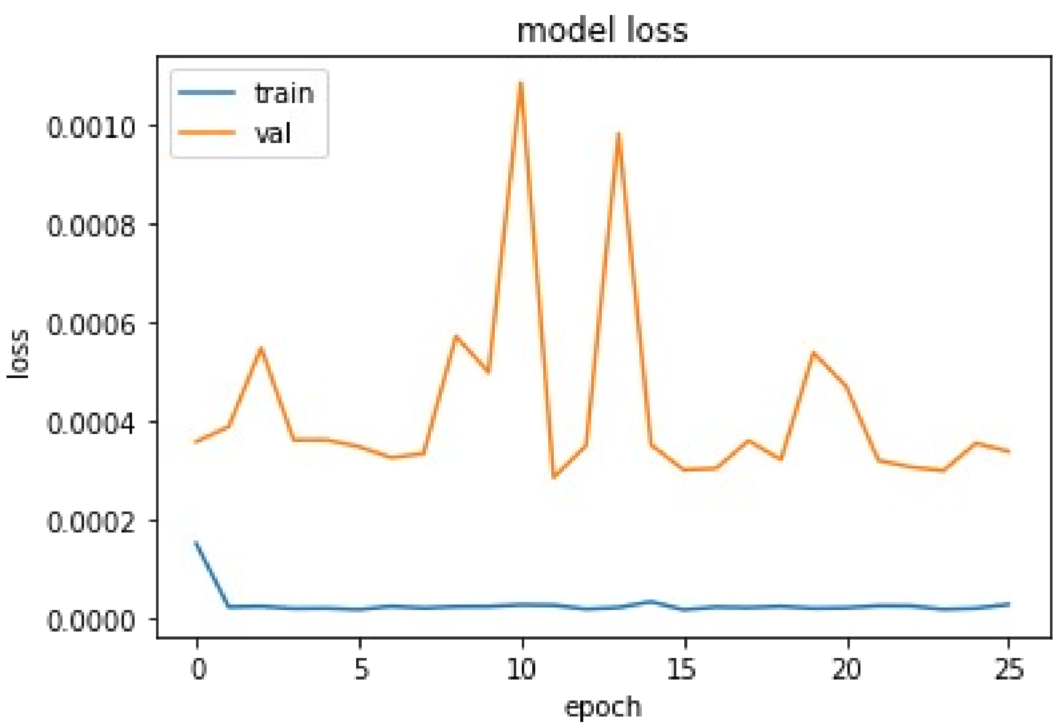
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate =
LEARNING_RATE*0.75),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 7s 49ms/step - loss: 1.4978e-
04 - val_loss: 3.5713e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0652e-
05 - val_loss: 3.8746e-04
```

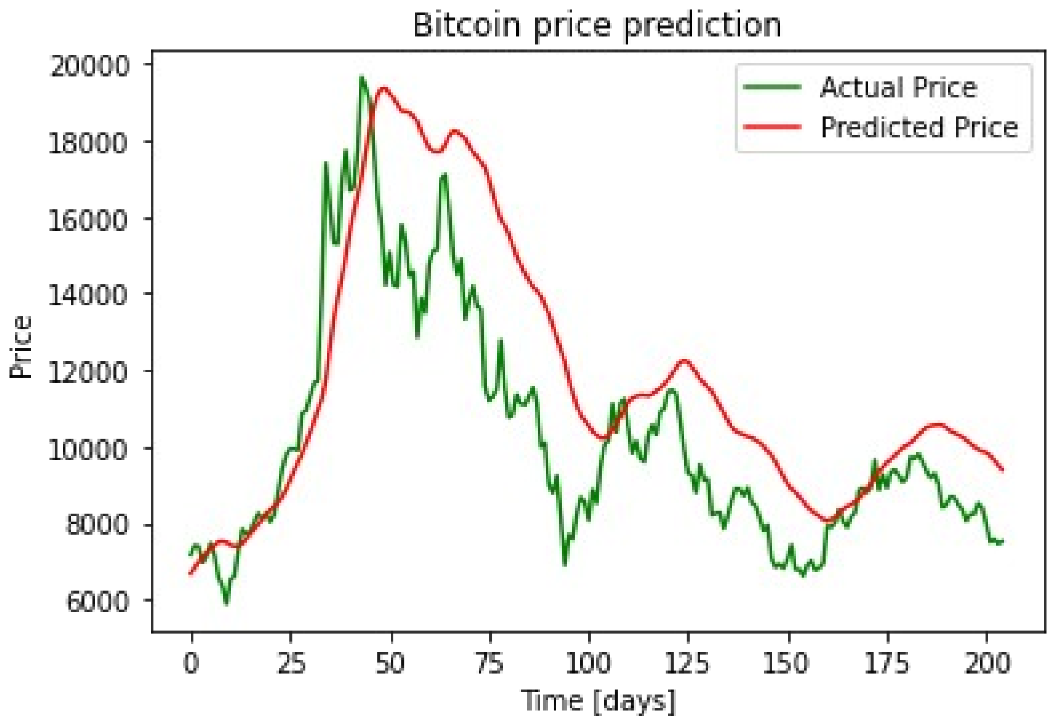
```
Epoch 3/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1944e-
05 - val_loss: 5.4779e-04
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7431e-
05 - val_loss: 3.6059e-04
Epoch 5/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8171e-
05 - val_loss: 3.6084e-04
Epoch 6/30
41/41 [==============================] - 1s 29ms/step - loss: 1.5317e-
05 - val_loss: 3.4729e-04
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1963e-
05 - val_loss: 3.2476e-04
Epoch 8/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8500e-
05 - val_loss: 3.3271e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1379e-
05 - val_loss: 5.7123e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1589e-
05 - val_loss: 4.9826e-04
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5154e-
05 - val_loss: 0.0011
Epoch 12/30
41/41 [==============================] - 1s 28ms/step - loss: 2.4375e-
05 - val_loss: 2.8431e-04
Epoch 13/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6298e-
05 - val_loss: 3.4924e-04
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9526e-
05 - val_loss: 9.8400e-04
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 3.1361e-
05 - val_loss: 3.5081e-04
Epoch 16/30
41/41 [==============================] - 1s 28ms/step - loss: 1.4968e-
05 - val_loss: 2.9984e-04
Epoch 17/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0474e-
05 - val_loss: 3.0263e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9218e-
05 - val_loss: 3.5909e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1849e-
```

```
05 - val_loss: 3.2058e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7916e-
05 - val_loss: 5.3790e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8930e-
05 - val_loss: 4.7059e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.3055e-
05 - val_loss: 3.1894e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2783e-
05 - val_loss: 3.0547e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5761e-
05 - val_loss: 2.9807e-04
Epoch 25/30
41/41 [==============================] - 1s 28ms/step - loss: 1.8005e-
05 - val_loss: 3.5397e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5799e-
05 - val_loss: 3.3739e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```



```
7/7 [==============================] - 1s 22ms/step
26/26 [==============================] - 0s 17ms/step
Train Score: 0.0000 RMSE
Test Score: 0.0250 RMSE
```



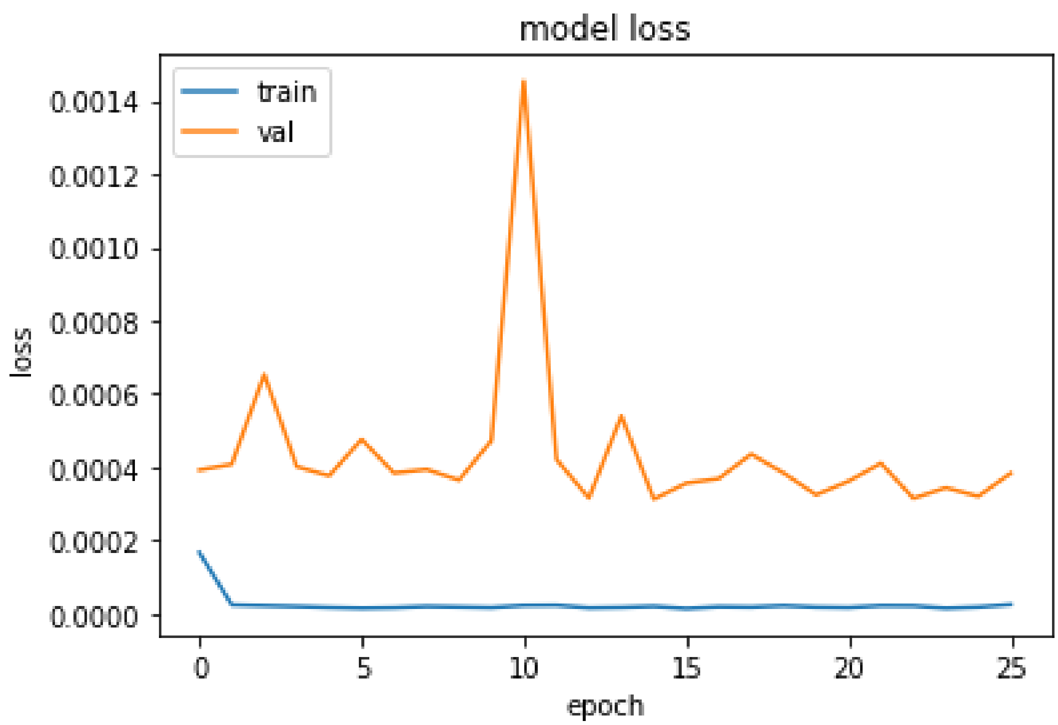
Taxa de Aprendizado: 0.0005

```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate =
LEARNING_RATE*0.5),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

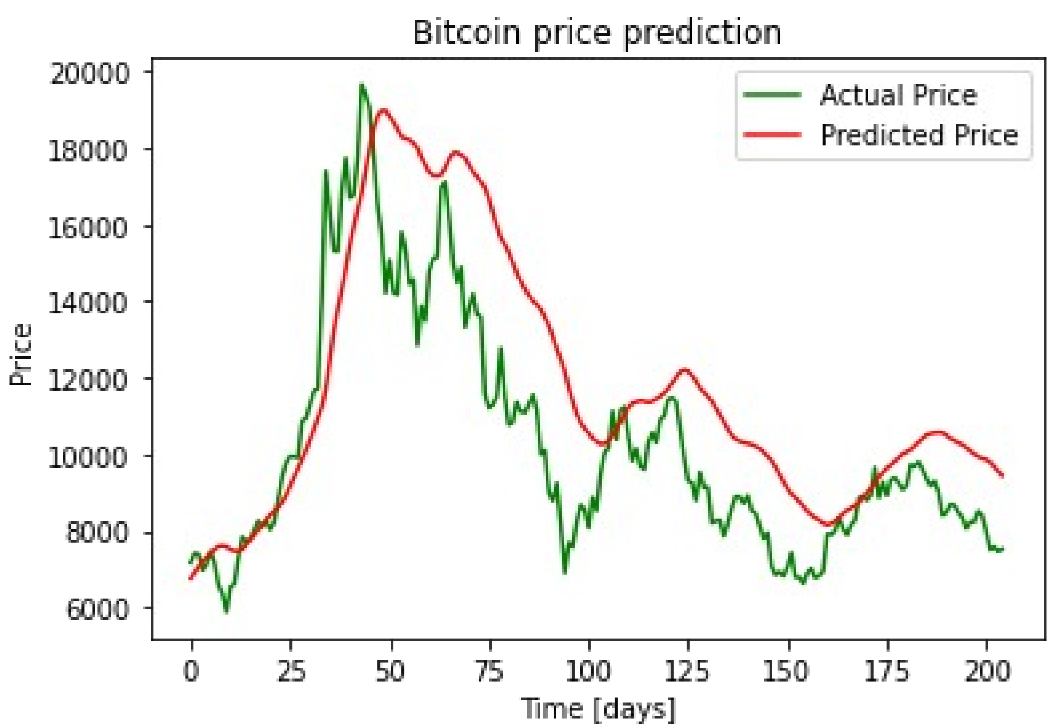
```
Epoch 1/30
41/41 [==============================] - 6s 51ms/step - loss: 1.6721e-
04 - val_loss: 3.9274e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 2.4307e-
05 - val_loss: 4.0824e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2235e-
05 - val_loss: 6.5347e-04
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0053e-
05 - val_loss: 4.0204e-04
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7322e-
05 - val_loss: 3.7695e-04
Epoch 6/30
41/41 [==============================] - 1s 28ms/step - loss: 1.5281e-
05 - val_loss: 4.7567e-04
Epoch 7/30
41/41 [==============================] - 1s 29ms/step - loss: 1.6688e-
05 - val_loss: 3.8450e-04
Epoch 8/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0201e-
05 - val_loss: 3.9446e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8599e-
05 - val_loss: 3.6522e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6962e-
05 - val_loss: 4.7226e-04
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2885e-
05 - val_loss: 0.0015
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 2.3410e-
05 - val_loss: 4.2170e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6183e-
05 - val_loss: 3.1590e-04
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7499e-
05 - val_loss: 5.3998e-04
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0451e-
05 - val_loss: 3.1319e-04
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 1.4170e-
05 - val_loss: 3.5675e-04
Epoch 17/30
41/41 [==============================] - 1s 29ms/step - loss: 1.9320e-
```

```
05 - val_loss: 3.6916e-04
Epoch 18/30
41/41 [==============================] - 1s 29ms/step - loss: 1.8263e-
05 - val_loss: 4.3563e-04
Epoch 19/30
41/41 [==============================] - 1s 28ms/step - loss: 2.2218e-
05 - val_loss: 3.8457e-04
Epoch 20/30
41/41 [==============================] - 1s 29ms/step - loss: 1.8168e-
05 - val_loss: 3.2488e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7003e-
05 - val_loss: 3.6197e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2267e-
05 - val_loss: 4.1112e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1815e-
05 - val_loss: 3.1544e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5157e-
05 - val_loss: 3.4416e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8428e-
05 - val_loss: 3.2091e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5388e-
05 - val_loss: 3.8403e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 12ms/step
Train Score: 0.0006 RMSE
Test Score: 0.0213 RMSE
```



Taxa de Aprendizado: 0.00025

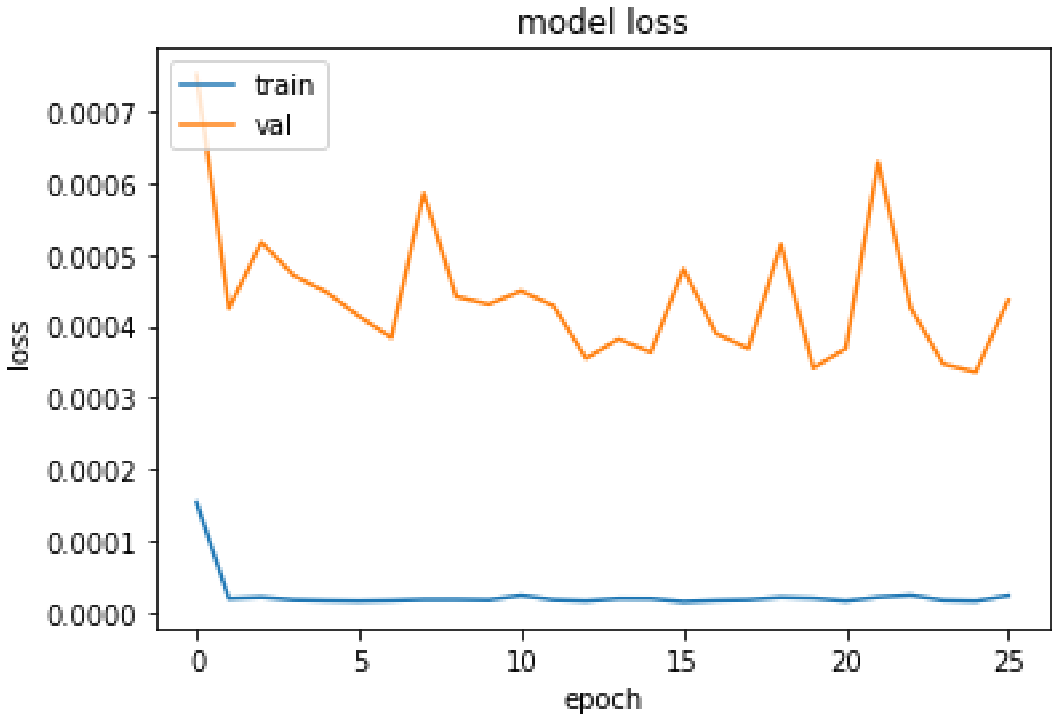
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate =
LEARNING_RATE*0.25),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 6s 47ms/step - loss: 1.5395e-
04 - val_loss: 7.5242e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8855e-
05 - val_loss: 4.2541e-04
Epoch 3/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0716e-
05 - val_loss: 5.1731e-04
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7048e-
05 - val_loss: 4.7111e-04
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6085e-
05 - val_loss: 4.4811e-04
Epoch 6/30
41/41 [==============================] - 1s 28ms/step - loss: 1.5443e-
05 - val_loss: 4.1440e-04
Epoch 7/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6230e-
05 - val_loss: 3.8434e-04
Epoch 8/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7702e-
05 - val_loss: 5.8582e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7736e-
05 - val_loss: 4.4171e-04
Epoch 10/30
```

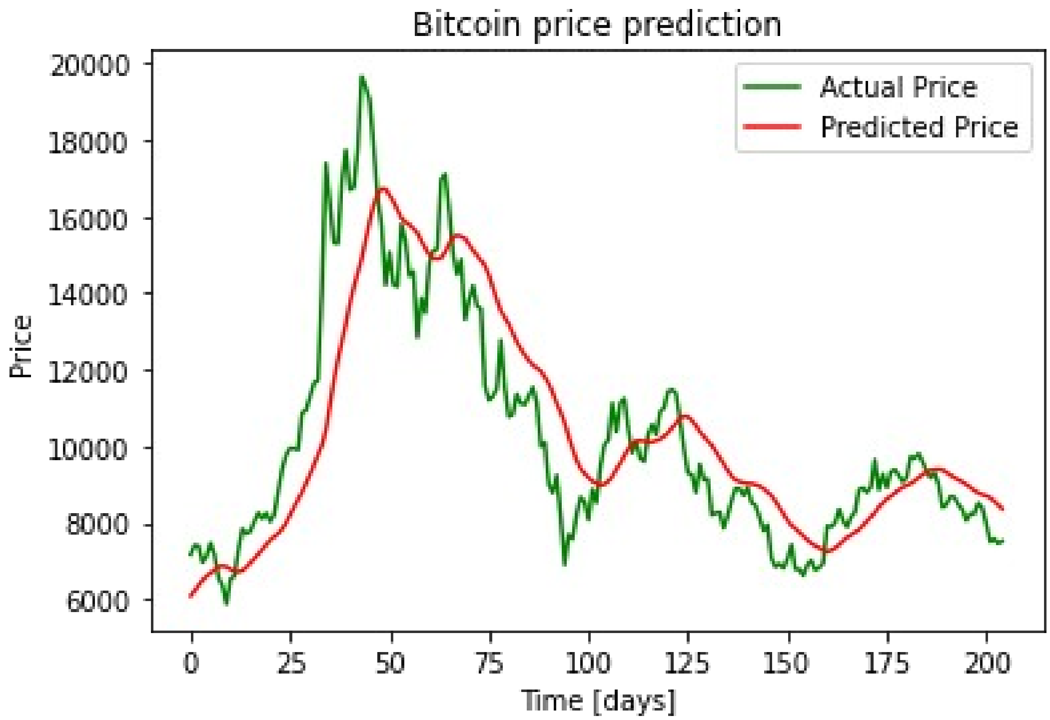
```
41/41 [==============================] - 1s 26ms/step - loss: 1.7067e-
05 - val_loss: 4.3090e-04
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.3137e-
05 - val_loss: 4.4951e-04
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7142e-
05 - val_loss: 4.2875e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5588e-
05 - val_loss: 3.5498e-04
Epoch 14/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8928e-
05 - val_loss: 3.8231e-04
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8786e-
05 - val_loss: 3.6365e-04
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 1.4391e-
05 - val_loss: 4.8070e-04
Epoch 17/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6273e-
05 - val_loss: 3.9011e-04
Epoch 18/30
41/41 [==============================] - 1s 28ms/step - loss: 1.7252e-
05 - val_loss: 3.6883e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0558e-
05 - val_loss: 5.1471e-04
Epoch 20/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9346e-
05 - val_loss: 3.4175e-04
Epoch 21/30
41/41 [==============================] - 1s 26ms/step - loss: 1.5588e-
05 - val_loss: 3.6903e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0782e-
05 - val_loss: 6.2971e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.3498e-
05 - val_loss: 4.2591e-04
Epoch 24/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6449e-
05 - val_loss: 3.4743e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5422e-
05 - val_loss: 3.3586e-04
Epoch 26/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2863e-
```

```
05 - val_loss: 4.3654e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0009 RMSE
Test Score: 0.0554 RMSE
```



Taxa de Aprendizado: 0.0001

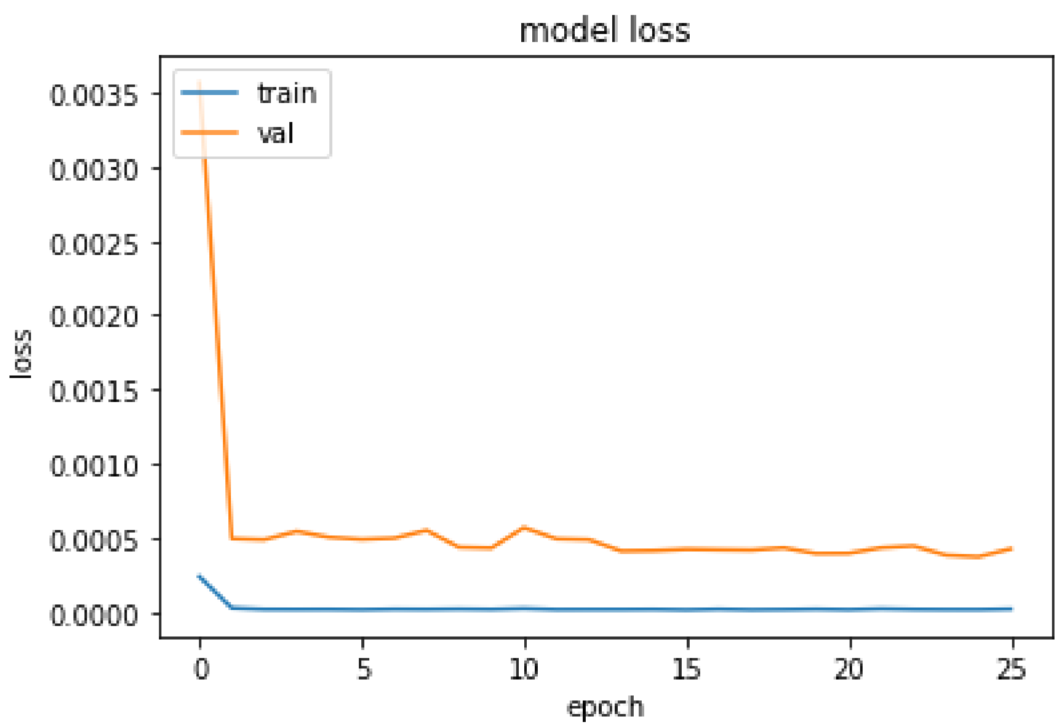
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate =
LEARNING_RATE*0.1),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 6s 47ms/step - loss: 2.3826e-
04 - val_loss: 0.0036
Epoch 2/30
41/41 [==============================] - 1s 26ms/step - loss: 2.5195e-
05 - val_loss: 4.9329e-04
```

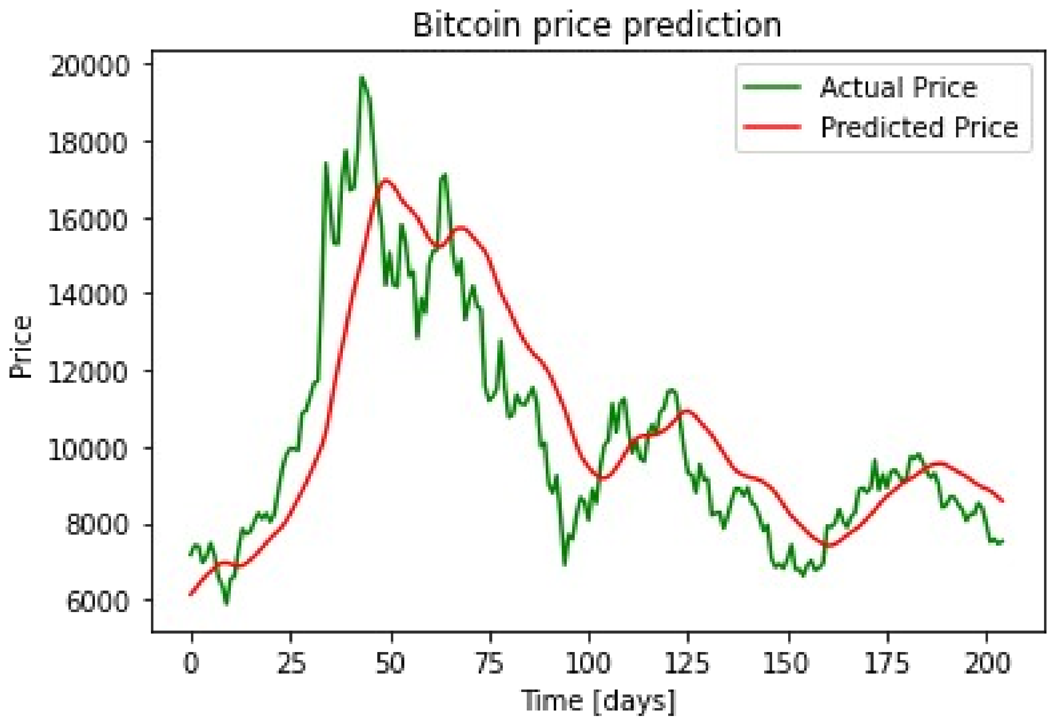
```
Epoch 3/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6881e-
05 - val_loss: 4.8666e-04
Epoch 4/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6512e-
05 - val_loss: 5.4236e-04
Epoch 5/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6774e-
05 - val_loss: 5.0289e-04
Epoch 6/30
41/41 [==============================] - 1s 27ms/step - loss: 1.4783e-
05 - val_loss: 4.8874e-04
Epoch 7/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7868e-
05 - val_loss: 4.9652e-04
Epoch 8/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6989e-
05 - val_loss: 5.4923e-04
Epoch 9/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8804e-
05 - val_loss: 4.3539e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6821e-
05 - val_loss: 4.3033e-04
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2007e-
05 - val_loss: 5.6763e-04
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5529e-
05 - val_loss: 4.9198e-04
Epoch 13/30
41/41 [==============================] - 1s 26ms/step - loss: 1.5808e-
05 - val_loss: 4.8680e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5938e-
05 - val_loss: 4.0939e-04
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 1.6908e-
05 - val_loss: 4.1223e-04
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 1.3563e-
05 - val_loss: 4.2223e-04
Epoch 17/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7953e-
05 - val_loss: 4.1895e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 1.4033e-
05 - val_loss: 4.1634e-04
Epoch 19/30
41/41 [==============================] - 1s 28ms/step - loss: 1.5597e-
```

```
05 - val_loss: 4.3131e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8101e-
05 - val_loss: 3.9327e-04
Epoch 21/30
41/41 [==============================] - 1s 26ms/step - loss: 1.4885e-
05 - val_loss: 3.9440e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0419e-
05 - val_loss: 4.3190e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6781e-
05 - val_loss: 4.4411e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5414e-
05 - val_loss: 3.8204e-04
Epoch 25/30
41/41 [==============================] - 1s 26ms/step - loss: 1.5187e-
05 - val_loss: 3.7097e-04
Epoch 26/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8814e-
05 - val_loss: 4.2459e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```



```
7/7 [==============================] - 1s 21ms/step
26/26 [==============================] - 0s 13ms/step
Train Score: 0.0016 RMSE
Test Score: 0.0528 RMSE
```



Continuidade

Observando o RMSE de teste e treinamento, para evitar overfitting, utilizaremos o learning rate 0,001 nas próximas análises.

Análise 5 (Dropout)

Dropout: 0.1

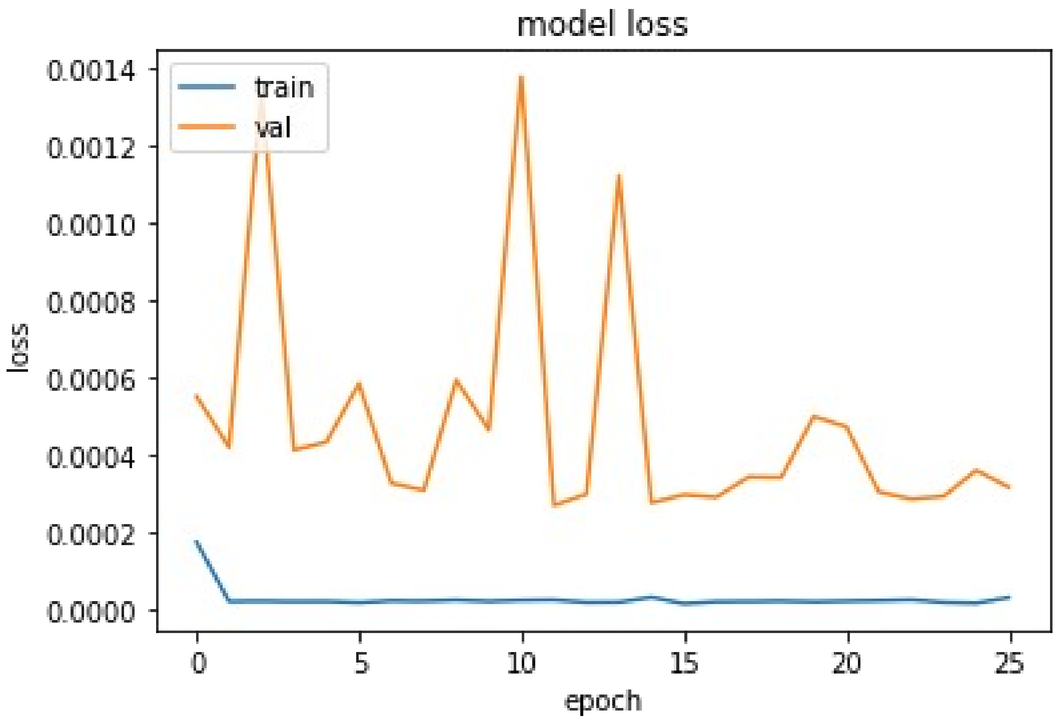
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
```

```
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

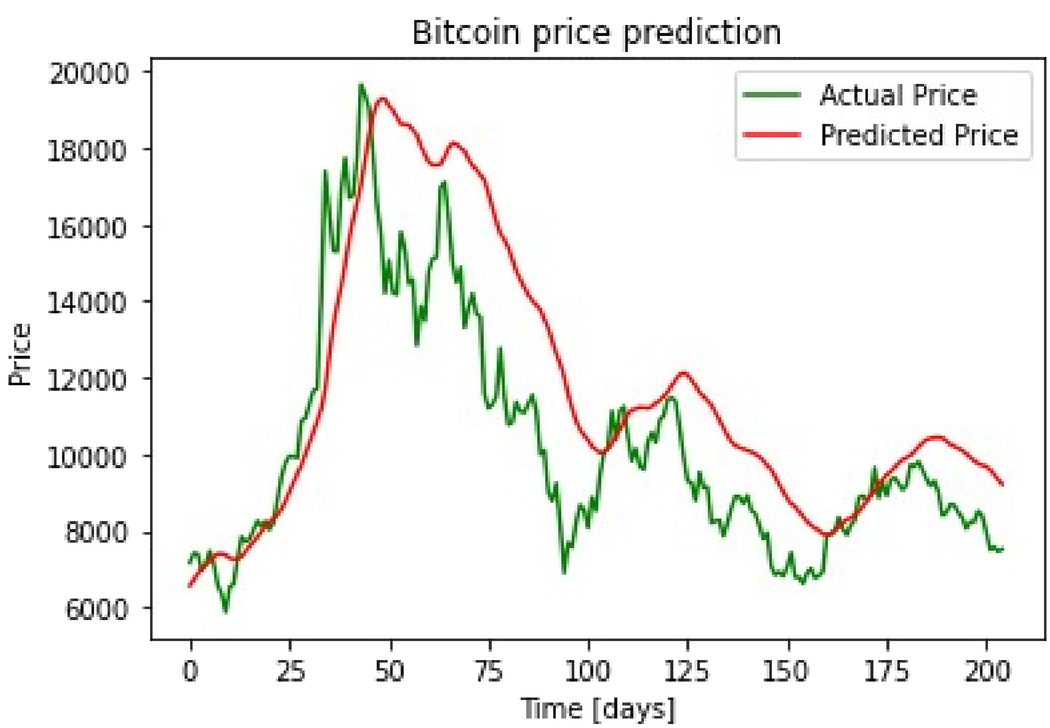
```
Epoch 1/30
41/41 [==============================] - 6s 47ms/step - loss: 1.7401e-
04 - val_loss: 5.4991e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0553e-
05 - val_loss: 4.1826e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1231e-
05 - val_loss: 0.0013
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0233e-
05 - val_loss: 4.1109e-04
Epoch 5/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0627e-
05 - val_loss: 4.3191e-04
Epoch 6/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7297e-
05 - val_loss: 5.8285e-04
Epoch 7/30
41/41 [==============================] - 1s 28ms/step - loss: 2.2040e-
05 - val_loss: 3.2571e-04
Epoch 8/30
41/41 [==============================] - 1s 29ms/step - loss: 2.1192e-
05 - val_loss: 3.0797e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.4141e-
05 - val_loss: 5.9160e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0618e-
05 - val_loss: 4.6348e-04
Epoch 11/30
41/41 [==============================] - 1s 26ms/step - loss: 2.3520e-
05 - val_loss: 0.0014
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 2.4480e-
05 - val_loss: 2.6856e-04
Epoch 13/30
41/41 [==============================] - 1s 26ms/step - loss: 1.7913e-
05 - val_loss: 2.9772e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8350e-
05 - val_loss: 0.0011
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 3.1336e-
05 - val_loss: 2.7517e-04
```

```
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 1.4575e-
05 - val_loss: 2.9626e-04
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9758e-
05 - val_loss: 2.8978e-04
Epoch 18/30
41/41 [==============================] - 1s 28ms/step - loss: 2.0375e-
05 - val_loss: 3.4249e-04
Epoch 19/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1359e-
05 - val_loss: 3.4110e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9655e-
05 - val_loss: 4.9816e-04
Epoch 21/30
41/41 [==============================] - 1s 31ms/step - loss: 2.1245e-
05 - val_loss: 4.7152e-04
Epoch 22/30
41/41 [==============================] - 1s 29ms/step - loss: 2.2529e-
05 - val_loss: 3.0345e-04
Epoch 23/30
41/41 [==============================] - 1s 30ms/step - loss: 2.4700e-
05 - val_loss: 2.8516e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7995e-
05 - val_loss: 2.9209e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.5997e-
05 - val_loss: 3.5908e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0442e-
05 - val_loss: 3.1582e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 12ms/step
Train Score: 0.0017 RMSE
Test Score: 0.0307 RMSE
```



Dropout: 0.2

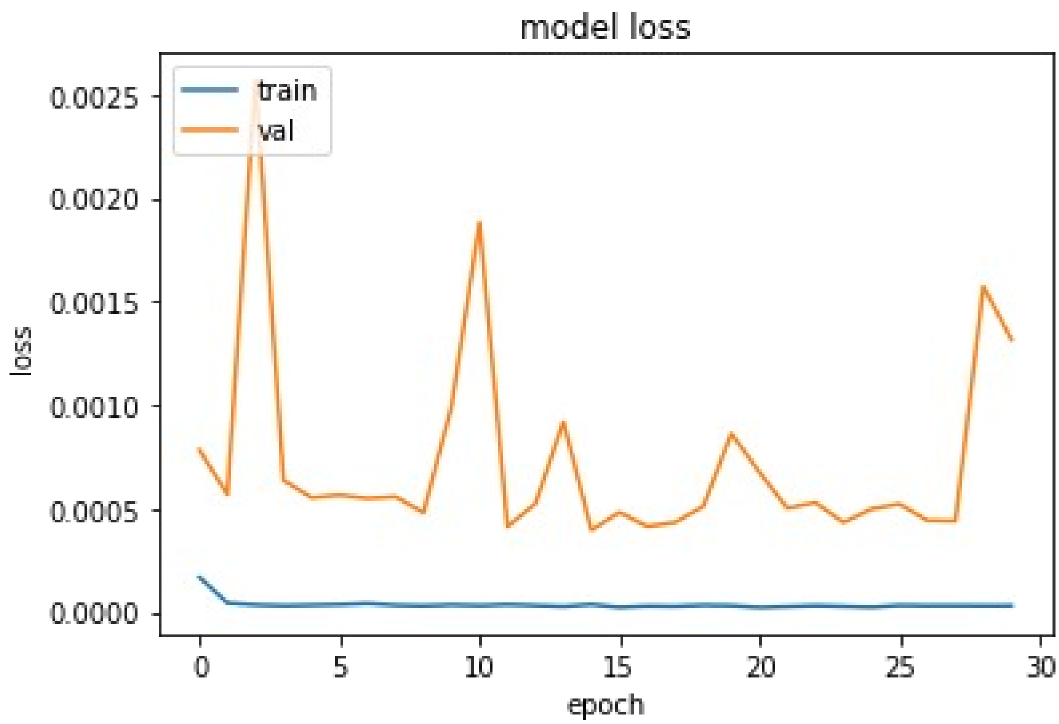
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT*2, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 6s 49ms/step - loss: 1.6796e-
04 - val_loss: 7.8196e-04
Epoch 2/30
41/41 [==============================] - 1s 26ms/step - loss: 4.3660e-
05 - val_loss: 5.6842e-04
Epoch 3/30
41/41 [==============================] - 1s 27ms/step - loss: 3.4101e-
05 - val_loss: 0.0026
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0254e-
05 - val_loss: 6.3638e-04
Epoch 5/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2855e-
05 - val_loss: 5.5301e-04
Epoch 6/30
41/41 [==============================] - 1s 27ms/step - loss: 3.5605e-
05 - val_loss: 5.6519e-04
Epoch 7/30
41/41 [==============================] - 1s 29ms/step - loss: 4.1372e-
05 - val_loss: 5.4933e-04
Epoch 8/30
41/41 [==============================] - 1s 30ms/step - loss: 3.2609e-
05 - val_loss: 5.5771e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9513e-
05 - val_loss: 4.8019e-04
Epoch 10/30
41/41 [==============================] - 1s 27ms/step - loss: 3.4266e-
```

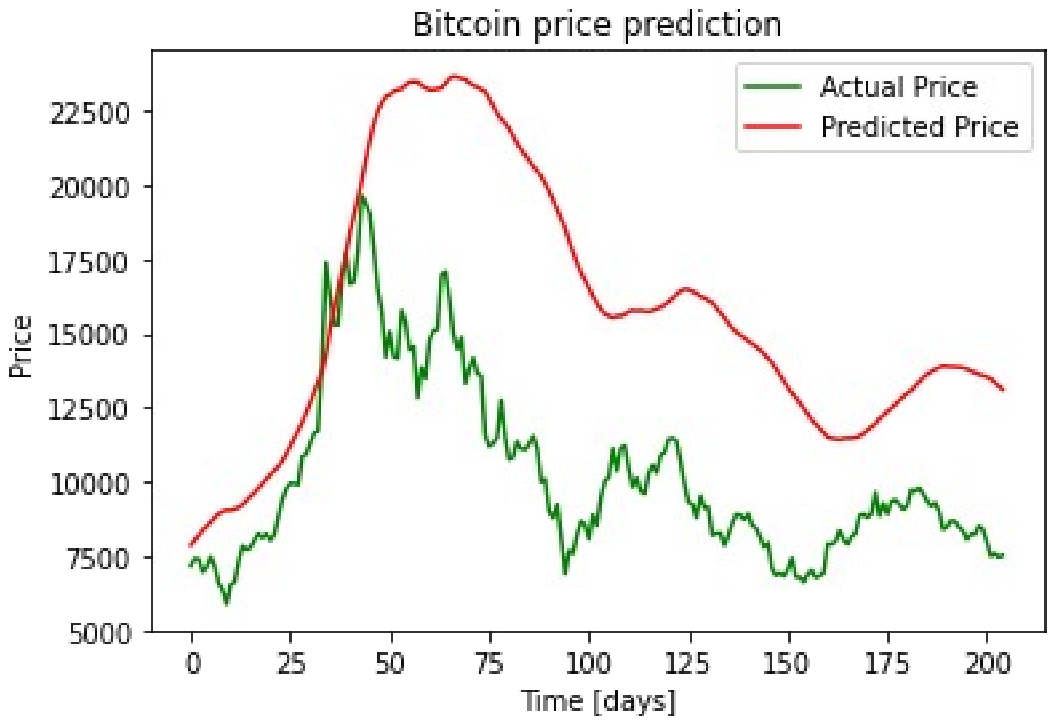
```
05 - val_loss: 9.9092e-04
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0818e-
05 - val_loss: 0.0019
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 3.5771e-
05 - val_loss: 4.1203e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 3.1157e-
05 - val_loss: 5.2391e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6184e-
05 - val_loss: 9.1849e-04
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 3.6345e-
05 - val_loss: 3.9490e-04
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1815e-
05 - val_loss: 4.8221e-04
Epoch 17/30
41/41 [==============================] - 1s 28ms/step - loss: 2.8577e-
05 - val_loss: 4.1341e-04
Epoch 18/30
41/41 [==============================] - 1s 30ms/step - loss: 2.7017e-
05 - val_loss: 4.3326e-04
Epoch 19/30
41/41 [==============================] - 1s 30ms/step - loss: 3.2696e-
05 - val_loss: 5.1104e-04
Epoch 20/30
41/41 [==============================] - 1s 28ms/step - loss: 3.0696e-
05 - val_loss: 8.6104e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1117e-
05 - val_loss: 6.7644e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5851e-
05 - val_loss: 5.0173e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0301e-
05 - val_loss: 5.2880e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6769e-
05 - val_loss: 4.3255e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2290e-
05 - val_loss: 4.9777e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2051e-
05 - val_loss: 5.2200e-04
Epoch 27/30
```

```
41/41 [==============================] - 1s 27ms/step - loss: 3.0346e-
05 - val_loss: 4.4188e-04
Epoch 28/30
41/41 [==============================] - 1s 28ms/step - loss: 3.0632e-
05 - val_loss: 4.3952e-04
Epoch 29/30
41/41 [==============================] - 1s 28ms/step - loss: 2.9670e-
05 - val_loss: 0.0016
Epoch 30/30
41/41 [==============================] - 1s 29ms/step - loss: 2.9959e-
05 - val_loss: 0.0013
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 21ms/step
26/26 [==============================] - 0s 16ms/step
Train Score: 0.0006 RMSE
Test Score: 0.0356 RMSE
```



Dropout: 0.3

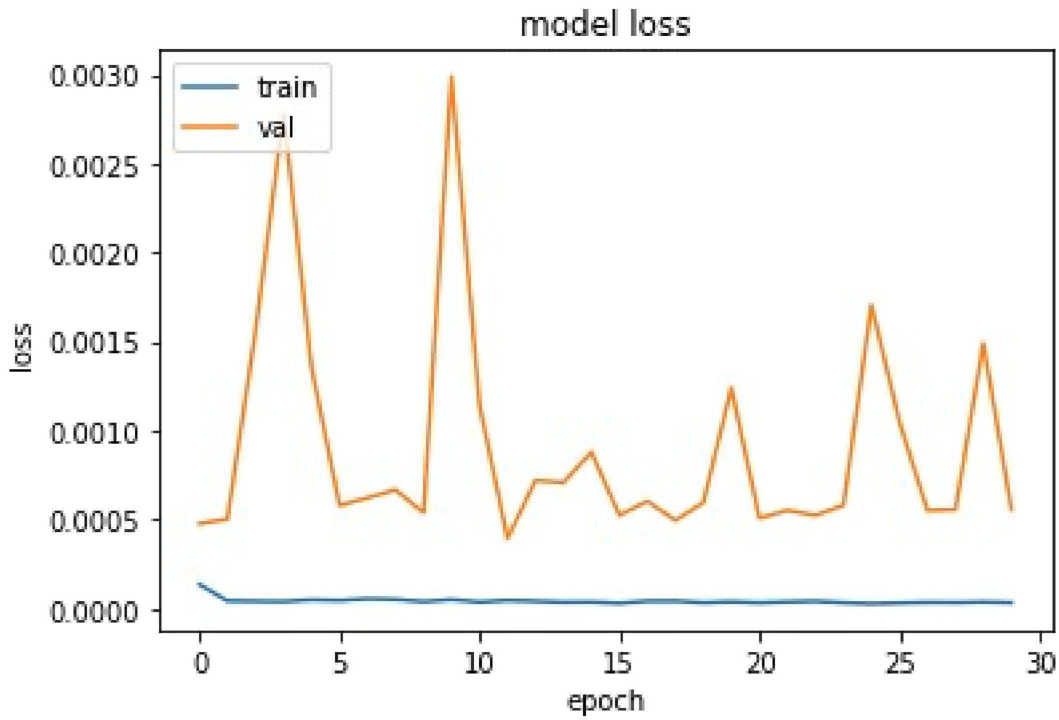
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT*3, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 7s 52ms/step - loss: 1.3537e-
04 - val_loss: 4.7734e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 4.3130e-
05 - val_loss: 5.0296e-04
Epoch 3/30
```

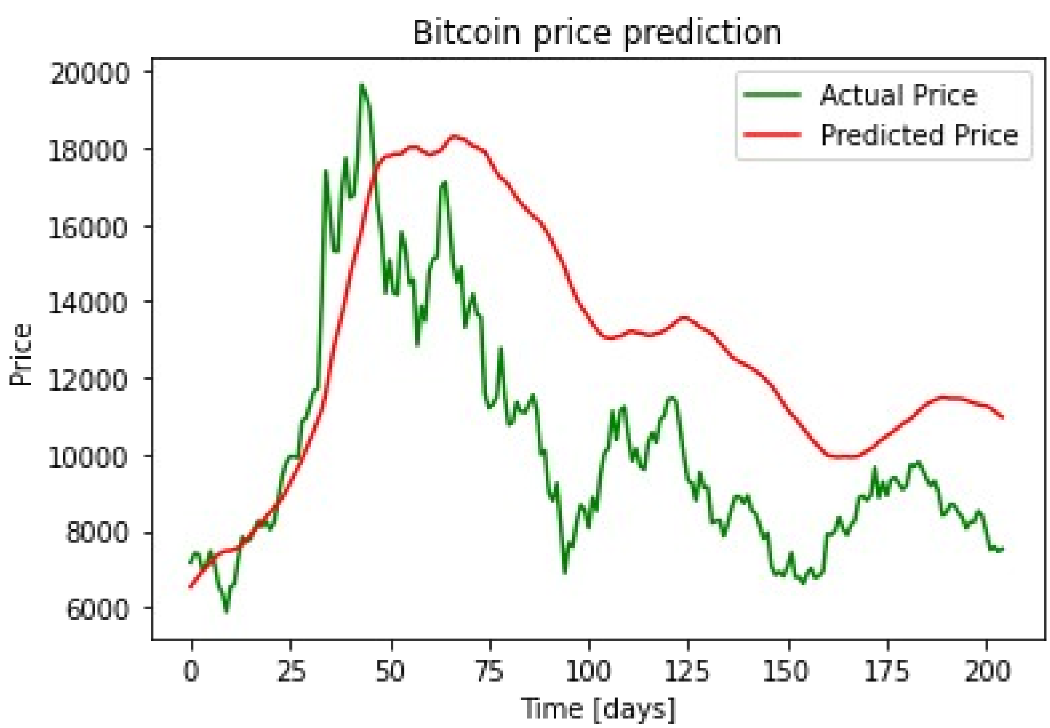
```
41/41 [==============================] - 1s 27ms/step - loss: 4.1173e-
05 - val_loss: 0.0016
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 3.9583e-
05 - val_loss: 0.0028
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 4.9154e-
05 - val_loss: 0.0014
Epoch 6/30
41/41 [==============================] - 1s 27ms/step - loss: 4.5440e-
05 - val_loss: 5.8002e-04
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 5.5224e-
05 - val_loss: 6.2242e-04
Epoch 8/30
41/41 [==============================] - 1s 28ms/step - loss: 5.1538e-
05 - val_loss: 6.6707e-04
Epoch 9/30
41/41 [==============================] - 1s 28ms/step - loss: 3.8544e-
05 - val_loss: 5.3938e-04
Epoch 10/30
41/41 [==============================] - 1s 29ms/step - loss: 5.0560e-
05 - val_loss: 0.0030
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 3.6163e-
05 - val_loss: 0.0011
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 4.5916e-
05 - val_loss: 3.9398e-04
Epoch 13/30
41/41 [==============================] - 1s 26ms/step - loss: 4.0842e-
05 - val_loss: 7.2009e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 3.5420e-
05 - val_loss: 7.0901e-04
Epoch 15/30
41/41 [==============================] - 1s 26ms/step - loss: 3.6497e-
05 - val_loss: 8.7826e-04
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 2.9644e-
05 - val_loss: 5.2492e-04
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 4.1734e-
05 - val_loss: 6.0375e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 4.2263e-
05 - val_loss: 4.9568e-04
Epoch 19/30
41/41 [==============================] - 1s 28ms/step - loss: 3.2722e-
05 - val_loss: 5.9582e-04
```

```
Epoch 20/30
41/41 [==============================] - 1s 29ms/step - loss: 3.8179e-
05 - val_loss: 0.0012
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2154e-
05 - val_loss: 5.0864e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 3.7497e-
05 - val_loss: 5.5217e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 4.1010e-
05 - val_loss: 5.2463e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 3.2481e-
05 - val_loss: 5.8044e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 2.7292e-
05 - val_loss: 0.0017
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0930e-
05 - val_loss: 0.0010
Epoch 27/30
41/41 [==============================] - 1s 28ms/step - loss: 3.4575e-
05 - val_loss: 5.5184e-04
Epoch 28/30
41/41 [==============================] - 1s 27ms/step - loss: 3.3317e-
05 - val_loss: 5.5670e-04
Epoch 29/30
41/41 [==============================] - 1s 27ms/step - loss: 3.6874e-
05 - val_loss: 0.0015
Epoch 30/30
41/41 [==============================] - 1s 29ms/step - loss: 3.3155e-
05 - val_loss: 5.5759e-04
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 12ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0026 RMSE
Test Score: 0.0323 RMSE
```



Dropout: 0.4

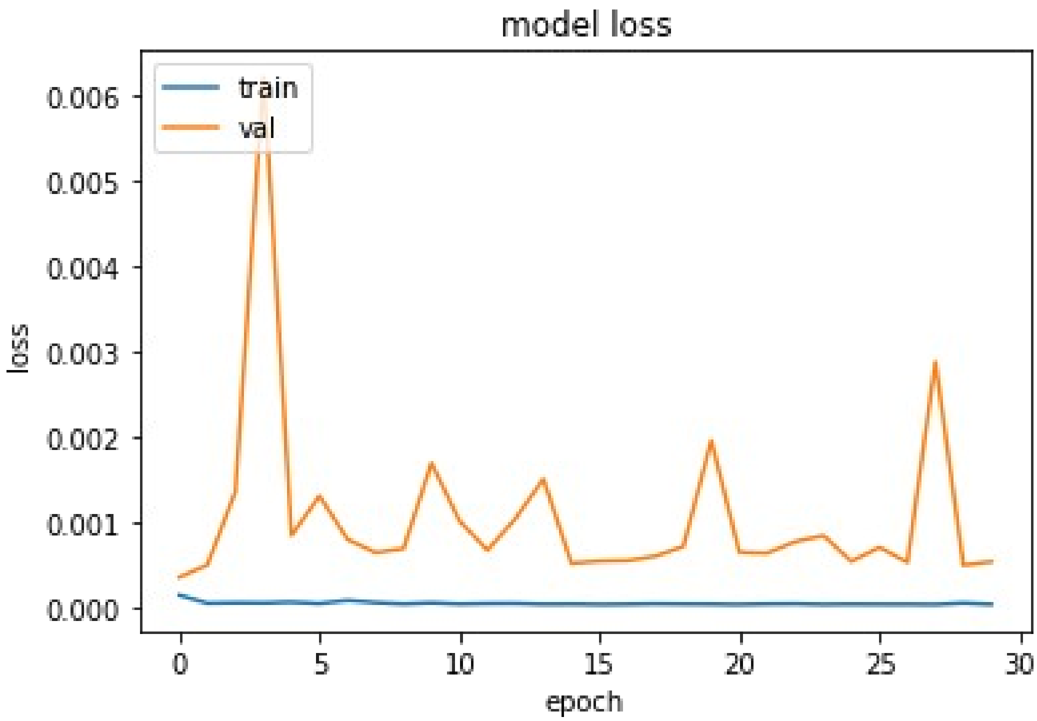
```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT*4, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 7s 51ms/step - loss: 1.4888e-
04 - val_loss: 3.5905e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 5.4365e-
05 - val_loss: 5.0390e-04
Epoch 3/30
41/41 [==============================] - 1s 29ms/step - loss: 5.9662e-
05 - val_loss: 0.0014
Epoch 4/30
41/41 [==============================] - 1s 30ms/step - loss: 5.7642e-
05 - val_loss: 0.0062
Epoch 5/30
41/41 [==============================] - 1s 28ms/step - loss: 6.8195e-
05 - val_loss: 8.5023e-04
Epoch 6/30
41/41 [==============================] - 1s 31ms/step - loss: 5.0349e-
05 - val_loss: 0.0013
Epoch 7/30
41/41 [==============================] - 1s 32ms/step - loss: 8.8054e-
05 - val_loss: 8.0257e-04
Epoch 8/30
41/41 [==============================] - 1s 28ms/step - loss: 6.2470e-
05 - val_loss: 6.4824e-04
Epoch 9/30
41/41 [==============================] - 1s 27ms/step - loss: 4.5646e-
05 - val_loss: 6.9258e-04
Epoch 10/30
41/41 [==============================] - 1s 27ms/step - loss: 6.0000e-
```

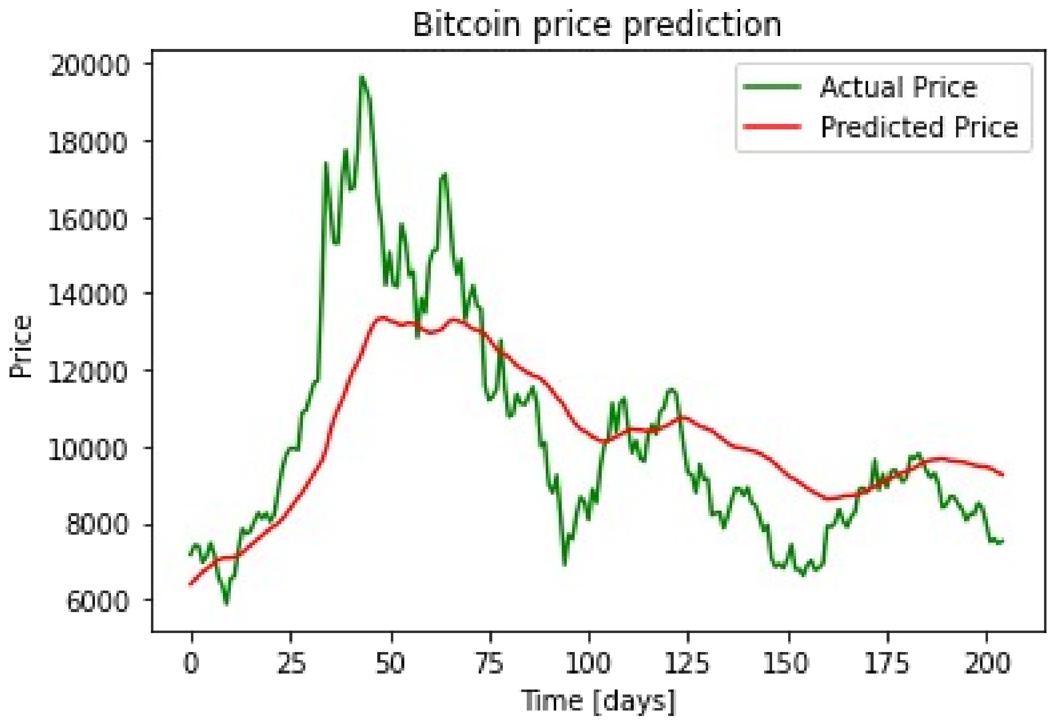
```
05 - val_loss: 0.0017
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 4.4966e-
05 - val_loss: 0.0010
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 5.1522e-
05 - val_loss: 6.7642e-04
Epoch 13/30
41/41 [==============================] - 1s 28ms/step - loss: 5.2600e-
05 - val_loss: 0.0010
Epoch 14/30
41/41 [==============================] - 1s 30ms/step - loss: 4.2260e-
05 - val_loss: 0.0015
Epoch 15/30
41/41 [==============================] - 1s 29ms/step - loss: 4.3967e-
05 - val_loss: 5.2261e-04
Epoch 16/30
41/41 [==============================] - 1s 27ms/step - loss: 3.9312e-
05 - val_loss: 5.4781e-04
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 4.2219e-
05 - val_loss: 5.5306e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 4.7927e-
05 - val_loss: 6.0544e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 4.4708e-
05 - val_loss: 7.1920e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 4.3425e-
05 - val_loss: 0.0020
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 3.9050e-
05 - val_loss: 6.5116e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 4.5708e-
05 - val_loss: 6.4176e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 4.8008e-
05 - val_loss: 7.7565e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 3.9638e-
05 - val_loss: 8.4709e-04
Epoch 25/30
41/41 [==============================] - 1s 29ms/step - loss: 4.2631e-
05 - val_loss: 5.4500e-04
Epoch 26/30
41/41 [==============================] - 1s 28ms/step - loss: 4.1222e-
05 - val_loss: 7.0908e-04
Epoch 27/30
```

```
41/41 [==============================] - 1s 27ms/step - loss: 4.1471e-
05 - val_loss: 5.3348e-04
Epoch 28/30
41/41 [==============================] - 1s 27ms/step - loss: 3.8312e-
05 - val_loss: 0.0029
Epoch 29/30
41/41 [==============================] - 1s 27ms/step - loss: 5.7558e-
05 - val_loss: 5.0023e-04
Epoch 30/30
41/41 [==============================] - 1s 27ms/step - loss: 4.0786e-
05 - val_loss: 5.4159e-04
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 23ms/step
26/26 [==============================] - 0s 17ms/step
Train Score: 0.0039 RMSE
Test Score: 0.0393 RMSE
```



Continuidade

Considerando essas análises, utilizaremos o valor de dropout de 10%, já que observamos um baixo RMSE tanto para o treinamento $(0{,}0017)$ quanto para os testes $(0{,}0307)$.

Análise 6 (Batch Size)

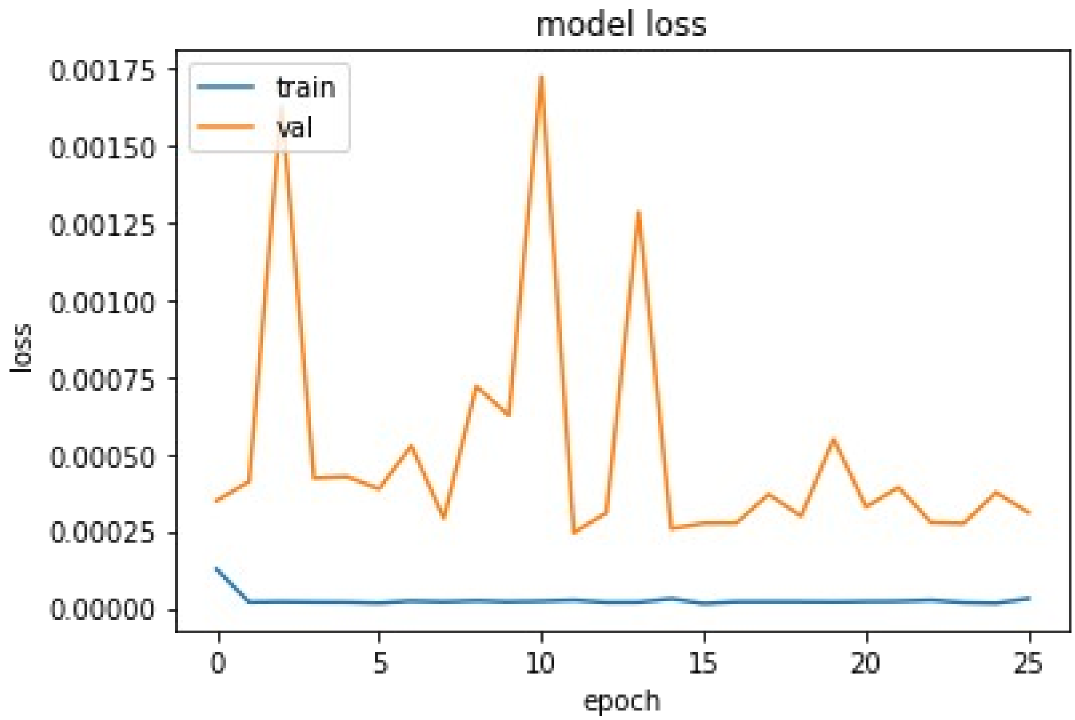
Batch Size: 16

```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

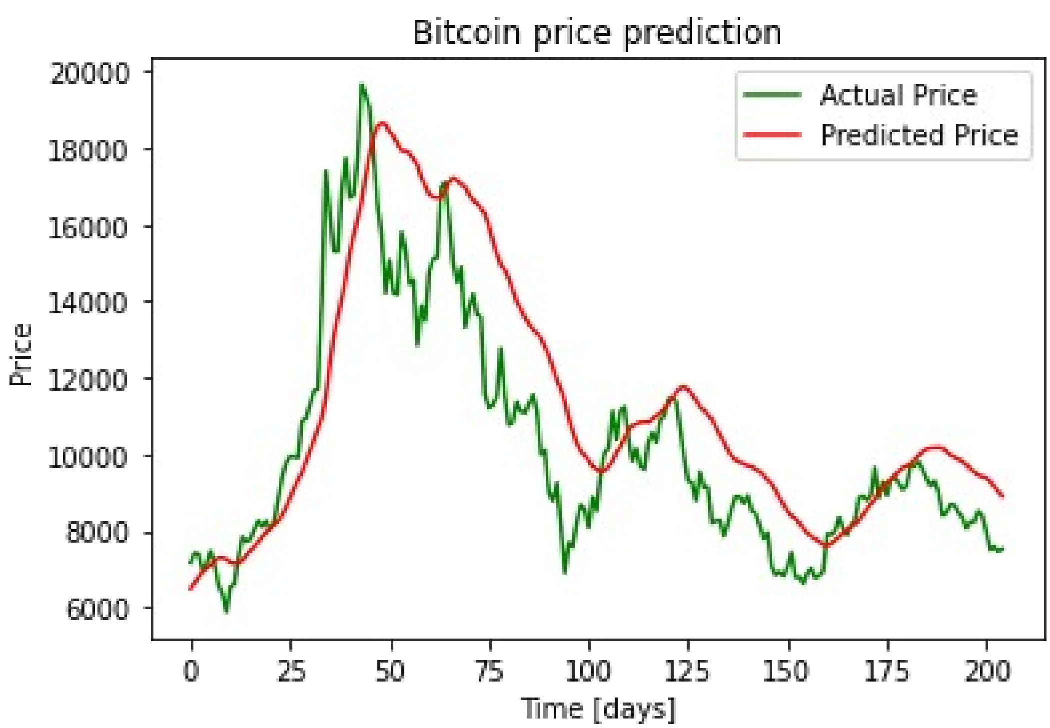
```
Epoch 1/30
41/41 [==============================] - 6s 48ms/step - loss: 1.2653e-
04 - val_loss: 3.4805e-04
Epoch 2/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9951e-
05 - val_loss: 4.0972e-04
Epoch 3/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1283e-
05 - val_loss: 0.0016
Epoch 4/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0024e-
05 - val_loss: 4.2090e-04
Epoch 5/30
41/41 [==============================] - 1s 28ms/step - loss: 1.9780e-
05 - val_loss: 4.2650e-04
Epoch 6/30
41/41 [==============================] - 1s 28ms/step - loss: 1.6865e-
05 - val_loss: 3.8597e-04
Epoch 7/30
41/41 [==============================] - 1s 27ms/step - loss: 2.3880e-
05 - val_loss: 5.2547e-04
Epoch 8/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1029e-
05 - val_loss: 2.9087e-04
Epoch 9/30
41/41 [==============================] - 1s 26ms/step - loss: 2.4428e-
05 - val_loss: 7.1788e-04
Epoch 10/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1167e-
05 - val_loss: 6.2378e-04
Epoch 11/30
41/41 [==============================] - 1s 27ms/step - loss: 2.3010e-
05 - val_loss: 0.0017
Epoch 12/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6575e-
05 - val_loss: 2.4449e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9155e-
05 - val_loss: 3.0893e-04
Epoch 14/30
41/41 [==============================] - 1s 29ms/step - loss: 1.9486e-
05 - val_loss: 0.0013
Epoch 15/30
41/41 [==============================] - 1s 28ms/step - loss: 3.1158e-
05 - val_loss: 2.5768e-04
Epoch 16/30
41/41 [==============================] - 1s 28ms/step - loss: 1.4965e-
05 - val_loss: 2.7517e-04
Epoch 17/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1314e-
```

```
05 - val_loss: 2.7561e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1493e-
05 - val_loss: 3.6872e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1173e-
05 - val_loss: 2.9799e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0434e-
05 - val_loss: 5.4800e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1973e-
05 - val_loss: 3.2782e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2709e-
05 - val_loss: 3.9117e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.6432e-
05 - val_loss: 2.7717e-04
Epoch 24/30
41/41 [==============================] - 1s 27ms/step - loss: 1.8469e-
05 - val_loss: 2.7442e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6379e-
05 - val_loss: 3.7463e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.1575e-
05 - val_loss: 3.0966e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 12ms/step
26/26 [==============================] - 0s 12ms/step
Train Score: 0.0024 RMSE
Test Score: 0.0346 RMSE
```



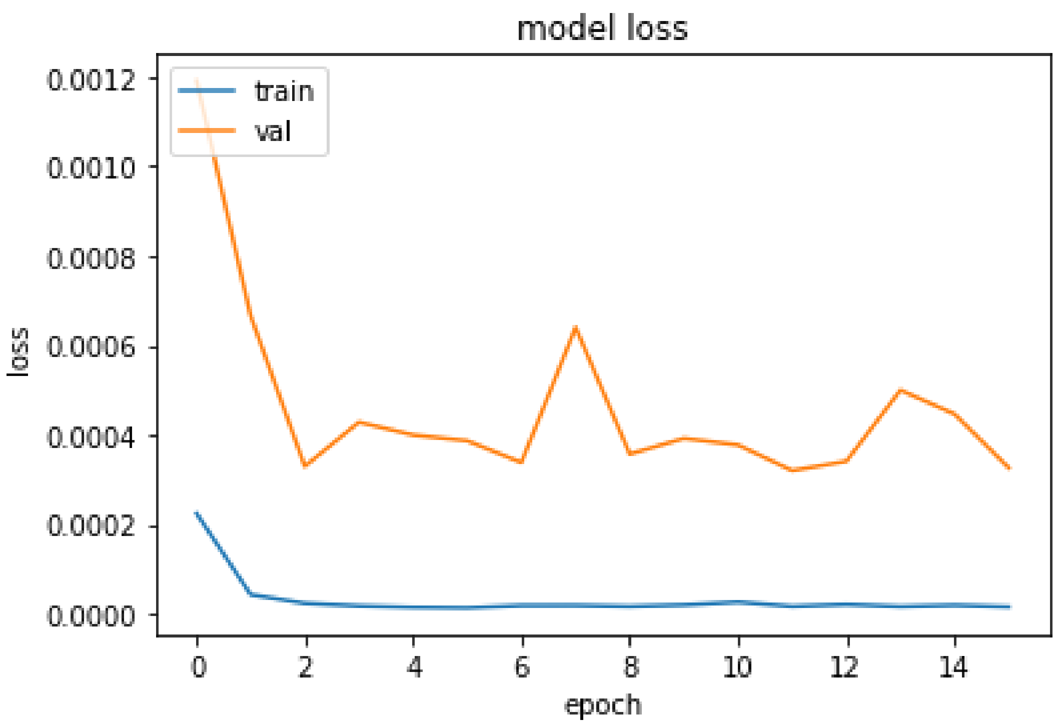
Batch Size: 32

```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE*2,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

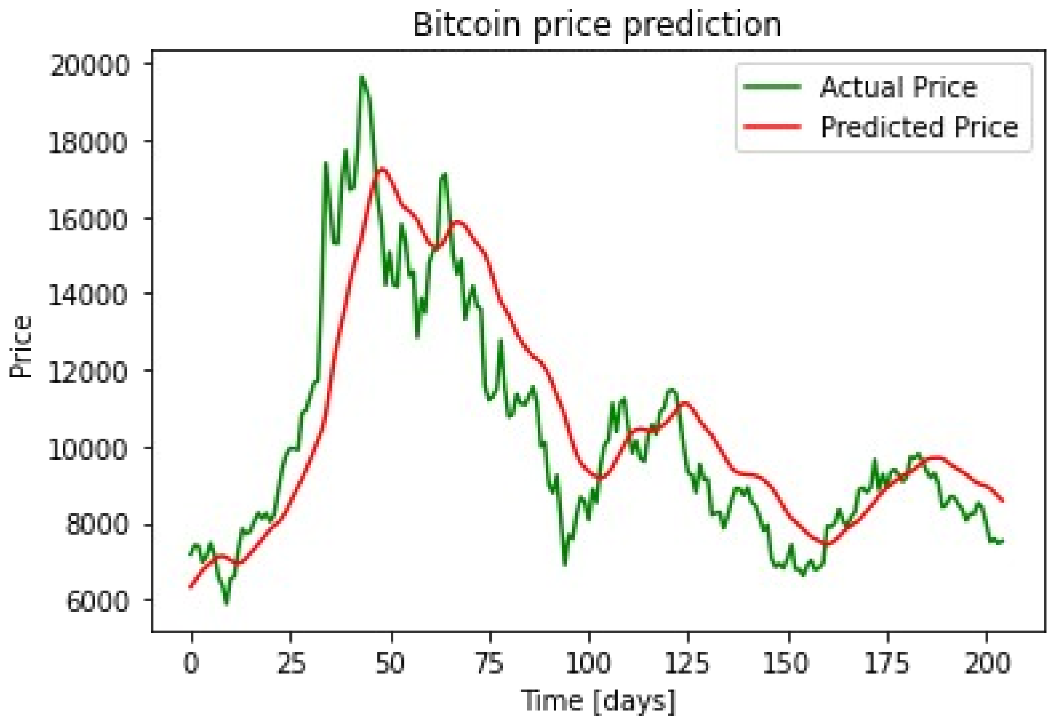
```
Epoch 1/30
21/21 [==============================] - 5s 75ms/step - loss: 2.2466e-
04 - val_loss: 0.0012
Epoch 2/30
21/21 [==============================] - 1s 33ms/step - loss: 4.2957e-
05 - val_loss: 6.6606e-04
Epoch 3/30
21/21 [==============================] - 1s 33ms/step - loss: 2.3603e-
05 - val_loss: 3.2983e-04
Epoch 4/30
21/21 [==============================] - 1s 33ms/step - loss: 1.7639e-
05 - val_loss: 4.2857e-04
Epoch 5/30
21/21 [==============================] - 1s 33ms/step - loss: 1.4691e-
05 - val_loss: 3.9993e-04
Epoch 6/30
21/21 [==============================] - 1s 33ms/step - loss: 1.3524e-
05 - val_loss: 3.8705e-04
Epoch 7/30
21/21 [==============================] - 1s 33ms/step - loss: 1.8555e-
05 - val_loss: 3.3839e-04
Epoch 8/30
21/21 [==============================] - 1s 34ms/step - loss: 1.8680e-
05 - val_loss: 6.4013e-04
Epoch 9/30
21/21 [==============================] - 1s 34ms/step - loss: 1.6564e-
05 - val_loss: 3.5731e-04
Epoch 10/30
21/21 [==============================] - 1s 35ms/step - loss: 1.9740e-
```

```
05 - val_loss: 3.9232e-04
Epoch 11/30
21/21 [==============================] - 1s 34ms/step - loss: 2.6367e-
05 - val_loss: 3.7770e-04
Epoch 12/30
21/21 [==============================] - 1s 33ms/step - loss: 1.6652e-
05 - val_loss: 3.2035e-04
Epoch 13/30
21/21 [==============================] - 1s 33ms/step - loss: 2.0895e-
05 - val_loss: 3.4109e-04
Epoch 14/30
21/21 [==============================] - 1s 33ms/step - loss: 1.6334e-
05 - val_loss: 5.0020e-04
Epoch 15/30
21/21 [==============================] - 1s 33ms/step - loss: 1.9092e-
05 - val_loss: 4.4674e-04
Epoch 16/30
21/21 [==============================] - 1s 37ms/step - loss: 1.5684e-
05 - val_loss: 3.2661e-04
Epoch 16: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 21ms/step
26/26 [==============================] - 0s 14ms/step
Train Score: 0.0010 RMSE
Test Score: 0.0434 RMSE
```



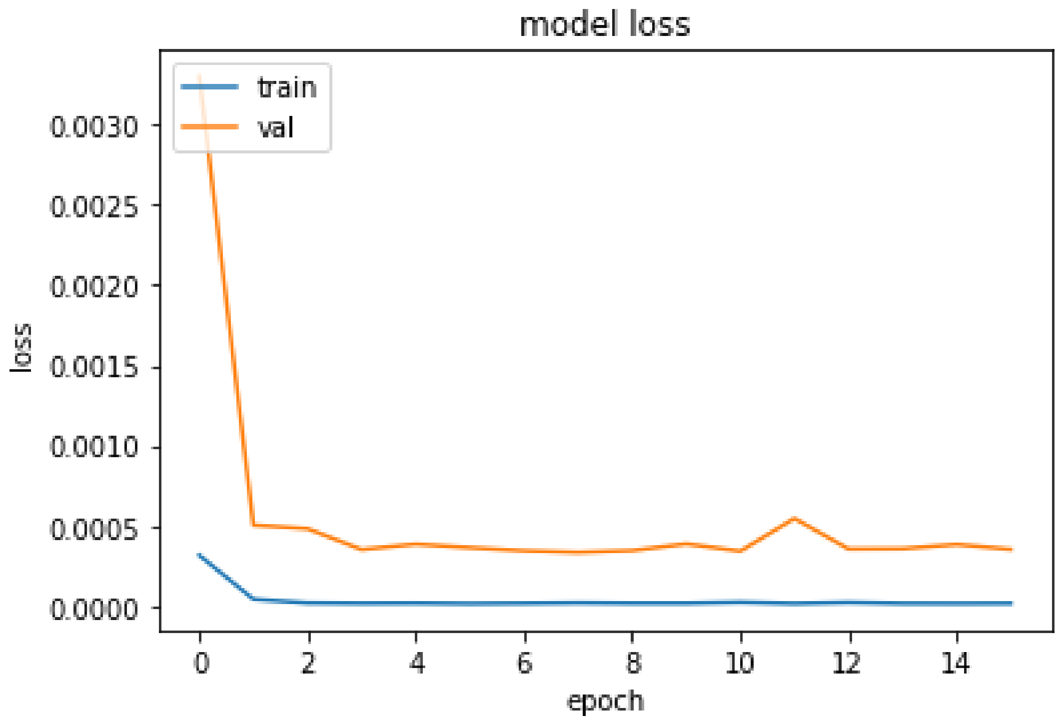
Batch Size: 64

```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE*4,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

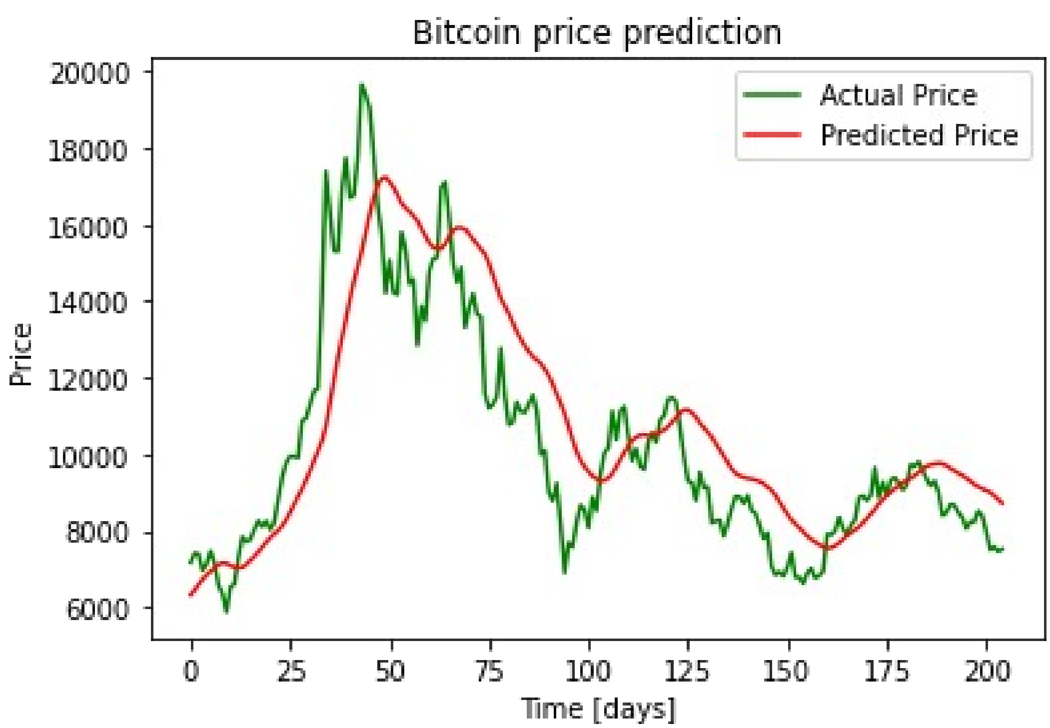
```
Epoch 1/30
11/11 [==============================] - 6s 136ms/step - loss:
3.1587e-04 - val_loss: 0.0033
Epoch 2/30
11/11 [==============================] - 0s 46ms/step - loss: 4.1620e-
05 - val_loss: 5.0383e-04
Epoch 3/30
```

```
11/11 [==============================] - 0s 45ms/step - loss: 1.8361e-
05 - val_loss: 4.8198e-04
Epoch 4/30
11/11 [==============================] - 1s 47ms/step - loss: 1.6085e-
05 - val_loss: 3.5166e-04
Epoch 5/30
11/11 [==============================] - 1s 50ms/step - loss: 1.7078e-
05 - val_loss: 3.8538e-04
Epoch 6/30
11/11 [==============================] - 1s 48ms/step - loss: 1.4036e-
05 - val_loss: 3.6315e-04
Epoch 7/30
11/11 [==============================] - 1s 49ms/step - loss: 1.6056e-
05 - val_loss: 3.4364e-04
Epoch 8/30
11/11 [==============================] - 1s 48ms/step - loss: 1.8942e-
05 - val_loss: 3.3428e-04
Epoch 9/30
11/11 [==============================] - 1s 46ms/step - loss: 1.6597e-
05 - val_loss: 3.4504e-04
Epoch 10/30
11/11 [==============================] - 1s 47ms/step - loss: 1.6576e-
05 - val_loss: 3.8694e-04
Epoch 11/30
11/11 [==============================] - 1s 48ms/step - loss: 2.2724e-
05 - val_loss: 3.4150e-04
Epoch 12/30
11/11 [==============================] - 1s 49ms/step - loss: 1.4709e-
05 - val_loss: 5.4607e-04
Epoch 13/30
11/11 [==============================] - 1s 49ms/step - loss: 2.1404e-
05 - val_loss: 3.5549e-04
Epoch 14/30
11/11 [==============================] - 1s 48ms/step - loss: 1.5311e-
05 - val_loss: 3.5685e-04
Epoch 15/30
11/11 [==============================] - 1s 46ms/step - loss: 1.4812e-
05 - val_loss: 3.8336e-04
Epoch 16/30
11/11 [==============================] - 1s 47ms/step - loss: 1.5688e-
05 - val_loss: 3.5278e-04
Epoch 16: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0022 RMSE
Test Score: 0.0434 RMSE
```



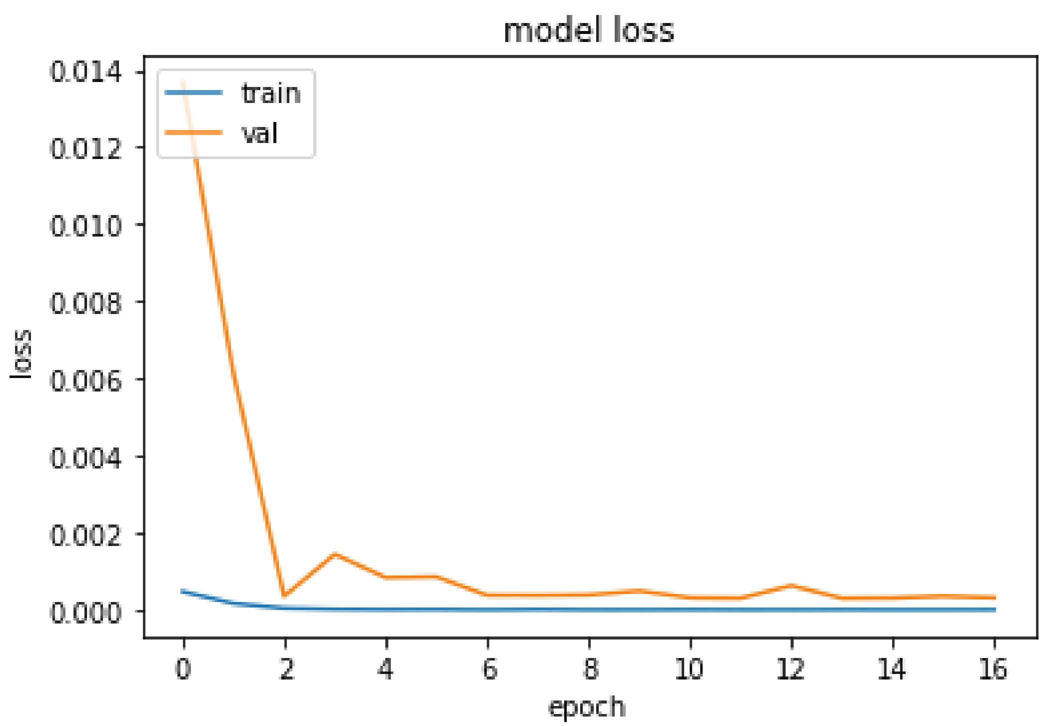
Batch Size: 128

```
model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(time_steps, input_shape=(time_steps,
X_train.shape[-1]), dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(time_steps, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE*8,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

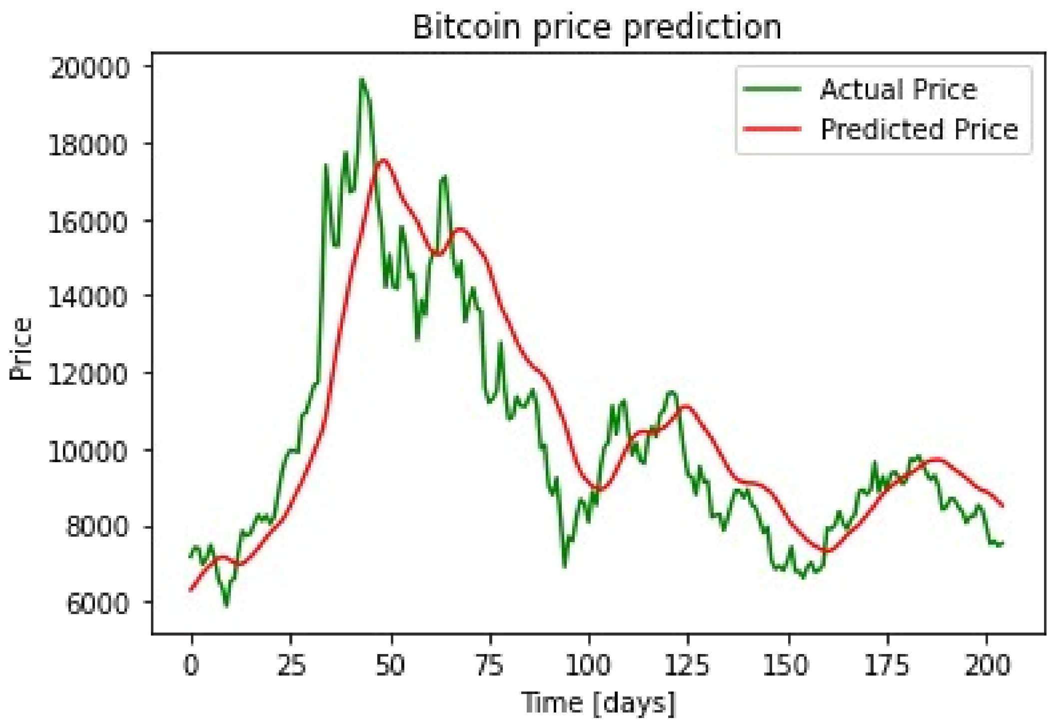
```
Epoch 1/30
6/6 [==============================] - 5s 296ms/step - loss: 4.8593e-
04 - val_loss: 0.0137
Epoch 2/30
6/6 [==============================] - 0s 77ms/step - loss: 1.8026e-04
- val_loss: 0.0061
Epoch 3/30
6/6 [==============================] - 0s 75ms/step - loss: 5.5321e-05
- val_loss: 3.6662e-04
Epoch 4/30
6/6 [==============================] - 0s 72ms/step - loss: 3.1434e-05
- val_loss: 0.0015
Epoch 5/30
6/6 [==============================] - 0s 71ms/step - loss: 2.2521e-05
- val_loss: 8.5220e-04
Epoch 6/30
6/6 [==============================] - 0s 76ms/step - loss: 2.5095e-05
- val_loss: 8.7103e-04
Epoch 7/30
6/6 [==============================] - 0s 77ms/step - loss: 1.6094e-05
- val_loss: 3.9221e-04
Epoch 8/30
6/6 [==============================] - 0s 73ms/step - loss: 2.5482e-05
- val_loss: 3.8857e-04
Epoch 9/30
6/6 [==============================] - 0s 73ms/step - loss: 1.7047e-05
- val_loss: 3.9910e-04
Epoch 10/30
6/6 [==============================] - 0s 73ms/step - loss: 1.6220e-05
```

```
- val_loss: 5.0256e-04
Epoch 11/30
6/6 [==============================] - 0s 72ms/step - loss: 2.0959e-05
- val_loss: 3.2712e-04
Epoch 12/30
6/6 [==============================] - 0s 72ms/step - loss: 1.6846e-05
- val_loss: 3.1626e-04
Epoch 13/30
6/6 [==============================] - 0s 77ms/step - loss: 1.6276e-05
- val_loss: 6.4190e-04
Epoch 14/30
6/6 [==============================] - 0s 73ms/step - loss: 2.0155e-05
- val_loss: 3.1491e-04
Epoch 15/30
6/6 [==============================] - 0s 77ms/step - loss: 1.6670e-05
- val_loss: 3.2195e-04
Epoch 16/30
6/6 [==============================] - 0s 77ms/step - loss: 1.7525e-05
- val_loss: 3.6745e-04
Epoch 17/30
6/6 [==============================] - 0s 76ms/step - loss: 1.9048e-05
- val_loss: 3.2933e-04
Epoch 17: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```



```
7/7 [==============================] - 1s 11ms/step
26/26 [==============================] - 0s 11ms/step
Train Score: 0.0002 RMSE
Test Score: 0.0445 RMSE
```



Continuidade

Observando os resultados encontrados, o batch size de tamanho 16 já é suficiente.

Análise 7 (Tamanho da Janela)

Nesta análise, testamos diferentes tamanhos de janela variando a quantidade de dias anteriores a serem utilizados na previsão. Para isso, utilizamos os parâmetros que consideramos melhores nas análises anteriores.

Tamanho da Janela: 50

```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=50)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(50, input_shape=(50, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
```

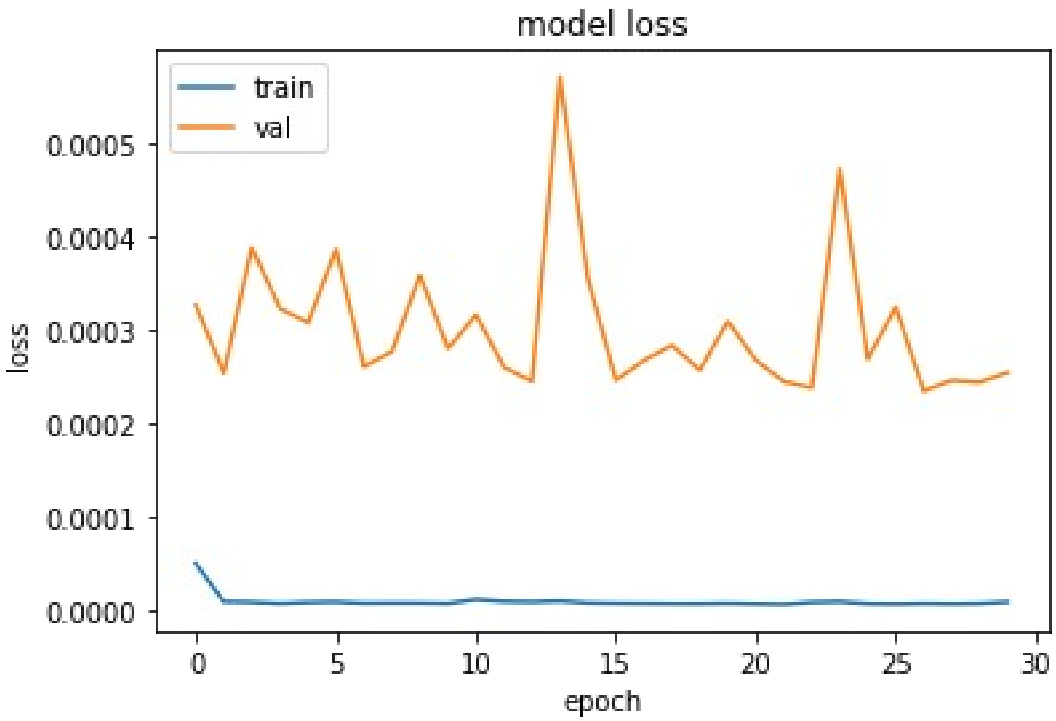
```
model_LSTM_2_adam.add(LSTM(50, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
49/49 [==============================] - 5s 23ms/step - loss: 5.0477e-
05 - val_loss: 3.2727e-04
Epoch 2/30
49/49 [==============================] - 0s 8ms/step - loss: 9.5347e-
06 - val_loss: 2.5429e-04
Epoch 3/30
49/49 [==============================] - 0s 9ms/step - loss: 9.0162e-
06 - val_loss: 3.8843e-04
Epoch 4/30
49/49 [==============================] - 0s 9ms/step - loss: 7.5338e-
06 - val_loss: 3.2334e-04
Epoch 5/30
49/49 [==============================] - 0s 8ms/step - loss: 8.8034e-
06 - val_loss: 3.0813e-04
Epoch 6/30
49/49 [==============================] - 0s 8ms/step - loss: 9.2773e-
06 - val_loss: 3.8691e-04
Epoch 7/30
49/49 [==============================] - 0s 8ms/step - loss: 7.8679e-
06 - val_loss: 2.6102e-04
Epoch 8/30
49/49 [==============================] - 0s 9ms/step - loss: 8.0148e-
06 - val_loss: 2.7734e-04
Epoch 9/30
49/49 [==============================] - 0s 9ms/step - loss: 8.0071e-
06 - val_loss: 3.5902e-04
Epoch 10/30
49/49 [==============================] - 0s 8ms/step - loss: 7.5234e-
06 - val_loss: 2.8039e-04
Epoch 11/30
49/49 [==============================] - 0s 8ms/step - loss: 1.2096e-
05 - val_loss: 3.1660e-04
Epoch 12/30
```

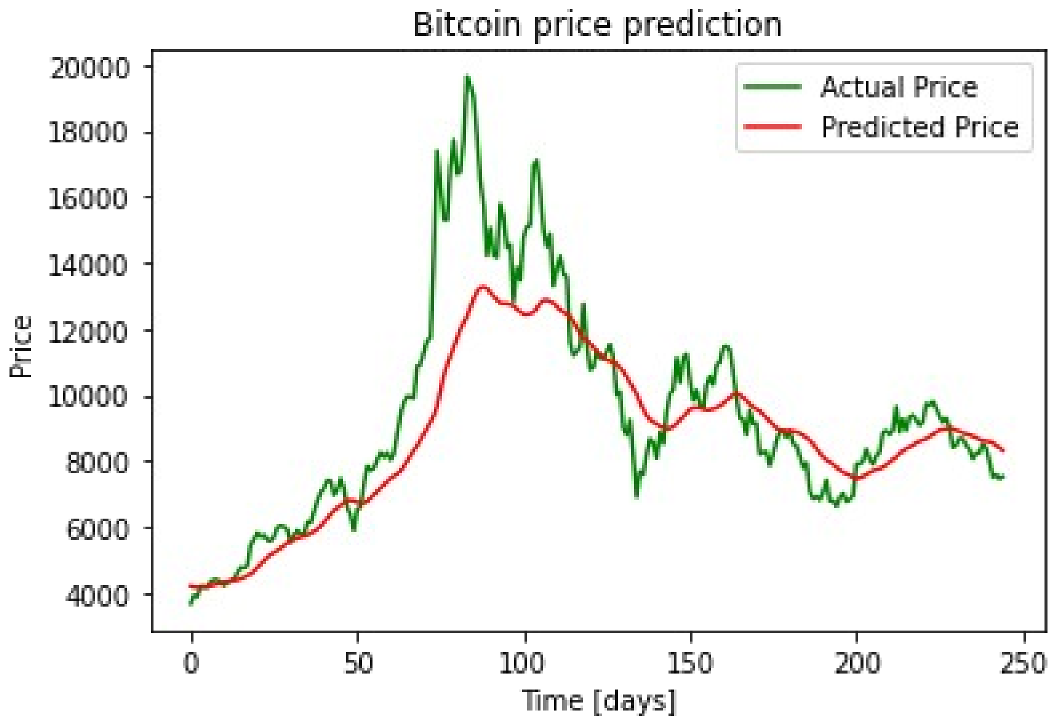
```
49/49 [==============================] - 0s 8ms/step - loss: 9.7144e-
06 - val_loss: 2.6059e-04
Epoch 13/30
49/49 [==============================] - 0s 9ms/step - loss: 9.2856e-
06 - val_loss: 2.4530e-04
Epoch 14/30
49/49 [==============================] - 0s 9ms/step - loss: 1.0227e-
05 - val_loss: 5.7157e-04
Epoch 15/30
49/49 [==============================] - 0s 9ms/step - loss: 8.1659e-
06 - val_loss: 3.5534e-04
Epoch 16/30
49/49 [==============================] - 0s 9ms/step - loss: 7.7107e-
06 - val_loss: 2.4652e-04
Epoch 17/30
49/49 [==============================] - 0s 9ms/step - loss: 7.5191e-
06 - val_loss: 2.6769e-04
Epoch 18/30
49/49 [==============================] - 0s 9ms/step - loss: 7.2843e-
06 - val_loss: 2.8396e-04
Epoch 19/30
49/49 [==============================] - 0s 8ms/step - loss: 7.2624e-
06 - val_loss: 2.5742e-04
Epoch 20/30
49/49 [==============================] - 0s 9ms/step - loss: 7.6767e-
06 - val_loss: 3.0973e-04
Epoch 21/30
49/49 [==============================] - 0s 9ms/step - loss: 7.0788e-
06 - val_loss: 2.6800e-04
Epoch 22/30
49/49 [==============================] - 1s 14ms/step - loss: 6.5679e-
06 - val_loss: 2.4513e-04
Epoch 23/30
49/49 [==============================] - 1s 14ms/step - loss: 8.9149e-
06 - val_loss: 2.3838e-04
Epoch 24/30
49/49 [==============================] - 1s 12ms/step - loss: 9.5267e-
06 - val_loss: 4.7318e-04
Epoch 25/30
49/49 [==============================] - 1s 11ms/step - loss: 7.3019e-
06 - val_loss: 2.6925e-04
Epoch 26/30
49/49 [==============================] - 0s 8ms/step - loss: 6.8503e-
06 - val_loss: 3.2495e-04
Epoch 27/30
49/49 [==============================] - 0s 9ms/step - loss: 7.5039e-
06 - val_loss: 2.3504e-04
Epoch 28/30
49/49 [==============================] - 0s 9ms/step - loss: 7.0768e-
06 - val_loss: 2.4650e-04
```

```
Epoch 29/30
49/49 [==============================] - 0s 9ms/step - loss: 7.5225e-
06 - val_loss: 2.4452e-04
Epoch 30/30
49/49 [==============================] - 0s 9ms/step - loss: 9.2386e-
06 - val_loss: 2.5489e-04
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
8/8 [==============================] - 1s 4ms/step
31/31 [==============================] - 0s 4ms/step
Train Score: 0.0015 RMSE
Test Score: 0.0273 RMSE
```



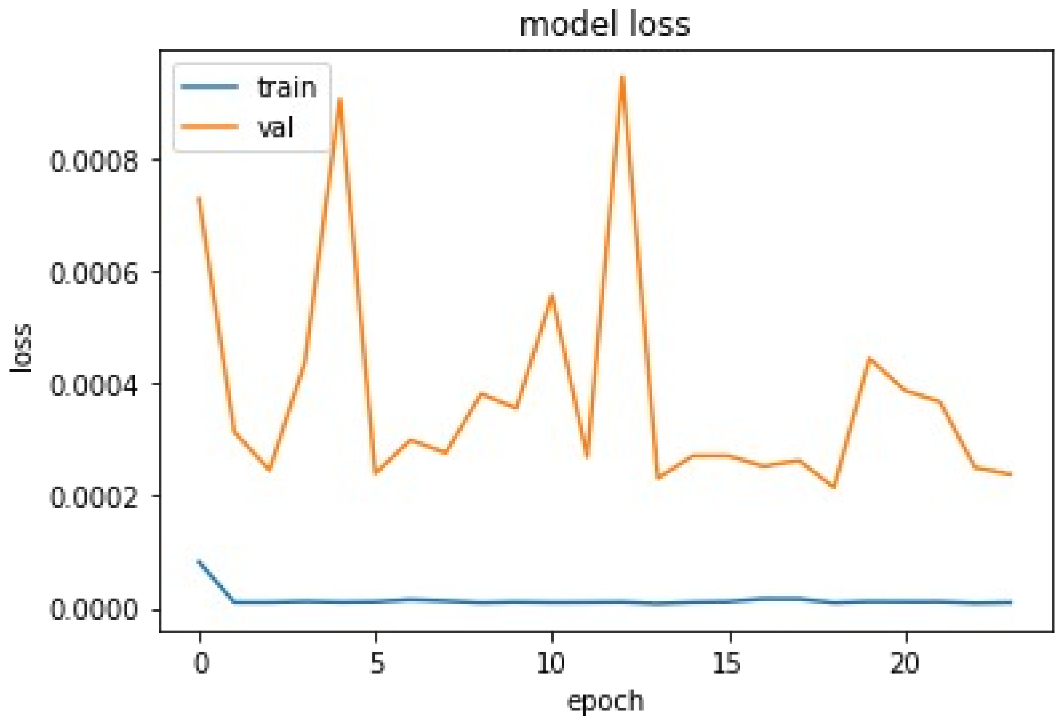
Tamanho da Janela: 100

```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=100)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(100, input_shape=(100, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(100, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
```

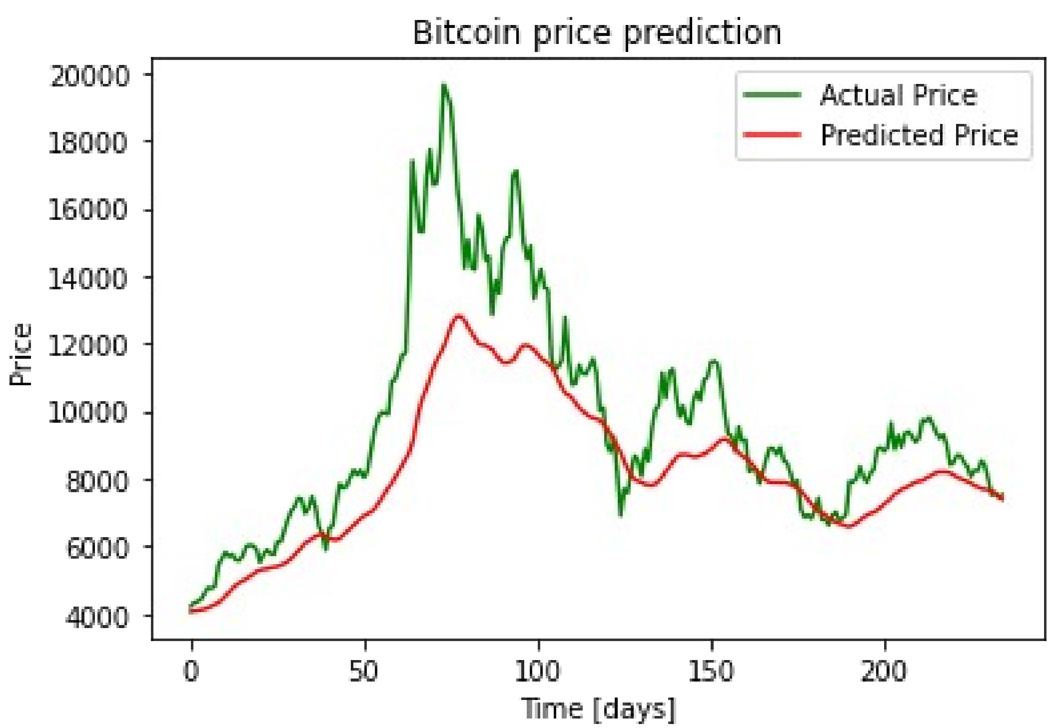
```
    callbacks=[callback]
)

Epoch 1/30
47/47 [==============================] - 6s 64ms/step - loss: 8.2393e-05 - val_loss: 7.2754e-04
Epoch 2/30
47/47 [==============================] - 1s 17ms/step - loss: 1.0372e-05 - val_loss: 3.1344e-04
Epoch 3/30
47/47 [==============================] - 1s 14ms/step - loss: 1.0352e-05 - val_loss: 2.4524e-04
Epoch 4/30
47/47 [==============================] - 1s 12ms/step - loss: 1.2006e-05 - val_loss: 4.3634e-04
Epoch 5/30
47/47 [==============================] - 1s 11ms/step - loss: 1.0670e-05 - val_loss: 9.0417e-04
Epoch 6/30
47/47 [==============================] - 1s 12ms/step - loss: 1.1335e-05 - val_loss: 2.3943e-04
Epoch 7/30
47/47 [==============================] - 1s 12ms/step - loss: 1.5235e-05 - val_loss: 2.9884e-04
Epoch 8/30
47/47 [==============================] - 1s 12ms/step - loss: 1.2795e-05 - val_loss: 2.7590e-04
Epoch 9/30
47/47 [==============================] - 1s 12ms/step - loss: 9.7294e-06 - val_loss: 3.8085e-04
Epoch 10/30
47/47 [==============================] - 1s 12ms/step - loss: 1.0973e-05 - val_loss: 3.5520e-04
Epoch 11/30
47/47 [==============================] - 1s 11ms/step - loss: 1.0214e-05 - val_loss: 5.5597e-04
Epoch 12/30
47/47 [==============================] - 1s 12ms/step - loss: 1.0482e-05 - val_loss: 2.6855e-04
Epoch 13/30
47/47 [==============================] - 1s 12ms/step - loss: 1.0978e-05 - val_loss: 9.4435e-04
Epoch 14/30
47/47 [==============================] - 1s 12ms/step - loss: 8.0665e-06 - val_loss: 2.3073e-04
Epoch 15/30
47/47 [==============================] - 1s 11ms/step - loss: 1.0675e-05 - val_loss: 2.7096e-04
Epoch 16/30
47/47 [==============================] - 1s 11ms/step - loss: 1.1612e-
```

```
05 - val_loss: 2.7085e-04
Epoch 17/30
47/47 [==============================] - 1s 12ms/step - loss: 1.6677e-
05 - val_loss: 2.5214e-04
Epoch 18/30
47/47 [==============================] - 1s 16ms/step - loss: 1.6440e-
05 - val_loss: 2.6241e-04
Epoch 19/30
47/47 [==============================] - 1s 16ms/step - loss: 9.5973e-
06 - val_loss: 2.1460e-04
Epoch 20/30
47/47 [==============================] - 1s 18ms/step - loss: 1.1864e-
05 - val_loss: 4.4380e-04
Epoch 21/30
47/47 [==============================] - 1s 16ms/step - loss: 1.1429e-
05 - val_loss: 3.8731e-04
Epoch 22/30
47/47 [==============================] - 1s 16ms/step - loss: 1.1558e-
05 - val_loss: 3.6676e-04
Epoch 23/30
47/47 [==============================] - 1s 16ms/step - loss: 8.9431e-
06 - val_loss: 2.4971e-04
Epoch 24/30
47/47 [==============================] - 1s 12ms/step - loss: 1.0189e-
05 - val_loss: 2.3808e-04
Epoch 24: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
8/8 [==============================] - 1s 7ms/step
30/30 [==============================] - 0s 7ms/step
Train Score: 0.0004 RMSE
Test Score: 0.0079 RMSE
```



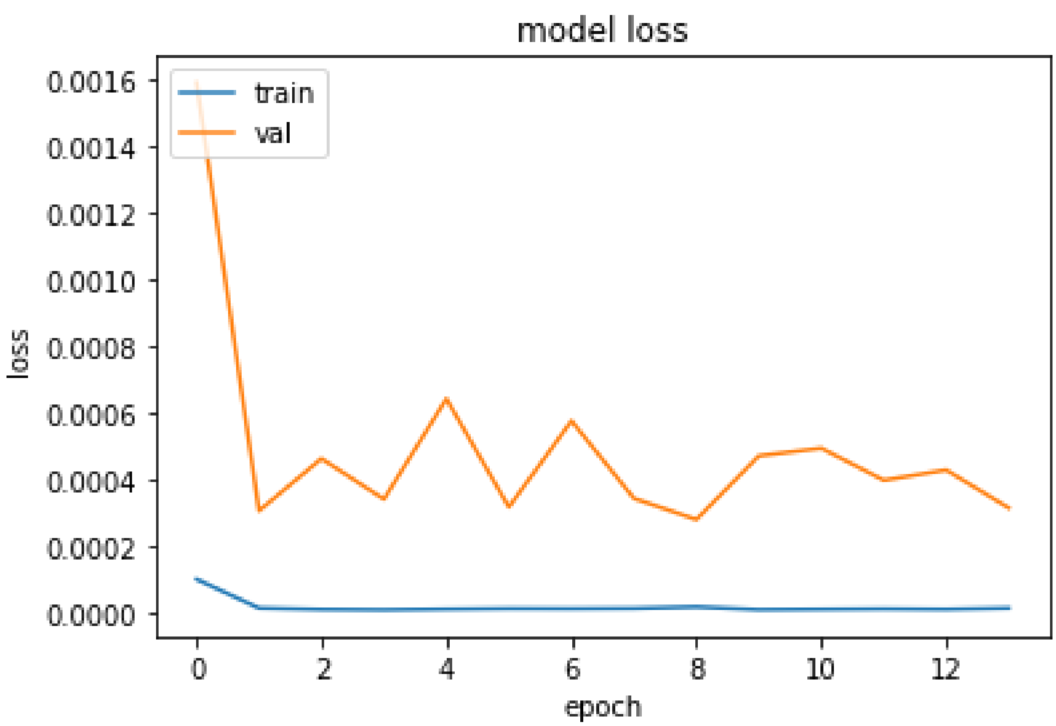
Tamanho da Janela: 150

```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=150)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(150, input_shape=(150, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(150, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

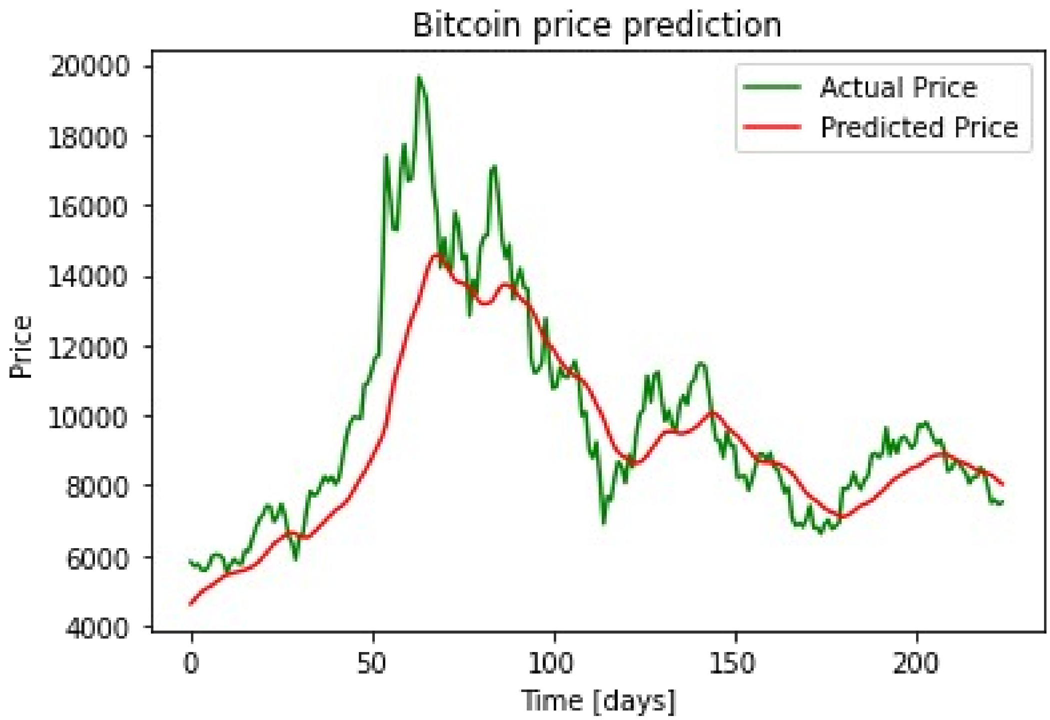
```
Epoch 1/30
45/45 [==============================] - 5s 39ms/step - loss: 1.0069e-
04 - val_loss: 0.0016
Epoch 2/30
45/45 [==============================] - 1s 19ms/step - loss: 1.3796e-
05 - val_loss: 3.0612e-04
Epoch 3/30
45/45 [==============================] - 1s 18ms/step - loss: 1.0047e-
05 - val_loss: 4.6295e-04
Epoch 4/30
45/45 [==============================] - 1s 14ms/step - loss: 8.8633e-
06 - val_loss: 3.4103e-04
Epoch 5/30
45/45 [==============================] - 1s 14ms/step - loss: 1.0873e-
05 - val_loss: 6.4266e-04
Epoch 6/30
45/45 [==============================] - 1s 14ms/step - loss: 1.2464e-
05 - val_loss: 3.1723e-04
Epoch 7/30
45/45 [==============================] - 1s 14ms/step - loss: 1.2180e-
```

```
05 - val_loss: 5.7638e-04
Epoch 8/30
45/45 [==============================] - 1s 14ms/step - loss: 1.2966e-
05 - val_loss: 3.4335e-04
Epoch 9/30
45/45 [==============================] - 1s 14ms/step - loss: 1.7281e-
05 - val_loss: 2.7999e-04
Epoch 10/30
45/45 [==============================] - 1s 15ms/step - loss: 9.3611e-
06 - val_loss: 4.7128e-04
Epoch 11/30
45/45 [==============================] - 1s 14ms/step - loss: 1.0549e-
05 - val_loss: 4.9423e-04
Epoch 12/30
45/45 [==============================] - 1s 14ms/step - loss: 1.1563e-
05 - val_loss: 3.9801e-04
Epoch 13/30
45/45 [==============================] - 1s 14ms/step - loss: 1.0513e-
05 - val_loss: 4.2870e-04
Epoch 14/30
45/45 [==============================] - 1s 14ms/step - loss: 1.3699e-
05 - val_loss: 3.1480e-04
Epoch 14: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```



```
8/8 [==============================] - 1s 5ms/step
29/29 [==============================] - 0s 5ms/step
Train Score: 0.0020 RMSE
Test Score: 0.0614 RMSE
```



Tamanho da Janela: 200

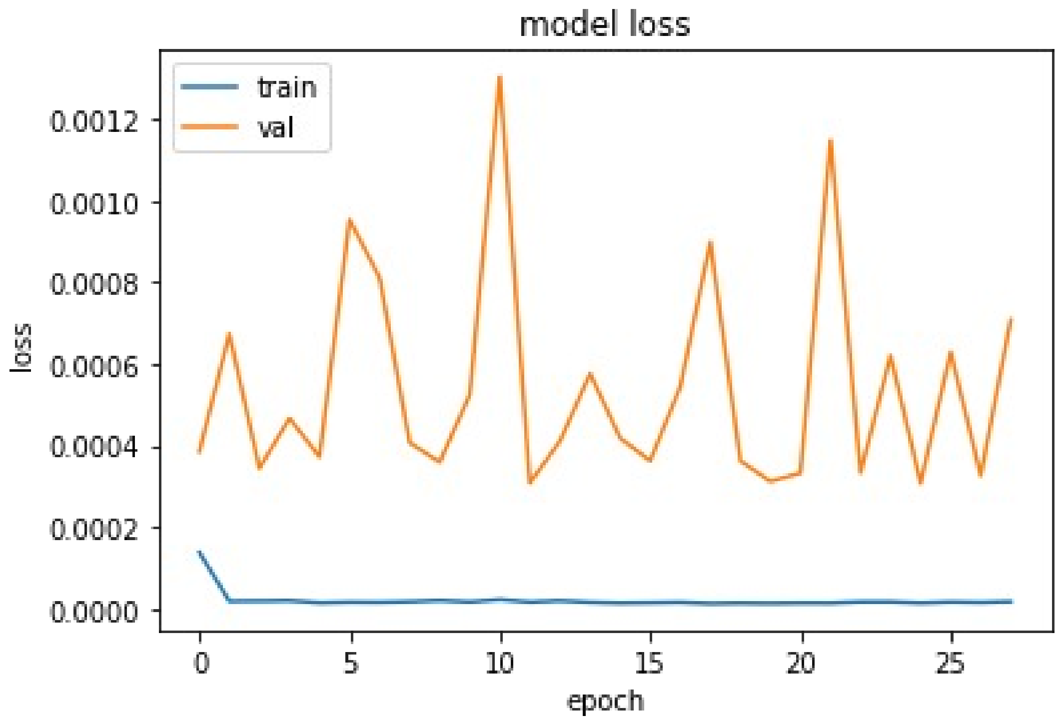
```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=200)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(200, input_shape=(200, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(200, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
```

```
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

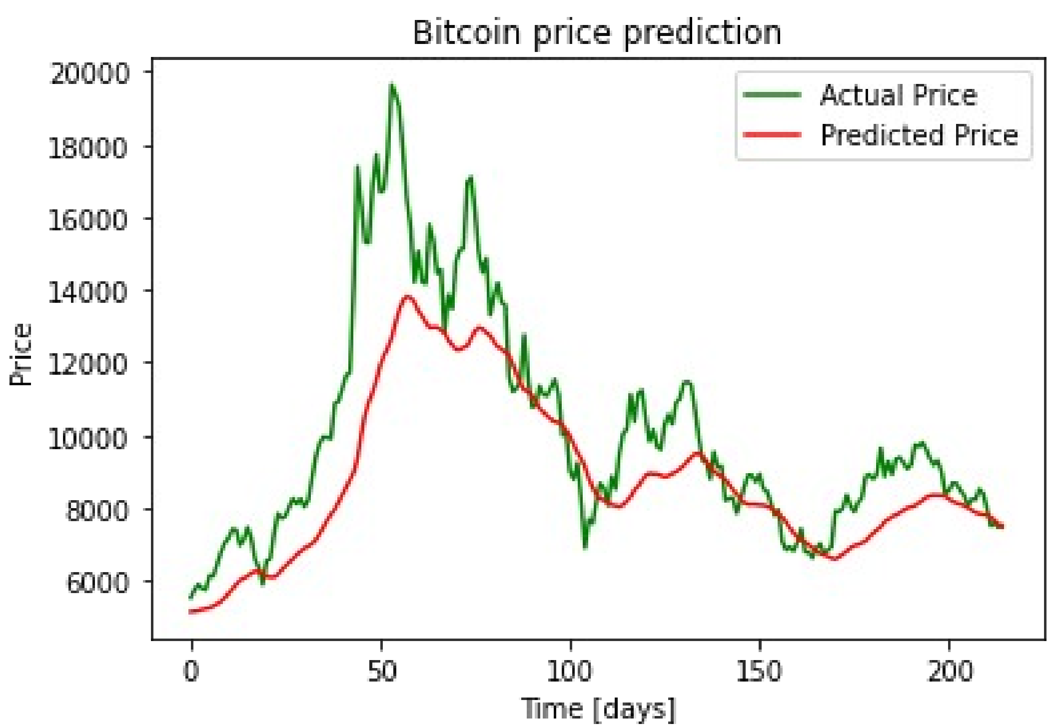
```
Epoch 1/30
43/43 [==============================] - 6s 40ms/step - loss: 1.3739e-
04 - val_loss: 3.8431e-04
Epoch 2/30
43/43 [==============================] - 1s 20ms/step - loss: 1.7494e-
05 - val_loss: 6.7280e-04
Epoch 3/30
43/43 [==============================] - 1s 20ms/step - loss: 1.8059e-
05 - val_loss: 3.4374e-04
Epoch 4/30
43/43 [==============================] - 1s 20ms/step - loss: 1.8970e-
05 - val_loss: 4.6605e-04
Epoch 5/30
43/43 [==============================] - 1s 22ms/step - loss: 1.3375e-
05 - val_loss: 3.7136e-04
Epoch 6/30
43/43 [==============================] - 1s 20ms/step - loss: 1.5009e-
05 - val_loss: 9.5330e-04
Epoch 7/30
43/43 [==============================] - 1s 20ms/step - loss: 1.4602e-
05 - val_loss: 8.1061e-04
Epoch 8/30
43/43 [==============================] - 1s 20ms/step - loss: 1.6177e-
05 - val_loss: 4.0604e-04
Epoch 9/30
43/43 [==============================] - 1s 20ms/step - loss: 1.9431e-
05 - val_loss: 3.5886e-04
Epoch 10/30
43/43 [==============================] - 1s 22ms/step - loss: 1.5492e-
05 - val_loss: 5.2353e-04
Epoch 11/30
43/43 [==============================] - 1s 22ms/step - loss: 2.1529e-
05 - val_loss: 0.0013
Epoch 12/30
43/43 [==============================] - 1s 22ms/step - loss: 1.5202e-
05 - val_loss: 3.0808e-04
Epoch 13/30
43/43 [==============================] - 1s 20ms/step - loss: 1.8644e-
05 - val_loss: 4.1036e-04
Epoch 14/30
43/43 [==============================] - 1s 20ms/step - loss: 1.4636e-
05 - val_loss: 5.7571e-04
Epoch 15/30
```

```
43/43 [==============================] - 1s 20ms/step - loss: 1.2809e-
05 - val_loss: 4.1737e-04
Epoch 16/30
43/43 [==============================] - 1s 20ms/step - loss: 1.3603e-
05 - val_loss: 3.6177e-04
Epoch 17/30
43/43 [==============================] - 1s 20ms/step - loss: 1.4628e-
05 - val_loss: 5.4309e-04
Epoch 18/30
43/43 [==============================] - 1s 20ms/step - loss: 1.1456e-
05 - val_loss: 8.9826e-04
Epoch 19/30
43/43 [==============================] - 1s 20ms/step - loss: 1.2664e-
05 - val_loss: 3.6204e-04
Epoch 20/30
43/43 [==============================] - 1s 20ms/step - loss: 1.1907e-
05 - val_loss: 3.1158e-04
Epoch 21/30
43/43 [==============================] - 1s 20ms/step - loss: 1.2939e-
05 - val_loss: 3.3196e-04
Epoch 22/30
43/43 [==============================] - 1s 20ms/step - loss: 1.2723e-
05 - val_loss: 0.0011
Epoch 23/30
43/43 [==============================] - 1s 21ms/step - loss: 1.5813e-
05 - val_loss: 3.3275e-04
Epoch 24/30
43/43 [==============================] - 1s 22ms/step - loss: 1.5915e-
05 - val_loss: 6.1969e-04
Epoch 25/30
43/43 [==============================] - 1s 23ms/step - loss: 1.2877e-
05 - val_loss: 3.0741e-04
Epoch 26/30
43/43 [==============================] - 1s 21ms/step - loss: 1.5555e-
05 - val_loss: 6.2829e-04
Epoch 27/30
43/43 [==============================] - 1s 20ms/step - loss: 1.4353e-
05 - val_loss: 3.2582e-04
Epoch 28/30
43/43 [==============================] - 1s 22ms/step - loss: 1.6414e-
05 - val_loss: 7.0768e-04
Epoch 28: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 15ms/step
27/27 [==============================] - 0s 12ms/step
Train Score: 0.0016 RMSE
Test Score: 0.0196 RMSE
```



Tamanho da Janela: 250

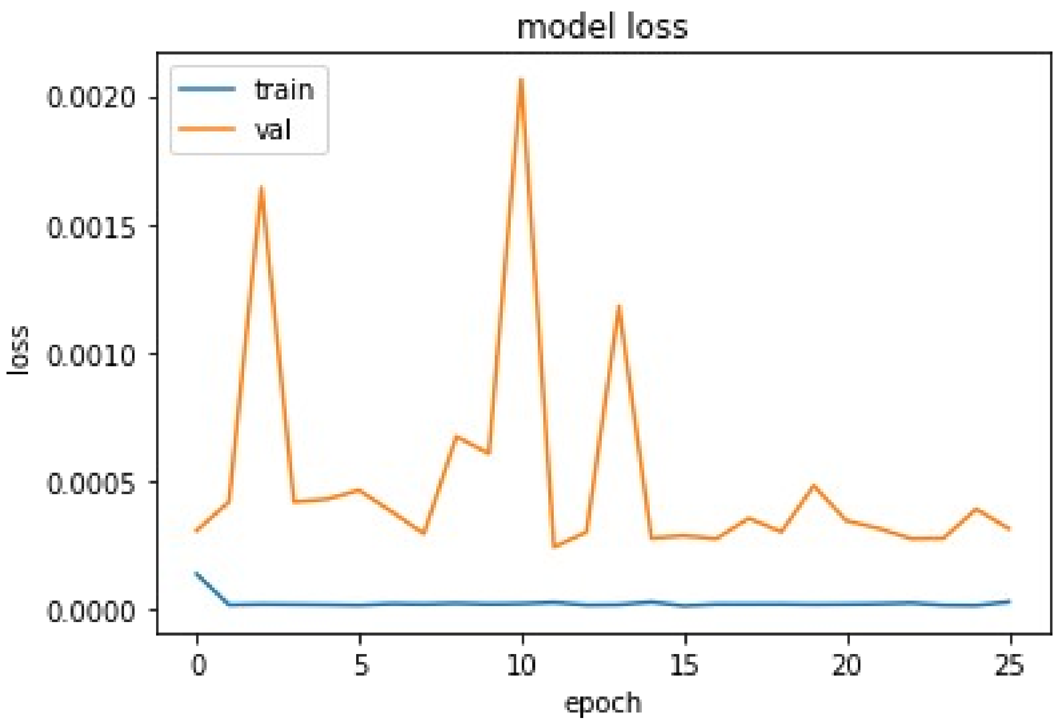
```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=250)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(250, input_shape=(250, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(250, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
    callbacks=[callback]
)
```

```
Epoch 1/30
41/41 [==============================] - 6s 47ms/step - loss: 1.3913e-
04 - val_loss: 3.0756e-04
Epoch 2/30
41/41 [==============================] - 1s 26ms/step - loss: 1.8720e-
05 - val_loss: 4.1934e-04
Epoch 3/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0926e-
05 - val_loss: 0.0016
Epoch 4/30
41/41 [==============================] - 1s 26ms/step - loss: 2.0155e-
05 - val_loss: 4.1954e-04
Epoch 5/30
41/41 [==============================] - 1s 26ms/step - loss: 1.9287e-
05 - val_loss: 4.2983e-04
Epoch 6/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7320e-
05 - val_loss: 4.6493e-04
Epoch 7/30
41/41 [==============================] - 1s 26ms/step - loss: 2.2789e-
```

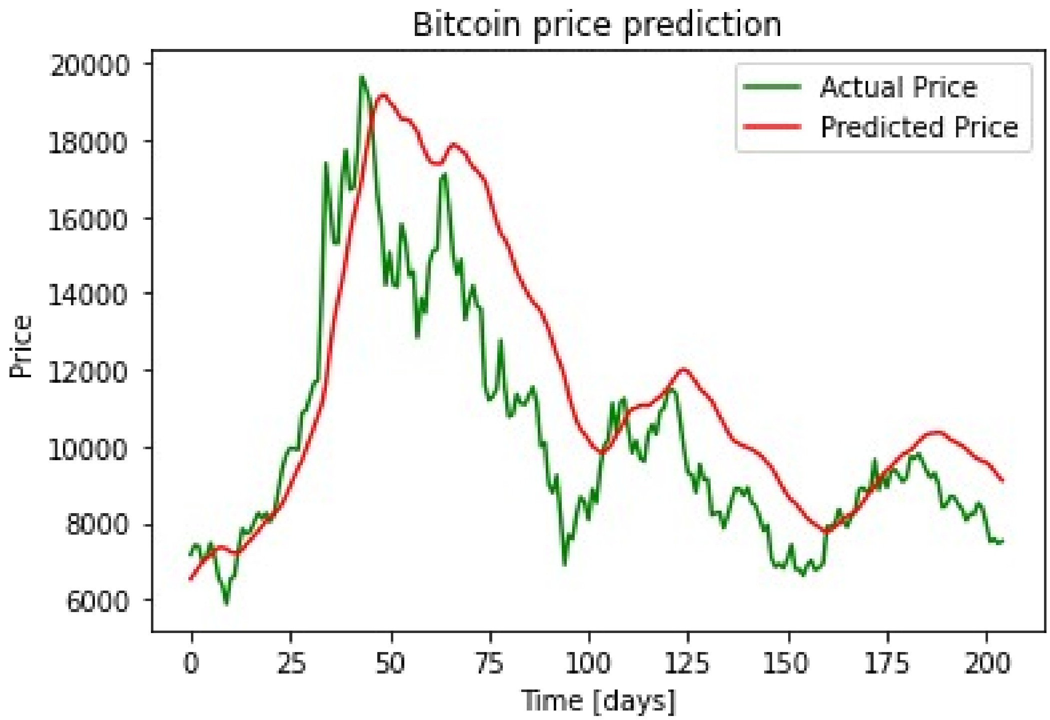
```
05 - val_loss: 3.8226e-04
Epoch 8/30
41/41 [==============================] - 1s 26ms/step - loss: 2.1222e-05 - val_loss: 2.9591e-04
Epoch 9/30
41/41 [==============================] - 1s 27ms/step - loss: 2.4568e-05 - val_loss: 6.7387e-04
Epoch 10/30
41/41 [==============================] - 1s 28ms/step - loss: 2.1455e-05 - val_loss: 6.0760e-04
Epoch 11/30
41/41 [==============================] - 1s 28ms/step - loss: 2.2957e-05 - val_loss: 0.0021
Epoch 12/30
41/41 [==============================] - 1s 26ms/step - loss: 2.8350e-05 - val_loss: 2.4381e-04
Epoch 13/30
41/41 [==============================] - 1s 27ms/step - loss: 1.7994e-05 - val_loss: 3.0202e-04
Epoch 14/30
41/41 [==============================] - 1s 27ms/step - loss: 1.9152e-05 - val_loss: 0.0012
Epoch 15/30
41/41 [==============================] - 1s 27ms/step - loss: 2.9811e-05 - val_loss: 2.7817e-04
Epoch 16/30
41/41 [==============================] - 1s 26ms/step - loss: 1.4806e-05 - val_loss: 2.8805e-04
Epoch 17/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1128e-05 - val_loss: 2.7615e-04
Epoch 18/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0980e-05 - val_loss: 3.5594e-04
Epoch 19/30
41/41 [==============================] - 1s 27ms/step - loss: 2.1283e-05 - val_loss: 3.0261e-04
Epoch 20/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0121e-05 - val_loss: 4.8265e-04
Epoch 21/30
41/41 [==============================] - 1s 27ms/step - loss: 2.0877e-05 - val_loss: 3.4654e-04
Epoch 22/30
41/41 [==============================] - 1s 27ms/step - loss: 2.2356e-05 - val_loss: 3.1591e-04
Epoch 23/30
41/41 [==============================] - 1s 27ms/step - loss: 2.5763e-05 - val_loss: 2.7634e-04
Epoch 24/30
```

```
41/41 [==============================] - 1s 27ms/step - loss: 1.7722e-05 - val_loss: 2.7844e-04
Epoch 25/30
41/41 [==============================] - 1s 27ms/step - loss: 1.6279e-05 - val_loss: 3.9151e-04
Epoch 26/30
41/41 [==============================] - 1s 27ms/step - loss: 3.0423e-05 - val_loss: 3.1556e-04
Epoch 26: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler, X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 21ms/step
26/26 [==============================] - 0s 13ms/step
Train Score: 0.0026 RMSE
Test Score: 0.0323 RMSE
```



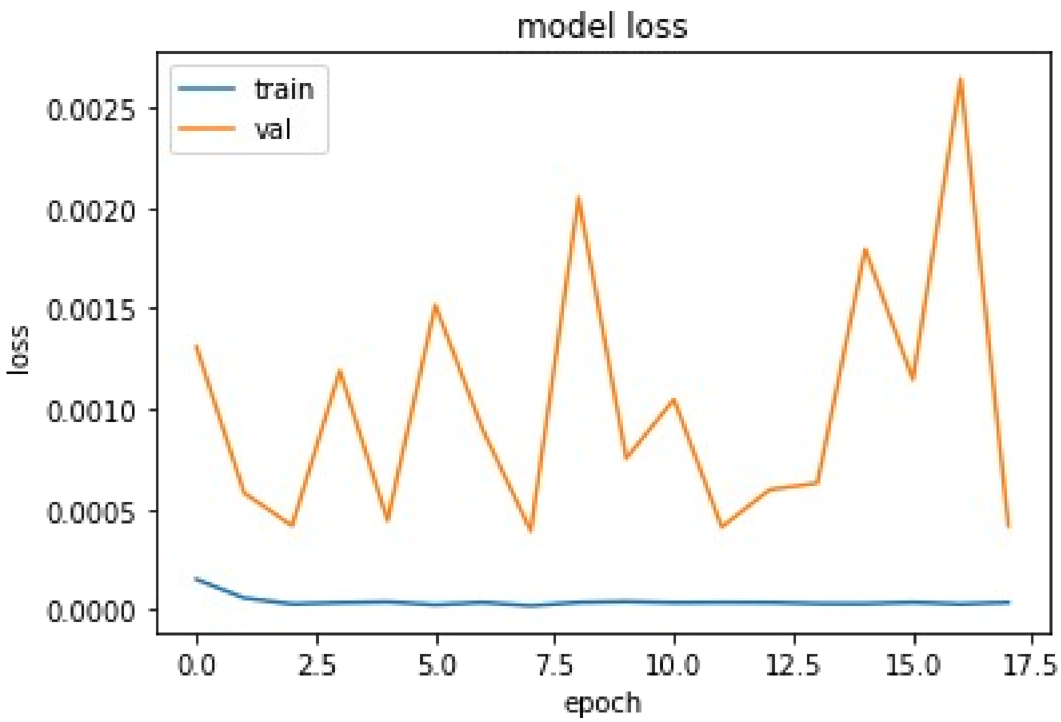
Tamanho da Janela: 300

```
X_train, y_train, X_test, y_test = split_data(scaled_df, 0.2,
time_steps=300)

X_train = X_train.reshape(X_train.shape[0], X_train.shape[1], 1)
X_test = X_test.reshape(X_test.shape[0], X_test.shape[1], 1)

y_train = y_train.reshape(-1, 1)
y_test = y_test.reshape(-1, 1)

model_LSTM_2_adam = tf.keras.Sequential()
model_LSTM_2_adam.add(LSTM(300, input_shape=(300, X_train.shape[-1]),
dropout=DROPOUT, return_sequences=True))
model_LSTM_2_adam.add(LSTM(300, dropout=DROPOUT))
model_LSTM_2_adam.add(Dense(1, activation='linear'))
model_LSTM_2_adam.compile(
    optimizer=tf.keras.optimizers.Adam(learning_rate = LEARNING_RATE),
    loss="mse"
)

history_LSTM_2_adam = model_LSTM_2_adam.fit(
    np.array(X_train).reshape(X_train.shape[0], X_train.shape[1], 1),
    y_train,
    batch_size=BATCH_SIZE,
    epochs=EPOCHS,
    verbose=VERBOSE,
    validation_split=0.2,
```

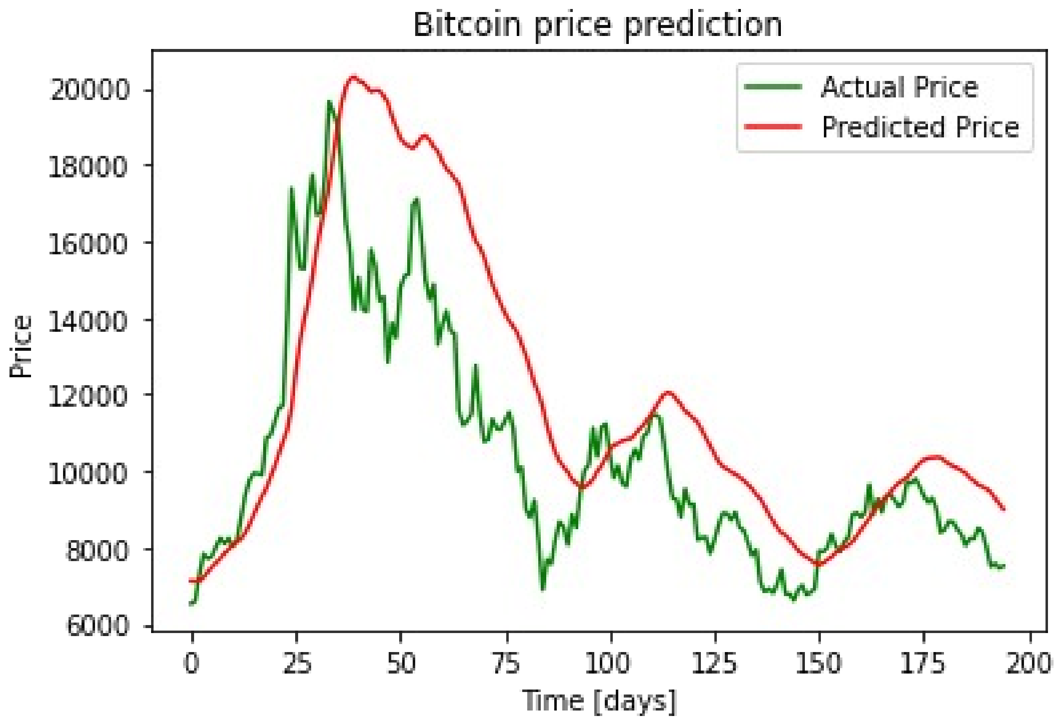
```
    callbacks=[callback]
)

Epoch 1/30
39/39 [==============================] - 8s 60ms/step - loss: 1.5022e-
04 - val_loss: 0.0013
Epoch 2/30
39/39 [==============================] - 1s 37ms/step - loss: 5.7369e-
05 - val_loss: 5.8094e-04
Epoch 3/30
39/39 [==============================] - 1s 37ms/step - loss: 2.7317e-
05 - val_loss: 4.1755e-04
Epoch 4/30
39/39 [==============================] - 1s 37ms/step - loss: 3.3659e-
05 - val_loss: 0.0012
Epoch 5/30
39/39 [==============================] - 1s 37ms/step - loss: 3.7953e-
05 - val_loss: 4.4349e-04
Epoch 6/30
39/39 [==============================] - 1s 37ms/step - loss: 2.3390e-
05 - val_loss: 0.0015
Epoch 7/30
39/39 [==============================] - 1s 38ms/step - loss: 3.5204e-
05 - val_loss: 8.9232e-04
Epoch 8/30
39/39 [==============================] - 1s 38ms/step - loss: 1.8590e-
05 - val_loss: 3.9149e-04
Epoch 9/30
39/39 [==============================] - 1s 38ms/step - loss: 3.5390e-
05 - val_loss: 0.0021
Epoch 10/30
39/39 [==============================] - 1s 37ms/step - loss: 3.9818e-
05 - val_loss: 7.5343e-04
Epoch 11/30
39/39 [==============================] - 1s 37ms/step - loss: 3.3972e-
05 - val_loss: 0.0010
Epoch 12/30
39/39 [==============================] - 1s 38ms/step - loss: 3.5221e-
05 - val_loss: 4.1082e-04
Epoch 13/30
39/39 [==============================] - 1s 38ms/step - loss: 3.4755e-
05 - val_loss: 5.9703e-04
Epoch 14/30
39/39 [==============================] - 1s 38ms/step - loss: 2.9296e-
05 - val_loss: 6.3030e-04
Epoch 15/30
39/39 [==============================] - 1s 38ms/step - loss: 2.8491e-
05 - val_loss: 0.0018
Epoch 16/30
39/39 [==============================] - 2s 39ms/step - loss: 3.5663e-
```

```
05 - val_loss: 0.0011
Epoch 17/30
39/39 [==============================] - 1s 38ms/step - loss: 2.7126e-
05 - val_loss: 0.0026
Epoch 18/30
39/39 [==============================] - 1s 38ms/step - loss: 3.4817e-
05 - val_loss: 4.1656e-04
Epoch 18: early stopping
```

```
model_evaluation(history_LSTM_2_adam, model_LSTM_2_adam, scaler,
X_test, X_train, y_train, y_test)
```




```
7/7 [==============================] - 1s 26ms/step
25/25 [==============================] - 0s 18ms/step
Train Score: 0.0053 RMSE
Test Score: 0.0305 RMSE
```



Continuidade

Olhando para os scores com RMSE, vemos que o melhor modelo é com tamanho de janela igual a 100.

Conclusão

Dessa forma, a partir dessa abordagem, os melhores parâmetros encontrados para a previsão de valores dee Bitcoin, com RMSE 0,0004 de treinamento e 0,0079 de teste, foram:

- 2 camadas LSTM
- Algoritmo de Otimização: ADAM
- Taxa de aprendizagem: 0.001
- Dropout: 10%
- Batch Size: 16
- Tamanho da janela: 100