7vsnqkizp

June 10, 2024

#Implementación del Modelo LSTM

Importación de bibliotecas:

[1]:
```
import pandas as pd
import numpy as np
from sklearn.preprocessing import MinMaxScaler
from sklearn.model_selection import train_test_split, GridSearchCV,␣
  ↪TimeSeriesSplit
from sklearn.feature_selection import mutual_info_regression, SelectKBest,␣
  ↪f_regression
from keras.models import Sequential
from keras.layers import LSTM, Dense, Dropout
from sklearn.metrics import mean_absolute_percentage_error, mean_squared_error
```

Limpieza de Datos

[2]:
```
def clean_data(data):
    data = data.dropna()
    return data
```

Normalización de las Variables

[3]:
```
def normalize_data(data):
    scaler = MinMaxScaler()
    data_scaled = scaler.fit_transform(data)
    return pd.DataFrame(data_scaled, columns=data.columns), scaler
```

Selección de Variables utilizando diferentes métodos

[4]:
```
def select_features(X, y, num_features):
    mutual_info = mutual_info_regression(X, y)
    k_best = SelectKBest(score_func=f_regression, k=num_features).fit(X, y)
    features = X.columns[k_best.get_support(indices=True)]
    return features.tolist()
```

Definición de la función para entrenar el modelo LSTM:

[5]:
```
def train_lstm(X_train, y_train, input_shape):
    """
```

```
    Función para entrenar un modelo LSTM.

    Parámetros:
    X_train (numpy array): Conjunto de datos de entrenamiento (características).
    y_train (numpy array): Conjunto de datos de entrenamiento (objetivo).
    input_shape (tuple): Forma de los datos de entrada.

    Retorna:
    model (Sequential): Modelo LSTM entrenado.
    """
    model = Sequential()
    model.add(LSTM(units=50, return_sequences=True, input_shape=input_shape))
    model.add(Dropout(0.2))
    model.add(LSTM(units=50))
    model.add(Dropout(0.2))
    model.add(Dense(1))

    model.compile(optimizer='adam', loss='mean_squared_error')
    model.fit(X_train, y_train, epochs=500, batch_size=32, validation_split=0.2)

    return model
```

Preparacion de datos

[6]:
```
# Cargar datos
data = pd.read_csv('https://query1.finance.yahoo.com/v7/finance/download/FSM?
↪period1=1597123200&period2=1628659200&interval=1d&events=history&includeAdjustedClose=true'

# Mantener la columna de fechas para las gráficas
dates = data['Date']
data = data.drop(columns=['Date'])

# Limpiar y Normalizar
data = clean_data(data)
data, scaler = normalize_data(data)

# Seleccionar Variables
target_column = 'Close'
num_features = 5  # Número de características a seleccionar
selected_features = select_features(data.drop(columns=[target_column]),␣
↪data[target_column], num_features)
selected_features.append(target_column)
data = data[selected_features]

# Separar características y objetivo
X = data.drop(columns=[target_column])
y = data[target_column]
```

```
# Dividir los datos en conjuntos de entrenamiento y prueba
train_size = int(len(X) * 0.8)
X_train, X_test = X[:train_size], X[train_size:]
y_train, y_test = y[:train_size], y[train_size:]
dates_train, dates_test = dates[:train_size], dates[train_size:]

print(f'Características seleccionadas: {selected_features}')
```

```
Características seleccionadas: ['Open', 'High', 'Low', 'Adj Close', 'Volume',
'Close']
```

Preparación de los datos para LSTM:

[7]:
```
# Los datos de entrenamiento y prueba se reestructuran en un formato 3D␣
↪requerido por LSTM (samples, timesteps, features)
X_train_lstm = X_train.values.reshape((X_train.shape[0], 1, X_train.shape[1]))
X_test_lstm = X_test.values.reshape((X_test.shape[0], 1, X_test.shape[1]))
```

Entrenamiento del modelo LSTM:

[8]:
```
# Entrenamos el modelo LSTM usando los datos de entrenamiento reestructurados
lstm_model = train_lstm(X_train_lstm, y_train, (1, X_train.shape[1]))
```

```
Epoch 1/500
5/5 [==============================] - 12s 621ms/step - loss: 0.2882 - val_loss:
0.2055
Epoch 2/500
5/5 [==============================] - 0s 33ms/step - loss: 0.2498 - val_loss:
0.1731
Epoch 3/500
5/5 [==============================] - 0s 37ms/step - loss: 0.2109 - val_loss:
0.1393
Epoch 4/500
5/5 [==============================] - 0s 22ms/step - loss: 0.1680 - val_loss:
0.1042
Epoch 5/500
5/5 [==============================] - 0s 27ms/step - loss: 0.1199 - val_loss:
0.0690
Epoch 6/500
5/5 [==============================] - 0s 52ms/step - loss: 0.0770 - val_loss:
0.0369
Epoch 7/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0427 - val_loss:
0.0131
Epoch 8/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0133 - val_loss:
0.0031
Epoch 9/500
```

```
5/5 [==============================] - 0s 28ms/step - loss: 0.0058 - val_loss:
0.0058
Epoch 10/500
5/5 [==============================] - 0s 30ms/step - loss: 0.0084 - val_loss:
0.0102
Epoch 11/500
5/5 [==============================] - 0s 39ms/step - loss: 0.0120 - val_loss:
0.0080
Epoch 12/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0074 - val_loss:
0.0043
Epoch 13/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0056 - val_loss:
0.0029
Epoch 14/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0045 - val_loss:
0.0028
Epoch 15/500
5/5 [==============================] - 0s 29ms/step - loss: 0.0068 - val_loss:
0.0028
Epoch 16/500
5/5 [==============================] - 0s 32ms/step - loss: 0.0066 - val_loss:
0.0027
Epoch 17/500
5/5 [==============================] - 0s 34ms/step - loss: 0.0053 - val_loss:
0.0029
Epoch 18/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0057 - val_loss:
0.0031
Epoch 19/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0052 - val_loss:
0.0030
Epoch 20/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0054 - val_loss:
0.0028
Epoch 21/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0053 - val_loss:
0.0028
Epoch 22/500
5/5 [==============================] - 0s 45ms/step - loss: 0.0055 - val_loss:
0.0028
Epoch 23/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0044 - val_loss:
0.0027
Epoch 24/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0052 - val_loss:
0.0026
Epoch 25/500
```

```
5/5 [==============================] - 0s 53ms/step - loss: 0.0053 - val_loss:
0.0026
Epoch 26/500
5/5 [==============================] - 0s 49ms/step - loss: 0.0045 - val_loss:
0.0025
Epoch 27/500
5/5 [==============================] - 0s 33ms/step - loss: 0.0050 - val_loss:
0.0025
Epoch 28/500
5/5 [==============================] - 0s 46ms/step - loss: 0.0040 - val_loss:
0.0024
Epoch 29/500
5/5 [==============================] - 0s 43ms/step - loss: 0.0043 - val_loss:
0.0023
Epoch 30/500
5/5 [==============================] - 0s 38ms/step - loss: 0.0039 - val_loss:
0.0022
Epoch 31/500
5/5 [==============================] - 0s 37ms/step - loss: 0.0046 - val_loss:
0.0022
Epoch 32/500
5/5 [==============================] - 0s 34ms/step - loss: 0.0037 - val_loss:
0.0022
Epoch 33/500
5/5 [==============================] - 0s 27ms/step - loss: 0.0045 - val_loss:
0.0022
Epoch 34/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0046 - val_loss:
0.0022
Epoch 35/500
5/5 [==============================] - 0s 46ms/step - loss: 0.0040 - val_loss:
0.0021
Epoch 36/500
5/5 [==============================] - 0s 51ms/step - loss: 0.0053 - val_loss:
0.0020
Epoch 37/500
5/5 [==============================] - 0s 73ms/step - loss: 0.0036 - val_loss:
0.0020
Epoch 38/500
5/5 [==============================] - 0s 95ms/step - loss: 0.0039 - val_loss:
0.0019
Epoch 39/500
5/5 [==============================] - 1s 130ms/step - loss: 0.0039 - val_loss:
0.0019
Epoch 40/500
5/5 [==============================] - 0s 116ms/step - loss: 0.0041 - val_loss:
0.0020
Epoch 41/500
```

```
5/5 [==============================] - 0s 78ms/step - loss: 0.0053 - val_loss:
0.0018
Epoch 42/500
5/5 [==============================] - 0s 44ms/step - loss: 0.0048 - val_loss:
0.0017
Epoch 43/500
5/5 [==============================] - 0s 43ms/step - loss: 0.0035 - val_loss:
0.0017
Epoch 44/500
5/5 [==============================] - 0s 65ms/step - loss: 0.0058 - val_loss:
0.0016
Epoch 45/500
5/5 [==============================] - 0s 54ms/step - loss: 0.0049 - val_loss:
0.0018
Epoch 46/500
5/5 [==============================] - 0s 50ms/step - loss: 0.0043 - val_loss:
0.0018
Epoch 47/500
5/5 [==============================] - 0s 64ms/step - loss: 0.0041 - val_loss:
0.0015
Epoch 48/500
5/5 [==============================] - 0s 38ms/step - loss: 0.0045 - val_loss:
0.0014
Epoch 49/500
5/5 [==============================] - 0s 39ms/step - loss: 0.0036 - val_loss:
0.0014
Epoch 50/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0048 - val_loss:
0.0014
Epoch 51/500
5/5 [==============================] - 0s 36ms/step - loss: 0.0042 - val_loss:
0.0014
Epoch 52/500
5/5 [==============================] - 0s 27ms/step - loss: 0.0037 - val_loss:
0.0015
Epoch 53/500
5/5 [==============================] - 0s 33ms/step - loss: 0.0040 - val_loss:
0.0015
Epoch 54/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0043 - val_loss:
0.0013
Epoch 55/500
5/5 [==============================] - 0s 35ms/step - loss: 0.0052 - val_loss:
0.0013
Epoch 56/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0033 - val_loss:
0.0012
Epoch 57/500
```

```
5/5 [==============================] - 0s 21ms/step - loss: 0.0039 - val_loss:
0.0012
Epoch 58/500
5/5 [==============================] - 0s 32ms/step - loss: 0.0039 - val_loss:
0.0012
Epoch 59/500
5/5 [==============================] - 0s 38ms/step - loss: 0.0040 - val_loss:
0.0011
Epoch 60/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0039 - val_loss:
0.0011
Epoch 61/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0039 - val_loss:
0.0011
Epoch 62/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0047 - val_loss:
0.0011
Epoch 63/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0034 - val_loss:
0.0011
Epoch 64/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0036 - val_loss:
0.0010
Epoch 65/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0034 - val_loss:
0.0010
Epoch 66/500
5/5 [==============================] - 0s 30ms/step - loss: 0.0037 - val_loss:
9.5167e-04
Epoch 67/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0039 - val_loss:
9.2775e-04
Epoch 68/500
5/5 [==============================] - 0s 41ms/step - loss: 0.0032 - val_loss:
9.0833e-04
Epoch 69/500
5/5 [==============================] - 0s 47ms/step - loss: 0.0034 - val_loss:
8.9180e-04
Epoch 70/500
5/5 [==============================] - 0s 38ms/step - loss: 0.0027 - val_loss:
9.3511e-04
Epoch 71/500
5/5 [==============================] - 0s 31ms/step - loss: 0.0033 - val_loss:
8.8216e-04
Epoch 72/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0036 - val_loss:
8.1131e-04
Epoch 73/500
```

```
5/5 [==============================] - 0s 26ms/step - loss: 0.0042 - val_loss:
8.9578e-04
Epoch 74/500
5/5 [==============================] - 0s 28ms/step - loss: 0.0033 - val_loss:
7.6935e-04
Epoch 75/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0032 - val_loss:
8.0943e-04
Epoch 76/500
5/5 [==============================] - 0s 28ms/step - loss: 0.0042 - val_loss:
7.6429e-04
Epoch 77/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0033 - val_loss:
7.3040e-04
Epoch 78/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0035 - val_loss:
7.1335e-04
Epoch 79/500
5/5 [==============================] - 0s 32ms/step - loss: 0.0033 - val_loss:
6.8846e-04
Epoch 80/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0037 - val_loss:
7.3325e-04
Epoch 81/500
5/5 [==============================] - 0s 30ms/step - loss: 0.0036 - val_loss:
6.2907e-04
Epoch 82/500
5/5 [==============================] - 0s 36ms/step - loss: 0.0044 - val_loss:
7.3350e-04
Epoch 83/500
5/5 [==============================] - 0s 39ms/step - loss: 0.0029 - val_loss:
6.5565e-04
Epoch 84/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0029 - val_loss:
6.1025e-04
Epoch 85/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0033 - val_loss:
5.7190e-04
Epoch 86/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0033 - val_loss:
5.6019e-04
Epoch 87/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0035 - val_loss:
5.4564e-04
Epoch 88/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0039 - val_loss:
5.5894e-04
Epoch 89/500
```

```
5/5 [==============================] - 0s 20ms/step - loss: 0.0035 - val_loss:
5.9066e-04
Epoch 90/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0035 - val_loss:
5.9336e-04
Epoch 91/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0030 - val_loss:
4.9684e-04
Epoch 92/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0037 - val_loss:
5.1024e-04
Epoch 93/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0036 - val_loss:
4.7934e-04
Epoch 94/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0033 - val_loss:
5.4168e-04
Epoch 95/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0037 - val_loss:
5.7159e-04
Epoch 96/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0039 - val_loss:
4.5014e-04
Epoch 97/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0032 - val_loss:
5.0201e-04
Epoch 98/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0037 - val_loss:
5.5448e-04
Epoch 99/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0046 - val_loss:
4.9969e-04
Epoch 100/500
5/5 [==============================] - 0s 38ms/step - loss: 0.0034 - val_loss:
3.9909e-04
Epoch 101/500
5/5 [==============================] - 0s 29ms/step - loss: 0.0039 - val_loss:
5.1684e-04
Epoch 102/500
5/5 [==============================] - 0s 28ms/step - loss: 0.0032 - val_loss:
3.8593e-04
Epoch 103/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0033 - val_loss:
5.2032e-04
Epoch 104/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0031 - val_loss:
4.4928e-04
Epoch 105/500
```

```
5/5 [==============================] - 0s 38ms/step - loss: 0.0027 - val_loss:
3.8514e-04
Epoch 106/500
5/5 [==============================] - 0s 56ms/step - loss: 0.0029 - val_loss:
3.7675e-04
Epoch 107/500
5/5 [==============================] - 0s 52ms/step - loss: 0.0035 - val_loss:
4.9105e-04
Epoch 108/500
5/5 [==============================] - 0s 56ms/step - loss: 0.0030 - val_loss:
5.8172e-04
Epoch 109/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0024 - val_loss:
3.6290e-04
Epoch 110/500
5/5 [==============================] - 0s 32ms/step - loss: 0.0035 - val_loss:
3.6751e-04
Epoch 111/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0037 - val_loss:
3.9655e-04
Epoch 112/500
5/5 [==============================] - 0s 40ms/step - loss: 0.0044 - val_loss:
4.3258e-04
Epoch 113/500
5/5 [==============================] - 0s 53ms/step - loss: 0.0035 - val_loss:
3.7351e-04
Epoch 114/500
5/5 [==============================] - 0s 33ms/step - loss: 0.0028 - val_loss:
4.1800e-04
Epoch 115/500
5/5 [==============================] - 0s 36ms/step - loss: 0.0030 - val_loss:
3.7421e-04
Epoch 116/500
5/5 [==============================] - 0s 35ms/step - loss: 0.0034 - val_loss:
3.8733e-04
Epoch 117/500
5/5 [==============================] - 0s 27ms/step - loss: 0.0048 - val_loss:
3.7535e-04
Epoch 118/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0029 - val_loss:
3.6071e-04
Epoch 119/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0032 - val_loss:
4.0626e-04
Epoch 120/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0027 - val_loss:
4.0235e-04
Epoch 121/500
```

```
5/5 [==============================] - 0s 16ms/step - loss: 0.0033 - val_loss:
3.9590e-04
Epoch 122/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0034 - val_loss:
3.8472e-04
Epoch 123/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0030 - val_loss:
3.8875e-04
Epoch 124/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0041 - val_loss:
3.5514e-04
Epoch 125/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0037 - val_loss:
3.8916e-04
Epoch 126/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0022 - val_loss:
5.2115e-04
Epoch 127/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0029 - val_loss:
3.8682e-04
Epoch 128/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0026 - val_loss:
3.5161e-04
Epoch 129/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0030 - val_loss:
3.6223e-04
Epoch 130/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0031 - val_loss:
3.6758e-04
Epoch 131/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0030 - val_loss:
3.4180e-04
Epoch 132/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0027 - val_loss:
3.5065e-04
Epoch 133/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0027 - val_loss:
4.1101e-04
Epoch 134/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0025 - val_loss:
3.4629e-04
Epoch 135/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0026 - val_loss:
3.2461e-04
Epoch 136/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0033 - val_loss:
3.5976e-04
Epoch 137/500
```

```
5/5 [==============================] - 0s 16ms/step - loss: 0.0029 - val_loss:
3.4724e-04
Epoch 138/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0030 - val_loss:
3.4137e-04
Epoch 139/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0023 - val_loss:
3.1256e-04
Epoch 140/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0032 - val_loss:
3.0933e-04
Epoch 141/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0024 - val_loss:
4.0256e-04
Epoch 142/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0029 - val_loss:
3.3250e-04
Epoch 143/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0026 - val_loss:
3.4507e-04
Epoch 144/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0041 - val_loss:
3.1024e-04
Epoch 145/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0031 - val_loss:
5.4983e-04
Epoch 146/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0030 - val_loss:
6.7596e-04
Epoch 147/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0025 - val_loss:
3.1714e-04
Epoch 148/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0039 - val_loss:
3.1764e-04
Epoch 149/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0031 - val_loss:
4.1810e-04
Epoch 150/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0025 - val_loss:
3.3002e-04
Epoch 151/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0027 - val_loss:
2.9901e-04
Epoch 152/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0028 - val_loss:
3.4664e-04
Epoch 153/500
```

```
5/5 [==============================] - 0s 21ms/step - loss: 0.0026 - val_loss:
3.3533e-04
Epoch 154/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0030 - val_loss:
2.9405e-04
Epoch 155/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0026 - val_loss:
2.9966e-04
Epoch 156/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0028 - val_loss:
2.8801e-04
Epoch 157/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0025 - val_loss:
4.8648e-04
Epoch 158/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0028 - val_loss:
3.0956e-04
Epoch 159/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0030 - val_loss:
2.9332e-04
Epoch 160/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0030 - val_loss:
2.8673e-04
Epoch 161/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0030 - val_loss:
4.3558e-04
Epoch 162/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0027 - val_loss:
6.0159e-04
Epoch 163/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0031 - val_loss:
3.0097e-04
Epoch 164/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0028 - val_loss:
3.7235e-04
Epoch 165/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0026 - val_loss:
3.5714e-04
Epoch 166/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0025 - val_loss:
3.8383e-04
Epoch 167/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0030 - val_loss:
3.4100e-04
Epoch 168/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0021 - val_loss:
2.9631e-04
Epoch 169/500
```

```
5/5 [==============================] - 0s 15ms/step - loss: 0.0021 - val_loss:
3.4103e-04
Epoch 170/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0028 - val_loss:
3.1576e-04
Epoch 171/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0026 - val_loss:
3.0497e-04
Epoch 172/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0024 - val_loss:
3.1277e-04
Epoch 173/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0027 - val_loss:
2.7579e-04
Epoch 174/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0029 - val_loss:
3.4877e-04
Epoch 175/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0030 - val_loss:
4.1510e-04
Epoch 176/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0026 - val_loss:
3.9034e-04
Epoch 177/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0033 - val_loss:
2.7866e-04
Epoch 178/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0026 - val_loss:
3.1857e-04
Epoch 179/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0025 - val_loss:
2.9339e-04
Epoch 180/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0019 - val_loss:
4.0230e-04
Epoch 181/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0025 - val_loss:
2.9371e-04
Epoch 182/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0029 - val_loss:
2.6474e-04
Epoch 183/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0023 - val_loss:
2.5367e-04
Epoch 184/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0031 - val_loss:
3.0565e-04
Epoch 185/500
```

```
5/5 [==============================] - 0s 13ms/step - loss: 0.0023 - val_loss:
2.7684e-04
Epoch 186/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0023 - val_loss:
2.6016e-04
Epoch 187/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0021 - val_loss:
4.3397e-04
Epoch 188/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0030 - val_loss:
3.7924e-04
Epoch 189/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0023 - val_loss:
2.6777e-04
Epoch 190/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0026 - val_loss:
2.5484e-04
Epoch 191/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0029 - val_loss:
5.2071e-04
Epoch 192/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0024 - val_loss:
2.8225e-04
Epoch 193/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0027 - val_loss:
5.6574e-04
Epoch 194/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0028 - val_loss:
3.4384e-04
Epoch 195/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0031 - val_loss:
5.9430e-04
Epoch 196/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0026 - val_loss:
2.7050e-04
Epoch 197/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0022 - val_loss:
2.5908e-04
Epoch 198/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0022 - val_loss:
2.4737e-04
Epoch 199/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0024 - val_loss:
2.4960e-04
Epoch 200/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0021 - val_loss:
3.7333e-04
Epoch 201/500
```

```
5/5 [==============================] - 0s 12ms/step - loss: 0.0024 - val_loss:
2.4265e-04
Epoch 202/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0025 - val_loss:
2.3637e-04
Epoch 203/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0026 - val_loss:
2.9017e-04
Epoch 204/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0023 - val_loss:
2.3915e-04
Epoch 205/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0024 - val_loss:
2.9858e-04
Epoch 206/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
2.5333e-04
Epoch 207/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0025 - val_loss:
2.2982e-04
Epoch 208/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0024 - val_loss:
2.6711e-04
Epoch 209/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0022 - val_loss:
3.8699e-04
Epoch 210/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0019 - val_loss:
2.3973e-04
Epoch 211/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0024 - val_loss:
2.3211e-04
Epoch 212/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0030 - val_loss:
2.4851e-04
Epoch 213/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0025 - val_loss:
3.3564e-04
Epoch 214/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0026 - val_loss:
2.2720e-04
Epoch 215/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0024 - val_loss:
2.7390e-04
Epoch 216/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0025 - val_loss:
2.6289e-04
Epoch 217/500
```

```
5/5 [==============================] - 0s 23ms/step - loss: 0.0022 - val_loss:
2.3618e-04
Epoch 218/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0029 - val_loss:
4.4194e-04
Epoch 219/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0026 - val_loss:
2.8562e-04
Epoch 220/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0029 - val_loss:
2.2658e-04
Epoch 221/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0022 - val_loss:
2.2251e-04
Epoch 222/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0022 - val_loss:
2.4503e-04
Epoch 223/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0021 - val_loss:
2.8811e-04
Epoch 224/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0023 - val_loss:
2.1840e-04
Epoch 225/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0021 - val_loss:
2.9100e-04
Epoch 226/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0022 - val_loss:
2.6043e-04
Epoch 227/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0023 - val_loss:
2.1381e-04
Epoch 228/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0023 - val_loss:
2.1949e-04
Epoch 229/500
5/5 [==============================] - 0s 26ms/step - loss: 0.0023 - val_loss:
2.1458e-04
Epoch 230/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0020 - val_loss:
3.7064e-04
Epoch 231/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0016 - val_loss:
2.2106e-04
Epoch 232/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0024 - val_loss:
1.9575e-04
Epoch 233/500
```

```
5/5 [==============================] - 0s 22ms/step - loss: 0.0029 - val_loss:
3.2451e-04
Epoch 234/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0027 - val_loss:
3.7861e-04
Epoch 235/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0029 - val_loss:
2.2276e-04
Epoch 236/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0022 - val_loss:
2.3574e-04
Epoch 237/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0024 - val_loss:
3.1645e-04
Epoch 238/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0027 - val_loss:
1.9097e-04
Epoch 239/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0019 - val_loss:
2.0696e-04
Epoch 240/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0031 - val_loss:
2.7087e-04
Epoch 241/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0022 - val_loss:
3.0890e-04
Epoch 242/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0023 - val_loss:
1.9795e-04
Epoch 243/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0018 - val_loss:
1.9323e-04
Epoch 244/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0023 - val_loss:
2.3050e-04
Epoch 245/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0022 - val_loss:
1.8667e-04
Epoch 246/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0020 - val_loss:
2.0891e-04
Epoch 247/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0022 - val_loss:
2.7025e-04
Epoch 248/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0022 - val_loss:
1.9264e-04
Epoch 249/500
```

```
5/5 [==============================] - 0s 12ms/step - loss: 0.0027 - val_loss:
1.7387e-04
Epoch 250/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0020 - val_loss:
1.9142e-04
Epoch 251/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0013 - val_loss:
1.9304e-04
Epoch 252/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0021 - val_loss:
1.9754e-04
Epoch 253/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0027 - val_loss:
1.7107e-04
Epoch 254/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0019 - val_loss:
2.7844e-04
Epoch 255/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0024 - val_loss:
2.1436e-04
Epoch 256/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0022 - val_loss:
2.0409e-04
Epoch 257/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0023 - val_loss:
1.9779e-04
Epoch 258/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0019 - val_loss:
3.2387e-04
Epoch 259/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0022 - val_loss:
1.8045e-04
Epoch 260/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0020 - val_loss:
1.7603e-04
Epoch 261/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0017 - val_loss:
2.4176e-04
Epoch 262/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0019 - val_loss:
4.2712e-04
Epoch 263/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0019 - val_loss:
1.8302e-04
Epoch 264/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0024 - val_loss:
2.0030e-04
Epoch 265/500
```

```
5/5 [==============================] - 0s 16ms/step - loss: 0.0022 - val_loss:
2.4154e-04
Epoch 266/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0022 - val_loss:
1.7402e-04
Epoch 267/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0019 - val_loss:
2.6533e-04
Epoch 268/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0022 - val_loss:
1.6312e-04
Epoch 269/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0018 - val_loss:
2.8381e-04
Epoch 270/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0020 - val_loss:
1.6452e-04
Epoch 271/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0023 - val_loss:
1.5357e-04
Epoch 272/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0019 - val_loss:
1.6997e-04
Epoch 273/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0018 - val_loss:
2.0171e-04
Epoch 274/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0018 - val_loss:
2.2108e-04
Epoch 275/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0024 - val_loss:
1.4940e-04
Epoch 276/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0018 - val_loss:
1.5122e-04
Epoch 277/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0019 - val_loss:
3.8037e-04
Epoch 278/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
2.3337e-04
Epoch 279/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0023 - val_loss:
1.6897e-04
Epoch 280/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0020 - val_loss:
1.5485e-04
Epoch 281/500
```

```
5/5 [==============================] - 0s 13ms/step - loss: 0.0019 - val_loss:
1.5495e-04
Epoch 282/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0019 - val_loss:
1.5465e-04
Epoch 283/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0022 - val_loss:
3.3934e-04
Epoch 284/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0017 - val_loss:
3.2883e-04
Epoch 285/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0026 - val_loss:
1.8116e-04
Epoch 286/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0019 - val_loss:
1.5180e-04
Epoch 287/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0020 - val_loss:
1.9539e-04
Epoch 288/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0018 - val_loss:
1.8148e-04
Epoch 289/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0022 - val_loss:
1.9961e-04
Epoch 290/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0019 - val_loss:
1.4632e-04
Epoch 291/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0019 - val_loss:
1.3432e-04
Epoch 292/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0019 - val_loss:
1.8334e-04
Epoch 293/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0016 - val_loss:
1.6679e-04
Epoch 294/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0014 - val_loss:
1.3245e-04
Epoch 295/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0023 - val_loss:
1.4864e-04
Epoch 296/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0014 - val_loss:
2.2566e-04
Epoch 297/500
```

```
5/5 [==============================] - 0s 21ms/step - loss: 0.0018 - val_loss:
1.6399e-04
Epoch 298/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0017 - val_loss:
1.6726e-04
Epoch 299/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0018 - val_loss:
2.7721e-04
Epoch 300/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0024 - val_loss:
2.1534e-04
Epoch 301/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0017 - val_loss:
1.3526e-04
Epoch 302/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0019 - val_loss:
1.2803e-04
Epoch 303/500
5/5 [==============================] - 0s 27ms/step - loss: 0.0019 - val_loss:
1.3224e-04
Epoch 304/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0016 - val_loss:
1.4036e-04
Epoch 305/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0016 - val_loss:
1.6968e-04
Epoch 306/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0016 - val_loss:
1.5016e-04
Epoch 307/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0020 - val_loss:
2.6786e-04
Epoch 308/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0018 - val_loss:
1.2032e-04
Epoch 309/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0020 - val_loss:
1.2162e-04
Epoch 310/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0018 - val_loss:
4.4597e-04
Epoch 311/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0021 - val_loss:
1.2740e-04
Epoch 312/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0015 - val_loss:
1.9502e-04
Epoch 313/500
```

```
5/5 [==============================] - 0s 21ms/step - loss: 0.0018 - val_loss:
2.1285e-04
Epoch 314/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0019 - val_loss:
1.3723e-04
Epoch 315/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0016 - val_loss:
1.3521e-04
Epoch 316/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0019 - val_loss:
1.2288e-04
Epoch 317/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0017 - val_loss:
1.0876e-04
Epoch 318/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0021 - val_loss:
1.6900e-04
Epoch 319/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0016 - val_loss:
1.5932e-04
Epoch 320/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0017 - val_loss:
1.0691e-04
Epoch 321/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0020 - val_loss:
1.0032e-04
Epoch 322/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0020 - val_loss:
1.1078e-04
Epoch 323/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0014 - val_loss:
1.8142e-04
Epoch 324/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0018 - val_loss:
1.0375e-04
Epoch 325/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0019 - val_loss:
1.0031e-04
Epoch 326/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
3.4840e-04
Epoch 327/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0018 - val_loss:
1.0545e-04
Epoch 328/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0021 - val_loss:
2.4683e-04
Epoch 329/500
```

```
5/5 [==============================] - 0s 14ms/step - loss: 0.0017 - val_loss:
2.4372e-04
Epoch 330/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
1.5460e-04
Epoch 331/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0018 - val_loss:
1.0909e-04
Epoch 332/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0019 - val_loss:
1.0169e-04
Epoch 333/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0018 - val_loss:
9.8665e-05
Epoch 334/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0015 - val_loss:
1.4479e-04
Epoch 335/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0016 - val_loss:
1.1459e-04
Epoch 336/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0015 - val_loss:
9.3361e-05
Epoch 337/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0013 - val_loss:
1.8337e-04
Epoch 338/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0017 - val_loss:
1.8708e-04
Epoch 339/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0017 - val_loss:
9.1815e-05
Epoch 340/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0019 - val_loss:
9.1369e-05
Epoch 341/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
1.7257e-04
Epoch 342/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0015 - val_loss:
1.6682e-04
Epoch 343/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0019 - val_loss:
2.1702e-04
Epoch 344/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0012 - val_loss:
1.0222e-04
Epoch 345/500
```

```
5/5 [==============================] - 0s 14ms/step - loss: 0.0016 - val_loss:
1.0369e-04
Epoch 346/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0018 - val_loss:
2.5636e-04
Epoch 347/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0014 - val_loss:
1.4463e-04
Epoch 348/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0018 - val_loss:
9.4357e-05
Epoch 349/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0019 - val_loss:
2.6383e-04
Epoch 350/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
1.7797e-04
Epoch 351/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
1.0744e-04
Epoch 352/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0014 - val_loss:
1.3752e-04
Epoch 353/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0017 - val_loss:
1.4070e-04
Epoch 354/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0014 - val_loss:
1.1543e-04
Epoch 355/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
1.0777e-04
Epoch 356/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0017 - val_loss:
8.8594e-05
Epoch 357/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0015 - val_loss:
9.1161e-05
Epoch 358/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0012 - val_loss:
1.1523e-04
Epoch 359/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0016 - val_loss:
1.8122e-04
Epoch 360/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0015 - val_loss:
7.8845e-05
Epoch 361/500
```

```
5/5 [==============================] - 0s 19ms/step - loss: 0.0016 - val_loss:
8.3087e-05
Epoch 362/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
1.9238e-04
Epoch 363/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0013 - val_loss:
9.0686e-05
Epoch 364/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0013 - val_loss:
1.2609e-04
Epoch 365/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0014 - val_loss:
1.9295e-04
Epoch 366/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
1.0182e-04
Epoch 367/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0018 - val_loss:
1.6127e-04
Epoch 368/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0013 - val_loss:
2.1886e-04
Epoch 369/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
8.8864e-05
Epoch 370/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
1.4227e-04
Epoch 371/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0017 - val_loss:
9.0721e-05
Epoch 372/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
9.6437e-05
Epoch 373/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0013 - val_loss:
1.1373e-04
Epoch 374/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
1.7051e-04
Epoch 375/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0017 - val_loss:
1.0154e-04
Epoch 376/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0015 - val_loss:
1.9843e-04
Epoch 377/500
```

```
5/5 [==============================] - 0s 12ms/step - loss: 0.0016 - val_loss:
3.0738e-04
Epoch 378/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0017 - val_loss:
6.5728e-05
Epoch 379/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
7.7227e-05
Epoch 380/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0019 - val_loss:
8.3487e-05
Epoch 381/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0018 - val_loss:
9.4798e-05
Epoch 382/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0016 - val_loss:
7.9667e-05
Epoch 383/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0016 - val_loss:
1.2094e-04
Epoch 384/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0015 - val_loss:
1.6737e-04
Epoch 385/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
1.0281e-04
Epoch 386/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
7.7488e-05
Epoch 387/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0017 - val_loss:
7.3213e-05
Epoch 388/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0017 - val_loss:
1.1979e-04
Epoch 389/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0012 - val_loss:
7.6036e-05
Epoch 390/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0012 - val_loss:
8.0427e-05
Epoch 391/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0015 - val_loss:
6.7479e-05
Epoch 392/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0017 - val_loss:
6.4596e-05
Epoch 393/500
```

```
5/5 [==============================] - 0s 16ms/step - loss: 9.9530e-04 -
val_loss: 6.7436e-05
Epoch 394/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
8.4544e-05
Epoch 395/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0012 - val_loss:
8.4352e-05
Epoch 396/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
1.1347e-04
Epoch 397/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
1.4998e-04
Epoch 398/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0018 - val_loss:
5.0233e-05
Epoch 399/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0015 - val_loss:
4.7874e-05
Epoch 400/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0014 - val_loss:
1.9087e-04
Epoch 401/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
4.9715e-05
Epoch 402/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0012 - val_loss:
2.0428e-04
Epoch 403/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0016 - val_loss:
5.7150e-05
Epoch 404/500
5/5 [==============================] - 0s 16ms/step - loss: 9.6679e-04 -
val_loss: 7.7368e-05
Epoch 405/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
1.1854e-04
Epoch 406/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0013 - val_loss:
9.5956e-05
Epoch 407/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0015 - val_loss:
7.3167e-05
Epoch 408/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0014 - val_loss:
8.3072e-05
Epoch 409/500
```

```
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
9.6119e-05
Epoch 410/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0011 - val_loss:
1.1445e-04
Epoch 411/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0014 - val_loss:
1.8172e-04
Epoch 412/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
6.8119e-05
Epoch 413/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0011 - val_loss:
7.0947e-05
Epoch 414/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0013 - val_loss:
5.9634e-05
Epoch 415/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
1.1268e-04
Epoch 416/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0014 - val_loss:
2.4939e-04
Epoch 417/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0016 - val_loss:
1.0677e-04
Epoch 418/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0014 - val_loss:
7.8958e-05
Epoch 419/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0014 - val_loss:
3.0993e-04
Epoch 420/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
1.0186e-04
Epoch 421/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0017 - val_loss:
4.9070e-05
Epoch 422/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
9.3361e-05
Epoch 423/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0015 - val_loss:
4.4142e-05
Epoch 424/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0013 - val_loss:
5.0496e-05
Epoch 425/500
```

```
5/5 [==============================] - 0s 13ms/step - loss: 0.0012 - val_loss:
5.3909e-05
Epoch 426/500
5/5 [==============================] - 0s 16ms/step - loss: 0.0010 - val_loss:
4.2691e-05
Epoch 427/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
4.4804e-05
Epoch 428/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0015 - val_loss:
1.1914e-04
Epoch 429/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0015 - val_loss:
4.2028e-05
Epoch 430/500
5/5 [==============================] - 0s 14ms/step - loss: 0.0011 - val_loss:
4.0223e-05
Epoch 431/500
5/5 [==============================] - 0s 16ms/step - loss: 9.5965e-04 -
val_loss: 5.5334e-05
Epoch 432/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0014 - val_loss:
1.8083e-04
Epoch 433/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0011 - val_loss:
4.2562e-05
Epoch 434/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0012 - val_loss:
5.3643e-05
Epoch 435/500
5/5 [==============================] - 0s 17ms/step - loss: 8.8408e-04 -
val_loss: 1.1036e-04
Epoch 436/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0015 - val_loss:
9.1791e-05
Epoch 437/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0013 - val_loss:
1.1104e-04
Epoch 438/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
1.2496e-04
Epoch 439/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0011 - val_loss:
3.9110e-05
Epoch 440/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0014 - val_loss:
9.7210e-05
Epoch 441/500
```

```
5/5 [==============================] - 0s 14ms/step - loss: 0.0012 - val_loss:
8.6851e-05
Epoch 442/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0012 - val_loss:
4.7905e-05
Epoch 443/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
4.4892e-05
Epoch 444/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0017 - val_loss:
1.8664e-04
Epoch 445/500
5/5 [==============================] - 0s 18ms/step - loss: 9.8753e-04 -
val_loss: 7.8578e-05
Epoch 446/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0011 - val_loss:
8.8549e-05
Epoch 447/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
1.0328e-04
Epoch 448/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0012 - val_loss:
2.1879e-04
Epoch 449/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
5.0996e-05
Epoch 450/500
5/5 [==============================] - 0s 12ms/step - loss: 0.0013 - val_loss:
1.7394e-04
Epoch 451/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0014 - val_loss:
2.2234e-04
Epoch 452/500
5/5 [==============================] - 0s 17ms/step - loss: 9.9446e-04 -
val_loss: 9.8510e-05
Epoch 453/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
9.5854e-05
Epoch 454/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0012 - val_loss:
2.6327e-04
Epoch 455/500
5/5 [==============================] - 0s 18ms/step - loss: 9.4526e-04 -
val_loss: 8.4269e-05
Epoch 456/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0011 - val_loss:
1.3061e-04
Epoch 457/500
```

```
5/5 [==============================] - 0s 23ms/step - loss: 0.0016 - val_loss:
9.4579e-05
Epoch 458/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0013 - val_loss:
1.3939e-04
Epoch 459/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0011 - val_loss:
1.0607e-04
Epoch 460/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0013 - val_loss:
1.3245e-04
Epoch 461/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0011 - val_loss:
1.0167e-04
Epoch 462/500
5/5 [==============================] - 0s 20ms/step - loss: 0.0011 - val_loss:
9.6944e-05
Epoch 463/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0014 - val_loss:
6.6236e-05
Epoch 464/500
5/5 [==============================] - 0s 18ms/step - loss: 9.3739e-04 -
val_loss: 1.5552e-04
Epoch 465/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0012 - val_loss:
5.8215e-05
Epoch 466/500
5/5 [==============================] - 0s 23ms/step - loss: 9.9902e-04 -
val_loss: 1.2450e-04
Epoch 467/500
5/5 [==============================] - 0s 28ms/step - loss: 0.0012 - val_loss:
2.0872e-04
Epoch 468/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0016 - val_loss:
6.4797e-05
Epoch 469/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0012 - val_loss:
9.2896e-05
Epoch 470/500
5/5 [==============================] - 0s 18ms/step - loss: 9.9799e-04 -
val_loss: 1.3583e-04
Epoch 471/500
5/5 [==============================] - 0s 24ms/step - loss: 0.0012 - val_loss:
1.1004e-04
Epoch 472/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0011 - val_loss:
5.0771e-05
Epoch 473/500
```

```
5/5 [==============================] - 0s 22ms/step - loss: 0.0014 - val_loss:
6.9127e-05
Epoch 474/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0011 - val_loss:
3.2355e-04
Epoch 475/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0010 - val_loss:
5.9108e-05
Epoch 476/500
5/5 [==============================] - 0s 23ms/step - loss: 8.8853e-04 -
val_loss: 5.2941e-05
Epoch 477/500
5/5 [==============================] - 0s 21ms/step - loss: 9.0420e-04 -
val_loss: 6.3423e-05
Epoch 478/500
5/5 [==============================] - 0s 20ms/step - loss: 9.9509e-04 -
val_loss: 1.0178e-04
Epoch 479/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0012 - val_loss:
1.0830e-04
Epoch 480/500
5/5 [==============================] - 0s 21ms/step - loss: 0.0010 - val_loss:
5.7170e-05
Epoch 481/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0012 - val_loss:
6.3400e-05
Epoch 482/500
5/5 [==============================] - 0s 19ms/step - loss: 9.6164e-04 -
val_loss: 4.4178e-05
Epoch 483/500
5/5 [==============================] - 0s 20ms/step - loss: 9.0798e-04 -
val_loss: 5.4542e-05
Epoch 484/500
5/5 [==============================] - 0s 25ms/step - loss: 0.0011 - val_loss:
8.0816e-05
Epoch 485/500
5/5 [==============================] - 0s 19ms/step - loss: 0.0010 - val_loss:
4.3282e-05
Epoch 486/500
5/5 [==============================] - 0s 22ms/step - loss: 0.0010 - val_loss:
5.9225e-05
Epoch 487/500
5/5 [==============================] - 0s 23ms/step - loss: 0.0011 - val_loss:
2.4141e-04
Epoch 488/500
5/5 [==============================] - 0s 28ms/step - loss: 0.0010 - val_loss:
8.3615e-05
Epoch 489/500
```

```
5/5 [==============================] - 0s 27ms/step - loss: 0.0011 - val_loss:
4.8538e-05
Epoch 490/500
5/5 [==============================] - 0s 15ms/step - loss: 0.0013 - val_loss:
3.2798e-04
Epoch 491/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0013 - val_loss:
5.6893e-05
Epoch 492/500
5/5 [==============================] - 0s 14ms/step - loss: 9.4746e-04 -
val_loss: 5.8685e-05
Epoch 493/500
5/5 [==============================] - 0s 18ms/step - loss: 0.0010 - val_loss:
8.7827e-05
Epoch 494/500
5/5 [==============================] - 0s 13ms/step - loss: 0.0013 - val_loss:
7.8305e-05
Epoch 495/500
5/5 [==============================] - 0s 14ms/step - loss: 9.0334e-04 -
val_loss: 2.3932e-04
Epoch 496/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0013 - val_loss:
6.3198e-05
Epoch 497/500
5/5 [==============================] - 0s 18ms/step - loss: 9.0533e-04 -
val_loss: 5.4453e-05
Epoch 498/500
5/5 [==============================] - 0s 17ms/step - loss: 9.2059e-04 -
val_loss: 7.9729e-05
Epoch 499/500
5/5 [==============================] - 0s 17ms/step - loss: 0.0012 - val_loss:
4.4347e-05
Epoch 500/500
5/5 [==============================] - 0s 18ms/step - loss: 9.3051e-04 -
val_loss: 5.7166e-05
```

Predicciones con el modelo LSTM:

[9]:
```python
# Generamos predicciones sobre los datos de prueba usando el modelo LSTM␣
 ↪entrenado
lstm_predictions = pd.Series(lstm_model.predict(X_test_lstm).flatten(),␣
 ↪index=X_test.index)
```

```
2/2 [==============================] - 1s 9ms/step
```

Cálculo de métricas de validación:

[10]:
```python
# Calculamos el MAPE (Mean Absolute Percentage Error) para evaluar la precisión␣
 ↪del modelo
```

```python
mape_lstm = mean_absolute_percentage_error(y_test, lstm_predictions)
# Calculamos el RMSE (Root Mean Squared Error) para evaluar el error del modelo
rmse_lstm = np.sqrt(mean_squared_error(y_test, lstm_predictions))

# Imprimimos las métricas de validación
print(f'MAPE LSTM: {mape_lstm}')
print(f'RMSE LSTM: {rmse_lstm}')
```

```
MAPE LSTM: 15383864263620.277
RMSE LSTM: 0.04525085860789593
```