```
# Install required libraries
!pip install yfinance numpy pandas matplotlib scikit-learn tensorflow

import yfinance as yf
import pandas as pd
import random
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import requests                                     #ADDED
from textblob import TextBlob                       #ADDED

data = pd.read_csv('Book.csv')         #ADDED

# Set seeds for reproducibility
random.seed(42)
np.random.seed(42)
tf.random.set_seed(42)

# Define the tickers for Bitcoin, Ethereum, and Litecoin
cryptos = ['BTC-USD', 'ETH-USD', 'LTC-USD']

# Define the start and end date for the data
start_date = '2019-01-01'
end_date = '2024-01-01'

# Create an empty dictionary to store the data
crypto_data = {}

# Download and store data in the dictionary
for ticker in cryptos:
    crypto_data[ticker] = yf.download(ticker, start=start_date,
end=end_date)

    # Display the first few rows of each dataframe
    print(f"Showing data for {ticker}:")
    display(crypto_data[ticker].head())

# Function to fetch sentiment data (example using Twitter API)
def fetch_sentiment_data(keyword, start_date, end_date):
#ADDED
    dates = pd.date_range(start=start_date, end=end_date)
    #sentiment_scores = np.random.uniform(-1, 1, len(dates))
#COMMENTED OUT
    sentiment_scores = [TextBlob(sentence).sentiment.polarity for
sentence in data['Tweet']]
    sentiment_data = pd.DataFrame({'Sentiment':
sentiment_scores},index=dates)                              #REMOVE
'Date': dates  #ADDED index=dates
```

```
    #sentiment_data.set_index('Date', inplace=True)
#COMMENTED OUT
    return sentiment_data

# Fetch sentiment data for Bitcoin
btc_sentiment = fetch_sentiment_data('Bitcoin', start_date,
end_date='2023-12-31')                              #ADDED

from sklearn.preprocessing import MinMaxScaler

# Assuming we're working with Bitcoin data for this example
btc_data = crypto_data['BTC-USD']

# 1. Handle missing data
# For simplicity, we'll fill missing values with the last available
value
btc_data.fillna(method='ffill', inplace=True)



# Flatten the multi-level columns in the Bitcoin data
#ADDED
btc_data.columns = [f"{col[0]}_{col[1]}" for col in btc_data.columns]

# Rename columns by removing '_BTC-USD' suffix
#ADDED
btc_data.columns = [col.replace('_BTC-USD', '') for col in
btc_data.columns]

# Ensure both DataFrames have datetime index
#ADDED
btc_data.index = pd.to_datetime(btc_data.index)
btc_sentiment.index = pd.to_datetime(btc_sentiment.index)









#btc_data = btc_data.merge(btc_sentiment, left_index=True,
right_index=True)                    #ADDED      #COMMENTED OUT

# Merge Bitcoin data with sentiment data
btc_data = btc_data.join(btc_sentiment, how='left')


print(btc_data)
```

```
# 2. Normalize the features
scaler = MinMaxScaler(feature_range=(0, 1))
scaled_data_btc = scaler.fit_transform(btc_data[['Open', 'High',
'Low', 'Close', 'Sentiment']])  #CHANGE: REMOVED 'Adj Close'
#ADDED 'Sentiment'

# 3. Convert the data into a time series format
def create_dataset(dataset, look_back=1):
    X, Y = [], []
    for i in range(len(dataset) - look_back - 1):
        #a = dataset[i:(i + look_back), :]
#WRONG
        a = dataset[i:(i + look_back), [0, 1, 2, 4]]  # Include
'Open', 'High', 'Low', and 'Sentiment'     #EXCLUDING TARGET
        X.append(a)
        Y.append(dataset[i + look_back, -2])  # Assuming close price
is the target variable   #ADDED CHANGE -1 TO -2 to refer to 'Close'
    return np.array(X), np.array(Y)

# Define look_back period
look_back = 60  # for example, using past 60 days to predict the next
day

# Split into features (X) and target (Y)
X_btc, Y_btc = create_dataset(scaled_data_btc, look_back)

# Reshape features into the format expected by LSTM (samples, time
steps, features)
X_btc = np.reshape(X_btc, (X_btc.shape[0], look_back, X_btc.shape[2]))

# Split into train and test sets
split_percent = 0.80
split = int(split_percent * len(X_btc))

X_train_btc = X_btc[:split]
Y_train_btc = Y_btc[:split]
X_test_btc = X_btc[split:]
Y_test_btc = Y_btc[split:]

print("Data preprocessed and ready for model training.")

# Import TensorFlow for model training
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, GRU, Bidirectional

# Define the LSTM model
lstm_model = Sequential()
```

```python
lstm_model.add(LSTM(units=100, return_sequences=True,
input_shape=(X_train_btc.shape[1], X_train_btc.shape[2])))
lstm_model.add(LSTM(units=100))
lstm_model.add(Dense(1))

lstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the GRU model
gru_model = Sequential()
gru_model.add(GRU(units=100, return_sequences=True,
input_shape=(X_train_btc.shape[1], X_train_btc.shape[2])))
gru_model.add(GRU(units=100))
gru_model.add(Dense(1))

gru_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the BiLSTM model
bilstm_model = Sequential()
bilstm_model.add(Bidirectional(LSTM(units=100, return_sequences=True),
input_shape=(X_train_btc.shape[1], X_train_btc.shape[2])))
bilstm_model.add(Bidirectional(LSTM(units=100)))
bilstm_model.add(Dense(1))

bilstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Train the models
lstm_history = lstm_model.fit(X_train_btc, Y_train_btc, epochs=100,
batch_size=32, validation_data=(X_test_btc, Y_test_btc), verbose=1)
gru_history = gru_model.fit(X_train_btc, Y_train_btc, epochs=100,
batch_size=32, validation_data=(X_test_btc, Y_test_btc), verbose=1)
bilstm_history = bilstm_model.fit(X_train_btc, Y_train_btc,
epochs=100, batch_size=32, validation_data=(X_test_btc, Y_test_btc),
verbose=1)

# Evaluate the models
lstm_scores = lstm_model.evaluate(X_test_btc, Y_test_btc, verbose=0)
gru_scores = gru_model.evaluate(X_test_btc, Y_test_btc, verbose=0)
bilstm_scores = bilstm_model.evaluate(X_test_btc, Y_test_btc,
verbose=0)

print('LSTM Test loss:', lstm_scores)
print('GRU Test loss:', gru_scores)
print('BiLSTM Test loss:', bilstm_scores)

# Plot training and validation loss
plt.figure(figsize=(18, 5))
plt.subplot(1, 3, 1)
plt.plot(lstm_history.history['loss'], label='LSTM training Loss')
plt.plot(lstm_history.history['val_loss'], label='LSTM Validation
Loss')
```

```
plt.title('LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()


plt.subplot(1, 3, 2)
plt.plot(gru_history.history['loss'], label='GRU training Loss')
plt.plot(gru_history.history['val_loss'], label='GRU Validation Loss')
plt.title('GRU Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()



plt.subplot(1, 3, 3)
plt.plot(bilstm_history.history['loss'], label='Bi-LSTM training
Loss')
plt.plot(bilstm_history.history['val_loss'], label='Bi-LSTM Validation
Loss')
plt.title('Bi-LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

# Save the plot to the current directory
plt.savefig('btc-loss.png')

plt.show()

from sklearn.metrics import mean_squared_error, mean_absolute_error

# Make predictions
lstm_predictions = lstm_model.predict(X_test_btc)
gru_predictions = gru_model.predict(X_test_btc)
bilstm_predictions = bilstm_model.predict(X_test_btc)

# Calculate MSE and MAE for LSTM
lstm_mse = mean_squared_error(Y_test_btc, lstm_predictions)
lstm_mae = mean_absolute_error(Y_test_btc, lstm_predictions)

# Calculate MSE and MAE for GRU
gru_mse = mean_squared_error(Y_test_btc, gru_predictions)
gru_mae = mean_absolute_error(Y_test_btc, gru_predictions)

# Calculate MSE and MAE for BiLSTM
bilstm_mse = mean_squared_error(Y_test_btc, bilstm_predictions)
bilstm_mae = mean_absolute_error(Y_test_btc, bilstm_predictions)
```

```
# Print the scores
print(f'LSTM MSE: {lstm_mse}, MAE: {lstm_mae}')
print(f'GRU MSE: {gru_mse}, MAE: {gru_mae}')
print(f'BiLSTM MSE: {bilstm_mse}, MAE: {bilstm_mae}')

# Generate date range for x-axis
date_range = pd.date_range(start=start_date, end=end_date,
periods=len(Y_test_btc))

# Plot actual vs. predicted prices for the LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_btc),
scaled_data_btc.shape[1]-1)), Y_test_btc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='b')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(lstm_prediction
s), scaled_data_btc.shape[1]-1)), lstm_predictions), axis=1))[:, -1],
label='Predicted Prices', color='red')
plt.title('For BTC Comparison of Actual and LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)

# Save the plot to the current directory
plt.savefig('btc-lstm.png')
plt.show()

# Plot actual vs. predicted prices for the GRU model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_btc),
scaled_data_btc.shape[1]-1)), Y_test_btc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='b')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(gru_predictions
), scaled_data_btc.shape[1]-1)), gru_predictions), axis=1))[:, -1],
label='Predicted Prices', color='red')
plt.title('For BTC Comparison of Actual and GRU Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
```

```
plt.legend()
plt.grid(True)

# Save the plot to the current directory
plt.savefig('btc-gru.png')
plt.show()

# Plot actual vs. predicted prices for the Bi-LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_btc),
scaled_data_btc.shape[1]-1)), Y_test_btc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='b')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(bilstm_predicti
ons), scaled_data_btc.shape[1]-1)), bilstm_predictions), axis=1))[:, -
1], label='Predicted Prices', color='red')
plt.title('For BTC Comparison of Actual and Bi-LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)

# Save the plot to the current directory
plt.savefig('btc-bilstm.png')
plt.show()

def calculate_rmse(actuals, predictions):
    """
    Calculate Root Mean Squared Error
    """
    mse = np.mean((actuals - predictions) ** 2)
    rmse = np.sqrt(mse)
    return rmse

def calculate_mape(actuals, predictions):
    """
    Calculate Mean Absolute Percentage Error
    """
    mape = np.mean(np.abs((actuals - predictions) / actuals)) * 100
    return mape


# Assuming Y_test, lstm_predictions, gru_predictions, and
bilstm_predictions are already defined
```

```
# Calculate RMSE for each model
lstm_rmse = calculate_rmse(Y_test_btc, lstm_predictions.flatten())
gru_rmse = calculate_rmse(Y_test_btc, gru_predictions.flatten())
bilstm_rmse = calculate_rmse(Y_test_btc, bilstm_predictions.flatten())

# Calculate MAPE for each model
lstm_mape = calculate_mape(Y_test_btc, lstm_predictions.flatten())
gru_mape = calculate_mape(Y_test_btc, gru_predictions.flatten())
bilstm_mape = calculate_mape(Y_test_btc, bilstm_predictions.flatten())

# Print RMSE and MAPE for each model
print(f'LSTM RMSE: {lstm_rmse:.3f}, MAPE: {lstm_mape:.2f}%')
print(f'GRU RMSE: {gru_rmse:.3f}, MAPE: {gru_mape:.2f}%')
print(f'BiLSTM RMSE: {bilstm_rmse:.3f}, MAPE: {bilstm_mape:.2f}%')








# Assuming we're working with Ethereum data for this example
eth_data = crypto_data['ETH-USD']

# 1. Handle missing data
# For simplicity, we'll fill missing values with the last available
value
eth_data.fillna(method='ffill', inplace=True)

# 2. Normalize the features
scaler = MinMaxScaler(feature_range=(0, 1))
scaled_data_eth = scaler.fit_transform(eth_data[['Open', 'High',
'Low', 'Close']])  #CHANGE, SAME As above

# 3. Convert the data into a time series format
def create_dataset(dataset, look_back=1):
    X, Y = [], []
    for i in range(len(dataset) - look_back - 1):
        a = dataset[i:(i + look_back), :]
        X.append(a)
        Y.append(dataset[i + look_back, -1])  # Assuming close price
is the target variable
    return np.array(X), np.array(Y)

# Define look_back period
look_back = 60  # for example, using past 60 days to predict the next
day

# Split into features (X) and target (Y)
X_eth, Y_eth = create_dataset(scaled_data_eth, look_back)
```

```python
# Reshape features into the format expected by LSTM (samples, time
steps, features)
X_eth = np.reshape(X_eth, (X_eth.shape[0], look_back, X_eth.shape[2]))

# Split into train and test sets
split_percent = 0.80
split = int(split_percent * len(X_eth))

X_train_eth = X_eth[:split]
Y_train_eth = Y_eth[:split]
X_test_eth = X_eth[split:]
Y_test_eth = Y_eth[split:]

print("Data preprocessed and ready for model training.")

# Import TensorFlow for model training
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, GRU, Bidirectional

# Define the LSTM model
lstm_model = Sequential()
lstm_model.add(LSTM(units=100, return_sequences=True,
input_shape=(X_train_eth.shape[1], X_train_eth.shape[2])))
lstm_model.add(LSTM(units=100))
lstm_model.add(Dense(1))

lstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the GRU model
gru_model = Sequential()
gru_model.add(GRU(units=100, return_sequences=True,
input_shape=(X_train_eth.shape[1], X_train_eth.shape[2])))
gru_model.add(GRU(units=100))
gru_model.add(Dense(1))

gru_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the BiLSTM model
bilstm_model = Sequential()
bilstm_model.add(Bidirectional(LSTM(units=100, return_sequences=True),
input_shape=(X_train_eth.shape[1], X_train_eth.shape[2])))
bilstm_model.add(Bidirectional(LSTM(units=100)))
bilstm_model.add(Dense(1))

bilstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Train the models
lstm_history = lstm_model.fit(X_train_eth, Y_train_eth, epochs=100,
batch_size=32, validation_data=(X_test_eth, Y_test_eth), verbose=1)
```

```
gru_history = gru_model.fit(X_train_eth, Y_train_eth, epochs=100,
batch_size=32, validation_data=(X_test_eth, Y_test_eth), verbose=1)
bilstm_history = bilstm_model.fit(X_train_eth, Y_train_eth,
epochs=100, batch_size=32, validation_data=(X_test_eth, Y_test_eth),
verbose=1)

# Evaluate the models
lstm_scores = lstm_model.evaluate(X_test_eth, Y_test_eth, verbose=0)
gru_scores = gru_model.evaluate(X_test_eth, Y_test_eth, verbose=0)
bilstm_scores = bilstm_model.evaluate(X_test_eth, Y_test_eth,
verbose=0)

print('LSTM Test loss:', lstm_scores)
print('GRU Test loss:', gru_scores)
print('BiLSTM Test loss:', bilstm_scores)

# Plot training and validation loss
plt.figure(figsize=(18, 5))
plt.subplot(1, 3, 1)
plt.plot(lstm_history.history['loss'], label='LSTM training Loss')
plt.plot(lstm_history.history['val_loss'], label='LSTM Validation
Loss')
plt.title('LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()



plt.subplot(1, 3, 2)
plt.plot(gru_history.history['loss'], label='GRU training Loss')
plt.plot(gru_history.history['val_loss'], label='GRU Validation Loss')
plt.title('GRU Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()



plt.subplot(1, 3, 3)
plt.plot(bilstm_history.history['loss'], label='Bi-LSTM training
Loss')
plt.plot(bilstm_history.history['val_loss'], label='Bi-LSTM Validation
Loss')
plt.title('Bi-LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

# Save the plot to the current directory
```

```
plt.savefig('eth-loss.png')

plt.show()

from sklearn.metrics import mean_squared_error, mean_absolute_error

# Make predictions
lstm_predictions = lstm_model.predict(X_test_eth)
gru_predictions = gru_model.predict(X_test_eth)
bilstm_predictions = bilstm_model.predict(X_test_eth)

# Calculate MSE and MAE for LSTM
lstm_mse = mean_squared_error(Y_test_eth, lstm_predictions)
lstm_mae = mean_absolute_error(Y_test_eth, lstm_predictions)

# Calculate MSE and MAE for GRU
gru_mse = mean_squared_error(Y_test_eth, gru_predictions)
gru_mae = mean_absolute_error(Y_test_eth, gru_predictions)

# Calculate MSE and MAE for BiLSTM
bilstm_mse = mean_squared_error(Y_test_eth, bilstm_predictions)
bilstm_mae = mean_absolute_error(Y_test_eth, bilstm_predictions)

# Print the scores
print(f'LSTM MSE: {lstm_mse}, MAE: {lstm_mae}')
print(f'GRU MSE: {gru_mse}, MAE: {gru_mae}')
print(f'BiLSTM MSE: {bilstm_mse}, MAE: {bilstm_mae}')

# Generate date range for x-axis
date_range = pd.date_range(start=start_date, end=end_date,
periods=len(Y_test_eth))

# Plot actual vs. predicted prices for the LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_eth),
scaled_data_eth.shape[1]-1)), Y_test_eth.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='m')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(lstm_prediction
s), scaled_data_eth.shape[1]-1)), lstm_predictions), axis=1))[:, -1],
label='Predicted Prices', color='lime')
plt.title('For ETH Comparison of Actual and LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
```

```
# Save the plot to the current directory
plt.savefig('eth-lstm.png')
plt.show()

# Plot actual vs. predicted prices for the GRU model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_eth),
scaled_data_eth.shape[1]-1)), Y_test_eth.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='m')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(gru_predictions
), scaled_data_eth.shape[1]-1)), gru_predictions), axis=1))[:, -1],
label='Predicted Prices', color='lime')
plt.title('For ETH Comparison of Actual and GRU Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
# Save the plot to the current directory
plt.savefig('eth-gru.png')
plt.show()

# Plot actual vs. predicted prices for the Bi-LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_eth),
scaled_data_eth.shape[1]-1)), Y_test_eth.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='m')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(bilstm_predicti
ons), scaled_data_eth.shape[1]-1)), bilstm_predictions), axis=1))[:, -
1], label='Predicted Prices', color='lime')
plt.title('For ETH Comparison of Actual and Bi-LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
# Save the plot to the current directory
plt.savefig('eth-bilstm.png')
plt.show()
```

```python
def calculate_rmse(actuals, predictions):
    """
    Calculate Root Mean Squared Error
    """
    mse = np.mean((actuals - predictions) ** 2)
    rmse = np.sqrt(mse)
    return rmse

def calculate_mape(actuals, predictions):
    """
    Calculate Mean Absolute Percentage Error
    """
    mape = np.mean(np.abs((actuals - predictions) / actuals)) * 100
    return mape


# Assuming Y_test, lstm_predictions, gru_predictions, and
bilstm_predictions are already defined

# Calculate RMSE for each model
lstm_rmse = calculate_rmse(Y_test_eth, lstm_predictions.flatten())
gru_rmse = calculate_rmse(Y_test_eth, gru_predictions.flatten())
bilstm_rmse = calculate_rmse(Y_test_eth, bilstm_predictions.flatten())

# Calculate MAPE for each model
lstm_mape = calculate_mape(Y_test_eth, lstm_predictions.flatten())
gru_mape = calculate_mape(Y_test_eth, gru_predictions.flatten())
bilstm_mape = calculate_mape(Y_test_eth, bilstm_predictions.flatten())

# Print RMSE and MAPE for each model
print(f'LSTM RMSE: {lstm_rmse:.3f}, MAPE: {lstm_mape:.2f}%')
print(f'GRU RMSE: {gru_rmse:.3f}, MAPE: {gru_mape:.2f}%')
print(f'BiLSTM RMSE: {bilstm_rmse:.3f}, MAPE: {bilstm_mape:.2f}%')




# Assuming we're working with Litecoin data for this example
ltc_data = crypto_data['LTC-USD']

# 1. Handle missing data
# For simplicity, we'll fill missing values with the last available
value
ltc_data.fillna(method='ffill', inplace=True)

# 2. Normalize the features
scaler = MinMaxScaler(feature_range=(0, 1))
scaled_data_ltc = scaler.fit_transform(ltc_data[['Open', 'High',
'Low', 'Close']]) #CHANGE SAME as above
```

```python
# 3. Convert the data into a time series format
def create_dataset(dataset, look_back=1):
    X, Y = [], []
    for i in range(len(dataset) - look_back - 1):
        a = dataset[i:(i + look_back), :]
        X.append(a)
        Y.append(dataset[i + look_back, -1])  # Assuming close price
is the target variable
    return np.array(X), np.array(Y)

# Define look_back period
look_back = 60  # for example, using past 60 days to predict the next
day

# Split into features (X) and target (Y)
X_ltc, Y_ltc = create_dataset(scaled_data_ltc, look_back)

# Reshape features into the format expected by LSTM (samples, time
steps, features)
X_ltc = np.reshape(X_ltc, (X_ltc.shape[0], look_back, X_ltc.shape[2]))

# Split into train and test sets
split_percent = 0.80
split = int(split_percent * len(X_ltc))

X_train_ltc = X_ltc[:split]
Y_train_ltc = Y_ltc[:split]
X_test_ltc = X_ltc[split:]
Y_test_ltc = Y_ltc[split:]

print("Data preprocessed and ready for model training.")

# Import TensorFlow for model training
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, GRU, Bidirectional

# Define the LSTM model
lstm_model = Sequential()
lstm_model.add(LSTM(units=100, return_sequences=True,
input_shape=(X_train_ltc.shape[1], X_train_ltc.shape[2])))
lstm_model.add(LSTM(units=100))
lstm_model.add(Dense(1))

lstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the GRU model
gru_model = Sequential()
gru_model.add(GRU(units=100, return_sequences=True,
input_shape=(X_train_ltc.shape[1], X_train_ltc.shape[2])))
gru_model.add(GRU(units=100))
```

```
gru_model.add(Dense(1))

gru_model.compile(optimizer='adam', loss='mean_squared_error')

# Define the BiLSTM model
bilstm_model = Sequential()
bilstm_model.add(Bidirectional(LSTM(units=100, return_sequences=True),
input_shape=(X_train_ltc.shape[1], X_train_ltc.shape[2])))
bilstm_model.add(Bidirectional(LSTM(units=100)))
bilstm_model.add(Dense(1))

bilstm_model.compile(optimizer='adam', loss='mean_squared_error')

# Train the models
lstm_history = lstm_model.fit(X_train_ltc, Y_train_ltc, epochs=100,
batch_size=32, validation_data=(X_test_ltc, Y_test_ltc), verbose=1)
gru_history = gru_model.fit(X_train_ltc, Y_train_ltc, epochs=100,
batch_size=32, validation_data=(X_test_ltc, Y_test_ltc), verbose=1)
bilstm_history = bilstm_model.fit(X_train_ltc, Y_train_ltc,
epochs=100, batch_size=32, validation_data=(X_test_ltc, Y_test_ltc),
verbose=1)

# Evaluate the models
lstm_scores = lstm_model.evaluate(X_test_ltc, Y_test_ltc, verbose=0)
gru_scores = gru_model.evaluate(X_test_ltc, Y_test_ltc, verbose=0)
bilstm_scores = bilstm_model.evaluate(X_test_ltc, Y_test_ltc,
verbose=0)

print('LSTM Test loss:', lstm_scores)
print('GRU Test loss:', gru_scores)
print('BiLSTM Test loss:', bilstm_scores)

# Plot training and validation loss
plt.figure(figsize=(18, 5))
plt.subplot(1, 3, 1)
plt.plot(lstm_history.history['loss'], label='LSTM training Loss')
plt.plot(lstm_history.history['val_loss'], label='LSTM Validation
Loss')
plt.title('LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()


plt.subplot(1, 3, 2)
plt.plot(gru_history.history['loss'], label='GRU training Loss')
plt.plot(gru_history.history['val_loss'], label='GRU Validation Loss')
plt.title('GRU Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
```

```
plt.legend()


plt.subplot(1, 3, 3)
plt.plot(bilstm_history.history['loss'], label='Bi-LSTM training
Loss')
plt.plot(bilstm_history.history['val_loss'], label='Bi-LSTM Validation
Loss')
plt.title('Bi-LSTM Training and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

# Save the plot to the current directory
plt.savefig('ltc-loss.png')

plt.show()

from sklearn.metrics import mean_squared_error, mean_absolute_error

# Make predictions
lstm_predictions = lstm_model.predict(X_test_ltc)
gru_predictions = gru_model.predict(X_test_ltc)
bilstm_predictions = bilstm_model.predict(X_test_ltc)

# Calculate MSE and MAE for LSTM
lstm_mse = mean_squared_error(Y_test_ltc, lstm_predictions)
lstm_mae = mean_absolute_error(Y_test_ltc, lstm_predictions)

# Calculate MSE and MAE for GRU
gru_mse = mean_squared_error(Y_test_ltc, gru_predictions)
gru_mae = mean_absolute_error(Y_test_ltc, gru_predictions)

# Calculate MSE and MAE for BiLSTM
bilstm_mse = mean_squared_error(Y_test_ltc, bilstm_predictions)
bilstm_mae = mean_absolute_error(Y_test_ltc, bilstm_predictions)

# Print the scores
print(f'LSTM MSE: {lstm_mse}, MAE: {lstm_mae}')
print(f'GRU MSE: {gru_mse}, MAE: {gru_mae}')
print(f'BiLSTM MSE: {bilstm_mse}, MAE: {bilstm_mae}')

# Generate date range for x-axis
date_range = pd.date_range(start=start_date, end=end_date,
periods=len(Y_test_ltc))

# Plot actual vs. predicted prices for the LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_ltc),
```

```
scaled_data_ltc.shape[1]-1)), Y_test_ltc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='deeppink')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(lstm_prediction
s), scaled_data_ltc.shape[1]-1)), lstm_predictions), axis=1))[:, -1],
label='Predicted Prices', color='c')
plt.title('For LTC Comparison of Actual and LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
# Save the plot to the current directory
plt.savefig('ltc-lstm.png')
plt.show()

# Plot actual vs. predicted prices for the GRU model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_ltc),
scaled_data_ltc.shape[1]-1)), Y_test_ltc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='deeppink')
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(gru_predictions
), scaled_data_ltc.shape[1]-1)), gru_predictions), axis=1))[:, -1],
label='Predicted Prices', color='c')
plt.title('For LTC Comparison of Actual and GRU Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
# Save the plot to the current directory
plt.savefig('ltc-gru.png')
plt.show()

# Plot actual vs. predicted prices for the Bi-LSTM model
plt.figure(figsize=(10, 6))
plt.plot(date_range,
scaler.inverse_transform(np.concatenate((np.zeros((len(Y_test_ltc),
scaled_data_ltc.shape[1]-1)), Y_test_ltc.reshape(-1, 1)), axis=1))[:,
-1], label='Actual Prices', color='deeppink')
plt.plot(date_range,
```

```
scaler.inverse_transform(np.concatenate((np.zeros((len(bilstm_predicti
ons), scaled_data_ltc.shape[1]-1)), bilstm_predictions), axis=1))[:, -
1], label='Predicted Prices', color='c')
plt.title('For LTC Comparison of Actual and Bi-LSTM Predicted Prices')
plt.xlabel('Time')
plt.ylabel('Price (USD)')
plt.gca().xaxis.set_major_locator(mdates.YearLocator())  # Set major
ticks to each year
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))  #
Format date to only show years
plt.legend()
plt.grid(True)
# Save the plot to the current directory
plt.savefig('ltc-bilstm.png')
plt.show()

def calculate_rmse(actuals, predictions):
    """
    Calculate Root Mean Squared Error
    """
    mse = np.mean((actuals - predictions) ** 2)
    rmse = np.sqrt(mse)
    return rmse

def calculate_mape(actuals, predictions):
    """
    Calculate Mean Absolute Percentage Error
    """
    mape = np.mean(np.abs((actuals - predictions) / actuals)) * 100
    return mape


# Assuming Y_test, lstm_predictions, gru_predictions, and
bilstm_predictions are already defined

# Calculate RMSE for each model
lstm_rmse = calculate_rmse(Y_test_ltc, lstm_predictions.flatten())
gru_rmse = calculate_rmse(Y_test_ltc, gru_predictions.flatten())
bilstm_rmse = calculate_rmse(Y_test_ltc, bilstm_predictions.flatten())

# Calculate MAPE for each model
lstm_mape = calculate_mape(Y_test_ltc, lstm_predictions.flatten())
gru_mape = calculate_mape(Y_test_ltc, gru_predictions.flatten())
bilstm_mape = calculate_mape(Y_test_ltc, bilstm_predictions.flatten())

# Print RMSE and MAPE for each model
print(f'LSTM RMSE: {lstm_rmse:.3f}, MAPE: {lstm_mape:.2f}%')
print(f'GRU RMSE: {gru_rmse:.3f}, MAPE: {gru_mape:.2f}%')
print(f'BiLSTM RMSE: {bilstm_rmse:.3f}, MAPE: {bilstm_mape:.2f}%')
```

```
Requirement already satisfied: yfinance in
/usr/local/lib/python3.11/dist-packages (0.2.55)
Requirement already satisfied: numpy in
/usr/local/lib/python3.11/dist-packages (2.0.2)
Requirement already satisfied: pandas in
/usr/local/lib/python3.11/dist-packages (2.2.2)
Requirement already satisfied: matplotlib in
/usr/local/lib/python3.11/dist-packages (3.10.0)
Requirement already satisfied: scikit-learn in
/usr/local/lib/python3.11/dist-packages (1.6.1)
Requirement already satisfied: tensorflow in
/usr/local/lib/python3.11/dist-packages (2.18.0)
Requirement already satisfied: requests>=2.31 in
/usr/local/lib/python3.11/dist-packages (from yfinance) (2.32.3)
Requirement already satisfied: multitasking>=0.0.7 in
/usr/local/lib/python3.11/dist-packages (from yfinance) (0.0.11)
Requirement already satisfied: platformdirs>=2.0.0 in
/usr/local/lib/python3.11/dist-packages (from yfinance) (4.3.7)
Requirement already satisfied: pytz>=2022.5 in
/usr/local/lib/python3.11/dist-packages (from yfinance) (2025.2)
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/usr/local/lib/python3.11/dist-packages (from yfinance) (2.4.6)
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Requirement already satisfied: beautifulsoup4>=4.11.1 in
/usr/local/lib/python3.11/dist-packages (from yfinance) (4.13.3)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas) (2.8.2)
Requirement already satisfied: tzdata>=2022.7 in
/usr/local/lib/python3.11/dist-packages (from pandas) (2025.2)
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/usr/local/lib/python3.11/dist-packages (from matplotlib) (1.3.1)
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/usr/local/lib/python3.11/dist-packages (from matplotlib) (0.12.1)
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/usr/local/lib/python3.11/dist-packages (from matplotlib) (3.2.3)
Requirement already satisfied: scipy>=1.6.0 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn) (1.14.1)
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/usr/local/lib/python3.11/dist-packages (from scikit-learn) (1.4.2)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn) (3.6.0)
```

```
Requirement already satisfied: absl-py>=1.0.0 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=24.3.25 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (25.2.10)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1
in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.6.0)
Requirement already satisfied: google-pasta>=0.1.1 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (0.2.0)
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Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!
=4.21.3,!=4.21.4,!=4.21.5,<6.0.0dev,>=3.20.3 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (5.29.4)
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/usr/local/lib/python3.11/dist-packages (from tensorflow) (2.5.0)
Requirement already satisfied: typing-extensions>=3.6.6 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (4.13.0)
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Requirement already satisfied: grpcio<2.0,>=1.24.3 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (1.71.0)
Requirement already satisfied: tensorboard<2.19,>=2.18 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (2.18.0)
Requirement already satisfied: keras>=3.5.0 in
/usr/local/lib/python3.11/dist-packages (from tensorflow) (3.8.0)
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/usr/local/lib/python3.11/dist-packages (from beautifulsoup4>=4.11.1-
>yfinance) (2.6)
Requirement already satisfied: rich in /usr/local/lib/python3.11/dist-
packages (from keras>=3.5.0->tensorflow) (13.9.4)
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```

```
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Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.11/dist-packages (from requests>=2.31-
>yfinance) (3.4.1)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.11/dist-packages (from requests>=2.31-
>yfinance) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests>=2.31-
>yfinance) (2.3.0)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.11/dist-packages (from requests>=2.31-
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>tensorflow) (3.7)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0
in /usr/local/lib/python3.11/dist-packages (from
tensorboard<2.19,>=2.18->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18-
>tensorflow) (3.1.3)
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>tensorboard<2.19,>=2.18->tensorflow) (3.0.2)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0-
>tensorflow) (3.0.0)
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/usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0-
>tensorflow) (2.18.0)
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>rich->keras>=3.5.0->tensorflow) (0.1.2)
YF.download() has changed argument auto_adjust default to True

 [*********************100%***********************]  1 of 1 completed

Showing data for BTC-USD:
```


```
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```

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[*********************100%***********************] 1 of 1 completed

Showing data for ETH-USD:

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\"dtype\": \"date\",\n   \"min\": \"2019-01-01 00:00:00\",\n
\"max\": \"2019-01-05 00:00:00\",\n   \"num_unique_values\": 5,\n

\"samples\": [\n   \"2019-01-02 00:00:00\",\n   \"2019-01-05 00:00:00\",\n   \"2019-01-03 00:00:00\"\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   },\n   {\n   \"column\": [\n   \"Close\",\n   \"ETH-USD\"\n   ],\n   \"properties\": {\n   \"dtype\": \"number\",\n   \"std\": 6.281784111781269,\n   \"min\": 140.8194122314453,\n   \"max\": 155.6385955810547,\n   \"num_unique_values\": 5,\n   \"samples\": [\n   155.0476837158203,\n   155.6385955810547,\n   149.135009765625\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   },\n   {\n   \"column\": [\n   \"High\",\n   \"ETH-USD\"\n   ],\n   \"properties\": {\n   \"dtype\": \"number\",\n   \"std\": 7.50040325733317,\n   \"min\": 141.3975067138672,\n   \"max\": 160.82489013671875,\n   \"num_unique_values\": 5,\n   \"samples\": [\n   156.92913818359375,\n   160.82489013671875,\n   155.86305236816406\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   },\n   {\n   \"column\": [\n   \"Low\",\n   \"ETH-USD\"\n   ],\n   \"properties\": {\n   \"dtype\": \"number\",\n   \"std\": 8.229112176351794,\n   \"min\": 132.6507110595703,\n   \"max\": 154.33741760253906,\n   \"num_unique_values\": 5,\n   \"samples\": [\n   140.6509552001953,\n   154.33741760253906,\n   147.1983642578125\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   },\n   {\n   \"column\": [\n   \"Open\",\n   \"ETH-USD\"\n   ],\n   \"properties\": {\n   \"dtype\": \"number\",\n   \"std\": 9.201250087544645,\n   \"min\": 133.41815185546875,\n   \"max\": 155.196044921875,\n   \"num_unique_values\": 5,\n   \"samples\": [\n   141.51951599121094,\n   154.33741760253906,\n   155.196044921875\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   },\n   {\n   \"column\": [\n   \"Volume\",\n   \"ETH-USD\"\n   ],\n   \"properties\": {\n   \"dtype\": \"number\",\n   \"std\": 468397462,\n   \"min\": 2258709868,\n   \"max\": 3338211928,\n   \"num_unique_values\": 5,\n   \"samples\": [\n   3328240369,\n   3338211928,\n   2676164880\n   ],\n   \"semantic_type\": \"\",\n   \"description\": \"\"\n   }\n   }\n]\n}","type":"dataframe"}

```
[*********************100%***********************]  1 of 1 completed
```

```
Showing data for LTC-USD:
```

{"summary":"{\n \"name\": \"print(f'BiLSTM RMSE: {bilstm_rmse:\",\n \"rows\": 5,\n \"fields\": [\n   {\n   \"column\": [\n   \"Date\",\n   \"\"\n   ],\n   \"properties\": {\n   \"dtype\": \"date\",\n   \"min\": \"2019-01-01 00:00:00\",\n

```
\"max\": \"2019-01-05 00:00:00\",\n        \"num_unique_values\": 5,\n
\"samples\": [\n          \"2019-01-02 00:00:00\",\n          \"2019-
01-05 00:00:00\",\n          \"2019-01-03 00:00:00\"\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\
n    },\n    {\n      \"column\": [\n        \"Close\",\n
\"LTC-USD\"\n      ],\n      \"properties\": {\n        \"dtype\":
\"number\",\n        \"std\": 1.252282215345374,\n        \"min\":
31.979930877685547,\n        \"max\": 34.936866760253906,\n
\"num_unique_values\": 5,\n        \"samples\": [\n
33.43368148803711,\n          34.936866760253906,\n
32.02669906616211\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\": [\n
\"High\",\n        \"LTC-USD\"\n      ],\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 1.506868926802265,\n
\"min\": 32.09758377075195,\n        \"max\": 36.14344024658203,\n
\"num_unique_values\": 5,\n        \"samples\": [\n
33.7933235168457,\n          36.14344024658203,\n
33.42070388793945\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\": [\n
\"Low\",\n        \"LTC-USD\"\n      ],\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 0.761917676081607,\n
\"min\": 30.264280319213867,\n        \"max\": 32.34479522705078,\n
\"num_unique_values\": 5,\n        \"samples\": [\n
31.765974044799805,\n          32.34479522705078,\n
31.592479705810547\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\": [\n
\"Open\",\n        \"LTC-USD\"\n      ],\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 1.0393762259537955,\n
\"min\": 30.458393096923828,\n        \"max\": 33.353572845458984,\n
\"num_unique_values\": 5,\n        \"samples\": [\n
32.0212287902832,\n          32.34554672241211,\n
33.353572845458984\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\": [\n
\"Volume\",\n        \"LTC-USD\"\n      ],\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 118119031,\n        \"min\":
345068249,\n        \"max\": 640607603,\n
\"num_unique_values\": 5,\n        \"samples\": [\n
414331918,\n          640607603,\n          345068249\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\
n    }\n  ]\n}","type":"dataframe"}
```


```
<ipython-input-1-11932f61a7e0>:58: FutureWarning: DataFrame.fillna
with 'method' is deprecated and will raise in a future version. Use
obj.ffill() or obj.bfill() instead.
  btc_data.fillna(method='ffill', inplace=True)
```

```
                  Close         High          Low         Open  \
Date
2019-01-01  3843.520020  3850.913818  3707.231201  3746.713379
2019-01-02  3943.409424  3947.981201  3817.409424  3849.216309
```

```
2019-01-03   3836.741211   3935.685059   3826.222900   3931.048584
2019-01-04   3857.717529   3865.934570   3783.853760   3832.040039
2019-01-05   3845.194580   3904.903076   3836.900146   3851.973877
...                  ...           ...           ...           ...
2023-12-27  43442.855469  43683.160156  42167.582031  42518.468750
2023-12-28  42627.855469  43804.781250  42318.550781  43468.199219
2023-12-29  42099.402344  43124.324219  41424.062500  42614.644531
2023-12-30  42156.902344  42584.125000  41556.226562  42091.753906
2023-12-31  42265.187500  42860.937500  41998.253906  42152.097656

                 Volume  Sentiment
Date
2019-01-01   4324200990   0.541667
2019-01-02   5244856836   0.000000
2019-01-03   4530215219   0.000000
2019-01-04   4847965467   0.000000
2019-01-05   5137609824   0.088636
...                 ...        ...
2023-12-27  25260941032   0.227273
2023-12-28  22992093014   0.000000
2023-12-29  26000021055   0.000000
2023-12-30  16013925945   0.160000
2023-12-31  16397498810   0.330303

[1826 rows x 6 columns]
Data preprocessed and ready for model training.

/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/
rnn.py:200: UserWarning: Do not pass an `input_shape`/`input_dim`
argument to a layer. When using Sequential models, prefer using an
`Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)

Epoch 1/100

/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/
bidirectional.py:107: UserWarning: Do not pass an
`input_shape`/`input_dim` argument to a layer. When using Sequential
models, prefer using an `Input(shape)` object as the first layer in
the model instead.
  super().__init__(**kwargs)

45/45 ━━━━━━━━━━━━━━━━━━━━ 5s 51ms/step - loss: 0.0263 - val_loss:
5.6327e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 13ms/step - loss: 0.0015 - val_loss:
5.6195e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 0.0014 - val_loss:
7.7429e-04
```

```
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 0.0013 - val_loss:
6.6081e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 0.0011 - val_loss:
5.2950e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 0.0010 - val_loss:
4.2895e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 9.5142e-04 - val_loss:
3.6824e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.9372e-04 - val_loss:
3.3800e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 8.4750e-04 - val_loss:
3.2733e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.1141e-04 - val_loss:
3.2731e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 7.8449e-04 - val_loss:
3.3155e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 7.6412e-04 - val_loss:
3.3520e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.4677e-04 - val_loss:
3.3569e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 7.2991e-04 - val_loss:
3.3243e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.1274e-04 - val_loss:
3.2568e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 6.9544e-04 - val_loss:
3.1604e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 6.7819e-04 - val_loss:
3.0415e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 6.6093e-04 - val_loss:
2.9056e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 6.4351e-04 - val_loss:
2.7575e-04
Epoch 20/100
```

```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 6.2590e-04 - val_loss:
2.6023e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 6.0816e-04 - val_loss:
2.4455e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 5.9051e-04 - val_loss:
2.2926e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 5.7322e-04 - val_loss:
2.1488e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 5.5657e-04 - val_loss:
2.0180e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 5.4084e-04 - val_loss:
1.9025e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.2620e-04 - val_loss:
1.8031e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 5.1275e-04 - val_loss:
1.7192e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.0051e-04 - val_loss:
1.6496e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.8944e-04 - val_loss:
1.5922e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7947e-04 - val_loss:
1.5452e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7051e-04 - val_loss:
1.5069e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6245e-04 - val_loss:
1.4758e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5519e-04 - val_loss:
1.4510e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.4867e-04 - val_loss:
1.4315e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.4280e-04 - val_loss:
1.4170e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3755e-04 - val_loss:
```

```
1.4067e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3285e-04 - val_loss:
1.4002e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2867e-04 - val_loss:
1.3970e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.2497e-04 - val_loss:
1.3965e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.2171e-04 - val_loss:
1.3981e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.1885e-04 - val_loss:
1.4012e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1636e-04 - val_loss:
1.4052e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1419e-04 - val_loss:
1.4097e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1231e-04 - val_loss:
1.4142e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1067e-04 - val_loss:
1.4185e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0924e-04 - val_loss:
1.4223e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0799e-04 - val_loss:
1.4254e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0690e-04 - val_loss:
1.4279e-04
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0592e-04 - val_loss:
1.4296e-04
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0506e-04 - val_loss:
1.4306e-04
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0428e-04 - val_loss:
1.4309e-04
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0356e-04 - val_loss:
1.4305e-04
```

```
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0291e-04 - val_loss:
1.4296e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0230e-04 - val_loss:
1.4282e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0172e-04 - val_loss:
1.4263e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0118e-04 - val_loss:
1.4240e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0065e-04 - val_loss:
1.4214e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0014e-04 - val_loss:
1.4184e-04
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9964e-04 - val_loss:
1.4152e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9915e-04 - val_loss:
1.4118e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.9866e-04 - val_loss:
1.4082e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.9817e-04 - val_loss:
1.4044e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.9769e-04 - val_loss:
1.4005e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.9720e-04 - val_loss:
1.3965e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9671e-04 - val_loss:
1.3924e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9622e-04 - val_loss:
1.3882e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9574e-04 - val_loss:
1.3840e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9525e-04 - val_loss:
1.3798e-04
Epoch 69/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9476e-04 - val_loss:
1.3755e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.9428e-04 - val_loss:
1.3713e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9380e-04 - val_loss:
1.3670e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9332e-04 - val_loss:
1.3627e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9285e-04 - val_loss:
1.3584e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9239e-04 - val_loss:
1.3541e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9193e-04 - val_loss:
1.3498e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9148e-04 - val_loss:
1.3454e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 3.9104e-04 - val_loss:
1.3410e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9061e-04 - val_loss:
1.3366e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9019e-04 - val_loss:
1.3321e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8978e-04 - val_loss:
1.3275e-04
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.8937e-04 - val_loss:
1.3228e-04
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.8897e-04 - val_loss:
1.3180e-04
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.8858e-04 - val_loss:
1.3130e-04
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8819e-04 - val_loss:
1.3079e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8781e-04 - val_loss:
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1.3027e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.8742e-04 - val_loss:
1.2973e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8703e-04 - val_loss:
1.2917e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.8664e-04 - val_loss:
1.2859e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8624e-04 - val_loss:
1.2798e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8585e-04 - val_loss:
1.2733e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8544e-04 - val_loss:
1.2664e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8501e-04 - val_loss:
1.2590e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8455e-04 - val_loss:
1.2510e-04
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8399e-04 - val_loss:
1.2426e-04
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8328e-04 - val_loss:
1.2343e-04
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8237e-04 - val_loss:
1.2272e-04
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8128e-04 - val_loss:
1.2218e-04
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8018e-04 - val_loss:
1.2181e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7923e-04 - val_loss:
1.2154e-04
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7846e-04 - val_loss:
1.2131e-04
Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 3s 23ms/step - loss: 0.0258 - val_loss:
2.8102e-04
```

```
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 8.1258e-04 - val_loss:
3.1674e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 6.9404e-04 - val_loss:
3.0227e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 6.3562e-04 - val_loss:
2.6503e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 5.8306e-04 - val_loss:
2.3461e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.4122e-04 - val_loss:
2.1635e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.1666e-04 - val_loss:
1.8786e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 5.0844e-04 - val_loss:
1.6916e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.0788e-04 - val_loss:
1.6742e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.9523e-04 - val_loss:
1.6414e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.8453e-04 - val_loss:
1.5983e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.8316e-04 - val_loss:
1.5558e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.8432e-04 - val_loss:
1.5132e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.8352e-04 - val_loss:
1.4715e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.7976e-04 - val_loss:
1.4335e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.7424e-04 - val_loss:
1.3999e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6812e-04 - val_loss:
1.3705e-04
Epoch 18/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.6192e-04 - val_loss:
1.3449e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.5585e-04 - val_loss:
1.3226e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.5004e-04 - val_loss:
1.3034e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.4457e-04 - val_loss:
1.2871e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.3950e-04 - val_loss:
1.2735e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.3488e-04 - val_loss:
1.2624e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.3072e-04 - val_loss:
1.2536e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.2702e-04 - val_loss:
1.2468e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.2377e-04 - val_loss:
1.2419e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2092e-04 - val_loss:
1.2385e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.1845e-04 - val_loss:
1.2364e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 4.1631e-04 - val_loss:
1.2353e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1445e-04 - val_loss:
1.2349e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1283e-04 - val_loss:
1.2351e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1141e-04 - val_loss:
1.2356e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1016e-04 - val_loss:
1.2362e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0904e-04 - val_loss:
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1.2369e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0802e-04 - val_loss:
1.2375e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0708e-04 - val_loss:
1.2378e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0622e-04 - val_loss:
1.2380e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0541e-04 - val_loss:
1.2380e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0464e-04 - val_loss:
1.2377e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0390e-04 - val_loss:
1.2371e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.0319e-04 - val_loss:
1.2364e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0250e-04 - val_loss:
1.2354e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0183e-04 - val_loss:
1.2342e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0117e-04 - val_loss:
1.2329e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 4.0052e-04 - val_loss:
1.2313e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9988e-04 - val_loss:
1.2297e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9924e-04 - val_loss:
1.2279e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9861e-04 - val_loss:
1.2261e-04
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9798e-04 - val_loss:
1.2242e-04
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9735e-04 - val_loss:
1.2222e-04
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Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9672e-04 - val_loss:
1.2202e-04
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9609e-04 - val_loss:
1.2181e-04
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9546e-04 - val_loss:
1.2160e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9483e-04 - val_loss:
1.2139e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9420e-04 - val_loss:
1.2118e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.9357e-04 - val_loss:
1.2098e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9294e-04 - val_loss:
1.2077e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.9231e-04 - val_loss:
1.2057e-04
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9168e-04 - val_loss:
1.2036e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9105e-04 - val_loss:
1.2017e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.9043e-04 - val_loss:
1.1997e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 3.8980e-04 - val_loss:
1.1978e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.8918e-04 - val_loss:
1.1960e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8856e-04 - val_loss:
1.1942e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8794e-04 - val_loss:
1.1924e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8733e-04 - val_loss:
1.1907e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.8672e-04 - val_loss:
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1.1891e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8612e-04 - val_loss:
1.1875e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.8552e-04 - val_loss:
1.1860e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.8493e-04 - val_loss:
1.1845e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.8435e-04 - val_loss:
1.1831e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8377e-04 - val_loss:
1.1818e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.8320e-04 - val_loss:
1.1805e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8263e-04 - val_loss:
1.1792e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8208e-04 - val_loss:
1.1781e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.8153e-04 - val_loss:
1.1770e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.8100e-04 - val_loss:
1.1759e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8047e-04 - val_loss:
1.1750e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7995e-04 - val_loss:
1.1740e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.7945e-04 - val_loss:
1.1732e-04
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7895e-04 - val_loss:
1.1724e-04
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.7847e-04 - val_loss:
1.1717e-04
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 3.7799e-04 - val_loss:
1.1710e-04
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Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 3.7753e-04 - val_loss:
1.1704e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7708e-04 - val_loss:
1.1698e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.7664e-04 - val_loss:
1.1693e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7622e-04 - val_loss:
1.1689e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.7581e-04 - val_loss:
1.1685e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.7540e-04 - val_loss:
1.1682e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.7502e-04 - val_loss:
1.1680e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.7465e-04 - val_loss:
1.1678e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7429e-04 - val_loss:
1.1677e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.7394e-04 - val_loss:
1.1676e-04
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.7361e-04 - val_loss:
1.1676e-04
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7329e-04 - val_loss:
1.1676e-04
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.7299e-04 - val_loss:
1.1677e-04
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - loss: 3.7271e-04 - val_loss:
1.1678e-04
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7243e-04 - val_loss:
1.1680e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - loss: 3.7218e-04 - val_loss:
1.1683e-04
Epoch 100/100
```

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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.7194e-04 - val_loss:
1.1685e-04
Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 5s 30ms/step - loss: 0.0303 - val_loss:
7.4682e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 0.0015 - val_loss:
9.6308e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 0.0012 - val_loss:
8.9513e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 0.0011 - val_loss:
5.7978e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 9.5064e-04 - val_loss:
4.1364e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 8.4495e-04 - val_loss:
3.6862e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 7.7061e-04 - val_loss:
3.8006e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 7.2648e-04 - val_loss:
4.2113e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 6.9442e-04 - val_loss:
4.5018e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.7219e-04 - val_loss:
4.7560e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 6.6207e-04 - val_loss:
4.9445e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.6743e-04 - val_loss:
4.9232e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 6.8971e-04 - val_loss:
4.4432e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.1551e-04 - val_loss:
3.5994e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 7.1028e-04 - val_loss:
3.0536e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.7786e-04 - val_loss:
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2.8993e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.5717e-04 - val_loss:
2.8507e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.4811e-04 - val_loss:
2.7776e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.3942e-04 - val_loss:
2.6853e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 6.2894e-04 - val_loss:
2.5967e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.1838e-04 - val_loss:
2.5138e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 6.0839e-04 - val_loss:
2.4333e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 44ms/step - loss: 5.9875e-04 - val_loss:
2.3544e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 5.8930e-04 - val_loss:
2.2775e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.8004e-04 - val_loss:
2.2029e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.7100e-04 - val_loss:
2.1307e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.6218e-04 - val_loss:
2.0611e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 5.5357e-04 - val_loss:
1.9944e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 5.4521e-04 - val_loss:
1.9307e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.3707e-04 - val_loss:
1.8702e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.2919e-04 - val_loss:
1.8130e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.2156e-04 - val_loss:
1.7594e-04
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Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 5.1419e-04 - val_loss:
1.7092e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 5.0710e-04 - val_loss:
1.6627e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.0027e-04 - val_loss:
1.6198e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.9373e-04 - val_loss:
1.5806e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8747e-04 - val_loss:
1.5449e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8151e-04 - val_loss:
1.5127e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.7584e-04 - val_loss:
1.4839e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.7048e-04 - val_loss:
1.4581e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.6542e-04 - val_loss:
1.4353e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.6067e-04 - val_loss:
1.4151e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.5623e-04 - val_loss:
1.3972e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.5208e-04 - val_loss:
1.3813e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.4822e-04 - val_loss:
1.3671e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.4464e-04 - val_loss:
1.3543e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4132e-04 - val_loss:
1.3426e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.3824e-04 - val_loss:
1.3318e-04
Epoch 49/100
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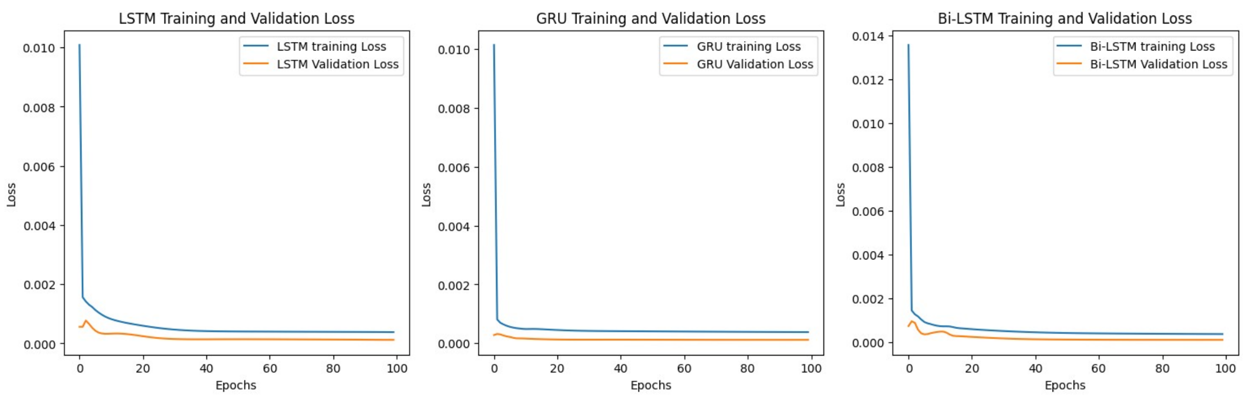
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.3537e-04 - val_loss:
1.3217e-04
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.3271e-04 - val_loss:
1.3121e-04
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.3023e-04 - val_loss:
1.3030e-04
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.2792e-04 - val_loss:
1.2942e-04
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2575e-04 - val_loss:
1.2858e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.2372e-04 - val_loss:
1.2777e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.2181e-04 - val_loss:
1.2698e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.2002e-04 - val_loss:
1.2623e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1832e-04 - val_loss:
1.2552e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1672e-04 - val_loss:
1.2483e-04
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1519e-04 - val_loss:
1.2418e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1374e-04 - val_loss:
1.2357e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.1235e-04 - val_loss:
1.2299e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1102e-04 - val_loss:
1.2245e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.0974e-04 - val_loss:
1.2194e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0851e-04 - val_loss:
1.2146e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0732e-04 - val_loss:
```

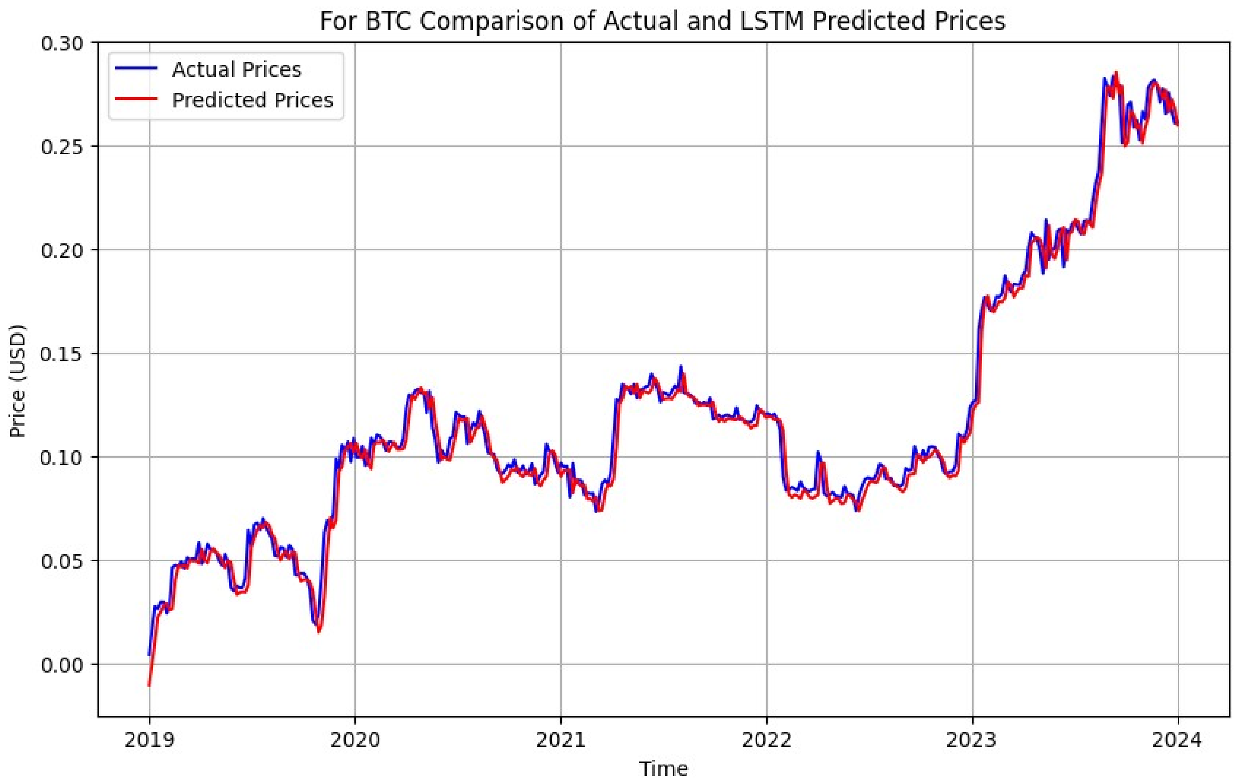
```
1.2102e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.0617e-04 - val_loss:
1.2060e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.0506e-04 - val_loss:
1.2022e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0398e-04 - val_loss:
1.1985e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0294e-04 - val_loss:
1.1952e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0192e-04 - val_loss:
1.1921e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0093e-04 - val_loss:
1.1892e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9997e-04 - val_loss:
1.1865e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 3.9903e-04 - val_loss:
1.1841e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 3.9811e-04 - val_loss:
1.1818e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9722e-04 - val_loss:
1.1797e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 3.9634e-04 - val_loss:
1.1778e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 22ms/step - loss: 3.9548e-04 - val_loss:
1.1761e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 3.9463e-04 - val_loss:
1.1746e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9380e-04 - val_loss:
1.1732e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9299e-04 - val_loss:
1.1719e-04
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9219e-04 - val_loss:
1.1708e-04
```

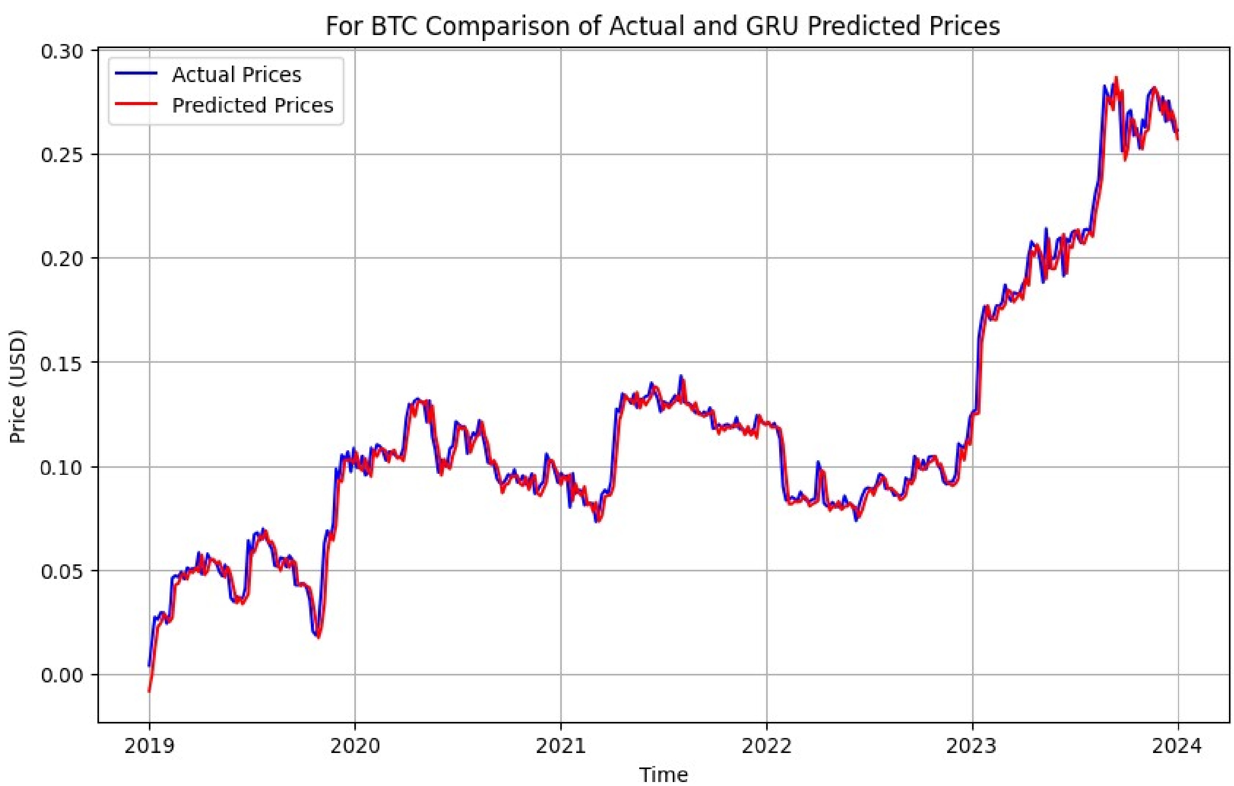
```
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9141e-04 - val_loss:
1.1698e-04
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9064e-04 - val_loss:
1.1690e-04
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.8989e-04 - val_loss:
1.1682e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.8915e-04 - val_loss:
1.1676e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.8842e-04 - val_loss:
1.1671e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.8770e-04 - val_loss:
1.1667e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 3.8700e-04 - val_loss:
1.1664e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 3.8632e-04 - val_loss:
1.1662e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.8565e-04 - val_loss:
1.1660e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.8500e-04 - val_loss:
1.1659e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.8436e-04 - val_loss:
1.1659e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.8374e-04 - val_loss:
1.1659e-04
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.8314e-04 - val_loss:
1.1659e-04
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.8255e-04 - val_loss:
1.1659e-04
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.8198e-04 - val_loss:
1.1660e-04
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.8144e-04 - val_loss:
1.1661e-04
Epoch 98/100
```

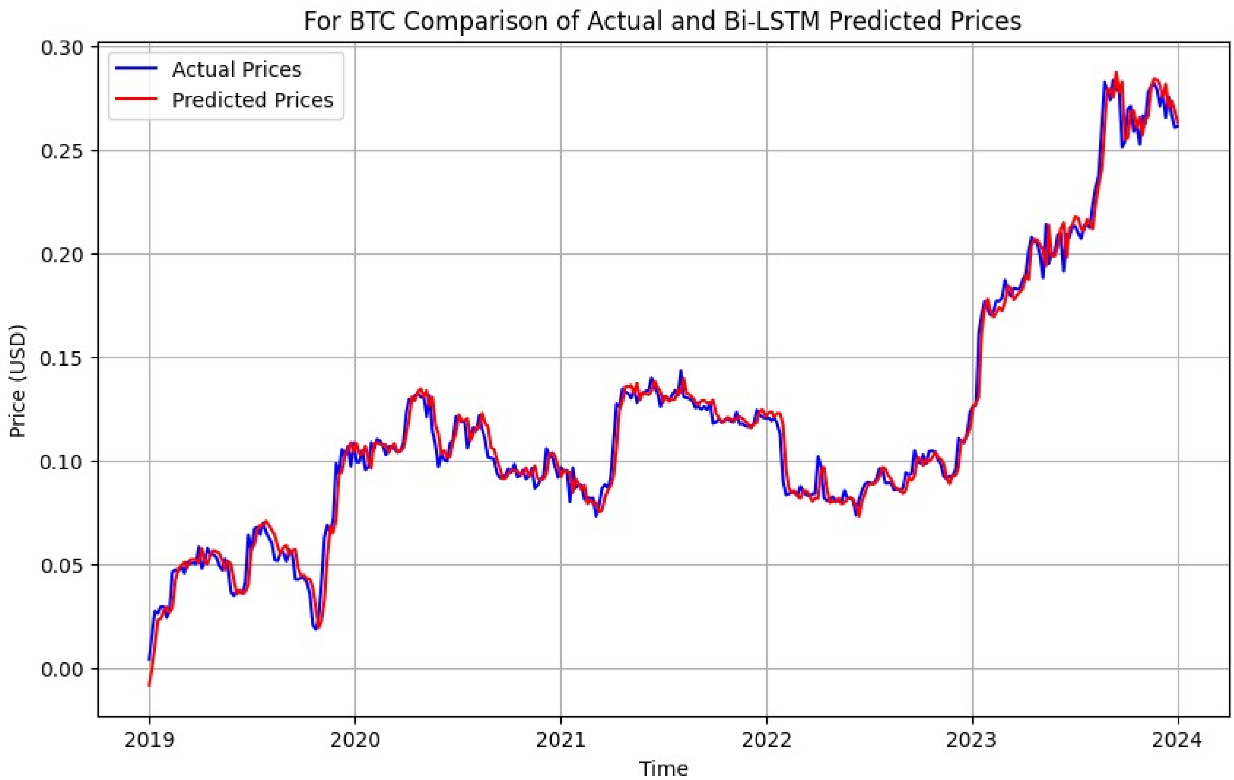
```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.8091e-04 - val_loss:
1.1662e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 23ms/step - loss: 3.8040e-04 - val_loss:
1.1663e-04
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 3.7992e-04 - val_loss:
1.1665e-04
LSTM Test loss: 0.00012131379480706528
GRU Test loss: 0.00011685465142363682
BiLSTM Test loss: 0.00011664778867270797
```




```
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 1s 62ms/step
LSTM MSE: 0.00012131379587472078, MAE: 0.007542441569756l125
GRU MSE: 0.00011685464335143394, MAE: 0.007413831859346532
BiLSTM MSE: 0.00011664778040768777, MAE: 0.007337559388208527
```


For BTC Comparison of Actual and LSTM Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
Time
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2019
2020
2021
2022
2023
2024


For BTC Comparison of Actual and GRU Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
Time
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2019
2020
2021
2022
2023
2024




```
LSTM RMSE: 0.011, MAPE: 1.93%
GRU RMSE: 0.011, MAPE: 1.88%
BiLSTM RMSE: 0.011, MAPE: 1.88%
Data preprocessed and ready for model training.

<ipython-input-1-11932f61a7e0>:320: FutureWarning: DataFrame.fillna
with 'method' is deprecated and will raise in a future version. Use
obj.ffill() or obj.bfill() instead.
  eth_data.fillna(method='ffill', inplace=True)
/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/rnn.py:20
0: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a
layer. When using Sequential models, prefer using an `Input(shape)`
object as the first layer in the model instead.
  super().__init__(**kwargs)
/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/bidirecti
onal.py:107: UserWarning: Do not pass an `input_shape`/`input_dim`
argument to a layer. When using Sequential models, prefer using an
`Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)

Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 19ms/step - loss: 0.0160 - val_loss:
5.0220e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 0.0019 - val_loss:
4.0901e-04
```

```
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 0.0016 - val_loss:
3.3181e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 0.0013 - val_loss:
3.9926e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 0.0012 - val_loss:
3.1581e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 0.0010 - val_loss:
2.3288e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 9.1697e-04 - val_loss:
2.0171e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 8.6296e-04 - val_loss:
1.9679e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 8.2146e-04 - val_loss:
1.9578e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.8520e-04 - val_loss:
1.9095e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 7.5318e-04 - val_loss:
1.8242e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.2488e-04 - val_loss:
1.7187e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 6.9989e-04 - val_loss:
1.6136e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.7754e-04 - val_loss:
1.5253e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.5694e-04 - val_loss:
1.4568e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.3736e-04 - val_loss:
1.4028e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.1837e-04 - val_loss:
1.3580e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.9982e-04 - val_loss:
1.3190e-04
Epoch 19/100
```

```
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.8183e-04 - val_loss:
1.2840e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.6459e-04 - val_loss:
1.2515e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.4836e-04 - val_loss:
1.2208e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.3337e-04 - val_loss:
1.1913e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.1981e-04 - val_loss:
1.1631e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.0782e-04 - val_loss:
1.1364e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.9743e-04 - val_loss:
1.1118e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.8856e-04 - val_loss:
1.0898e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.8107e-04 - val_loss:
1.0708e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.7474e-04 - val_loss:
1.0548e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6939e-04 - val_loss:
1.0419e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6483e-04 - val_loss:
1.0318e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6091e-04 - val_loss:
1.0241e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5753e-04 - val_loss:
1.0185e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.5460e-04 - val_loss:
1.0144e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.5202e-04 - val_loss:
1.0115e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4973e-04 - val_loss:
```

```
1.0095e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.4768e-04 - val_loss:
1.0080e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.4581e-04 - val_loss:
1.0069e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4410e-04 - val_loss:
1.0059e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.4250e-04 - val_loss:
1.0052e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4099e-04 - val_loss:
1.0045e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3955e-04 - val_loss:
1.0038e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3817e-04 - val_loss:
1.0032e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.3683e-04 - val_loss:
1.0025e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.3553e-04 - val_loss:
1.0020e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3427e-04 - val_loss:
1.0014e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.3303e-04 - val_loss:
1.0009e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.3182e-04 - val_loss:
1.0004e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.3063e-04 - val_loss:
9.9998e-05
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2946e-04 - val_loss:
9.9959e-05
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2831e-04 - val_loss:
9.9923e-05
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2719e-04 - val_loss:
9.9892e-05
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Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.2609e-04 - val_loss: 
9.9865e-05
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2501e-04 - val_loss: 
9.9839e-05
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2395e-04 - val_loss: 
9.9816e-05
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2293e-04 - val_loss: 
9.9795e-05
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2193e-04 - val_loss: 
9.9773e-05
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2097e-04 - val_loss: 
9.9750e-05
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2005e-04 - val_loss: 
9.9725e-05
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1917e-04 - val_loss: 
9.9696e-05
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1834e-04 - val_loss: 
9.9662e-05
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1757e-04 - val_loss: 
9.9619e-05
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1686e-04 - val_loss: 
9.9566e-05
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1623e-04 - val_loss: 
9.9499e-05
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1567e-04 - val_loss: 
9.9413e-05
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1521e-04 - val_loss: 
9.9305e-05
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.1485e-04 - val_loss: 
9.9165e-05
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.1458e-04 - val_loss: 
9.8987e-05
Epoch 68/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.1443e-04 - val_loss:
9.8759e-05
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1438e-04 - val_loss:
9.8473e-05
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1444e-04 - val_loss:
9.8115e-05
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1458e-04 - val_loss:
9.7677e-05
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1479e-04 - val_loss:
9.7154e-05
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1503e-04 - val_loss:
9.6547e-05
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.1526e-04 - val_loss:
9.5870e-05
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1542e-04 - val_loss:
9.5147e-05
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1546e-04 - val_loss:
9.4416e-05
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1530e-04 - val_loss:
9.3722e-05
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1492e-04 - val_loss:
9.3111e-05
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1428e-04 - val_loss:
9.2618e-05
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1339e-04 - val_loss:
9.2260e-05
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1230e-04 - val_loss:
9.2036e-05
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1106e-04 - val_loss:
9.1931e-05
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0972e-04 - val_loss:
9.1918e-05
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0834e-04 - val_loss:
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9.1973e-05
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0698e-04 - val_loss:
9.2074e-05
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0565e-04 - val_loss:
9.2201e-05
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.0437e-04 - val_loss:
9.2344e-05
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0314e-04 - val_loss:
9.2495e-05
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0198e-04 - val_loss:
9.2648e-05
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0087e-04 - val_loss:
9.2800e-05
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.9981e-04 - val_loss:
9.2950e-05
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9879e-04 - val_loss:
9.3098e-05
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9782e-04 - val_loss:
9.3242e-05
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 3.9688e-04 - val_loss:
9.3384e-05
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9598e-04 - val_loss:
9.3523e-05
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9511e-04 - val_loss:
9.3659e-05
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9426e-04 - val_loss:
9.3793e-05
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9344e-04 - val_loss:
9.3925e-05
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9264e-04 - val_loss:
9.4055e-05
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9187e-04 - val_loss:
9.4183e-05
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Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 16ms/step - loss: 0.0346 - val_loss:
5.4716e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.2486e-04 - val_loss:
1.5457e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 6.4241e-04 - val_loss:
1.6082e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 5.9707e-04 - val_loss:
1.6737e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.6019e-04 - val_loss:
1.5655e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 5.2509e-04 - val_loss:
1.4321e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.9702e-04 - val_loss:
1.4177e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.7835e-04 - val_loss:
1.4582e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6388e-04 - val_loss:
1.5088e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5087e-04 - val_loss:
1.4820e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3968e-04 - val_loss:
1.3784e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3173e-04 - val_loss:
1.2855e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2625e-04 - val_loss:
1.2123e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2311e-04 - val_loss:
1.1427e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2193e-04 - val_loss:
1.0759e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2219e-04 - val_loss:
1.0174e-04
Epoch 17/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2315e-04 - val_loss:
9.7343e-05
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2395e-04 - val_loss:
9.4595e-05
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2398e-04 - val_loss:
9.3193e-05
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2309e-04 - val_loss:
9.2640e-05
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2148e-04 - val_loss:
9.2499e-05
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.1953e-04 - val_loss:
9.2497e-05
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.1755e-04 - val_loss:
9.2503e-05
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1580e-04 - val_loss:
9.2485e-05
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1440e-04 - val_loss:
9.2455e-05
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1337e-04 - val_loss:
9.2437e-05
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1268e-04 - val_loss:
9.2447e-05
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1225e-04 - val_loss:
9.2494e-05
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1201e-04 - val_loss:
9.2577e-05
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1189e-04 - val_loss:
9.2695e-05
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1183e-04 - val_loss:
9.2843e-05
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1181e-04 - val_loss:
9.3015e-05
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1178e-04 - val_loss:
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9.3203e-05
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1173e-04 - val_loss:
9.3402e-05
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1164e-04 - val_loss:
9.3606e-05
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.1151e-04 - val_loss:
9.3809e-05
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.1134e-04 - val_loss:
9.4008e-05
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1112e-04 - val_loss:
9.4202e-05
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1086e-04 - val_loss:
9.4389e-05
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.1056e-04 - val_loss:
9.4568e-05
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.1024e-04 - val_loss:
9.4741e-05
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.0988e-04 - val_loss:
9.4909e-05
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0951e-04 - val_loss:
9.5072e-05
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0912e-04 - val_loss:
9.5233e-05
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0871e-04 - val_loss:
9.5393e-05
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0830e-04 - val_loss:
9.5555e-05
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0788e-04 - val_loss:
9.5720e-05
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0746e-04 - val_loss:
9.5889e-05
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0704e-04 - val_loss:
9.6066e-05
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Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0662e-04 - val_loss:
9.6251e-05
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0621e-04 - val_loss:
9.6445e-05
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0581e-04 - val_loss:
9.6651e-05
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0542e-04 - val_loss:
9.6869e-05
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0504e-04 - val_loss:
9.7101e-05
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0467e-04 - val_loss:
9.7347e-05
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0431e-04 - val_loss:
9.7609e-05
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0397e-04 - val_loss:
9.7887e-05
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0364e-04 - val_loss:
9.8183e-05
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0333e-04 - val_loss:
9.8498e-05
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.0303e-04 - val_loss:
9.8831e-05
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.0275e-04 - val_loss:
9.9184e-05
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.0249e-04 - val_loss:
9.9557e-05
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.0225e-04 - val_loss:
9.9951e-05
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0203e-04 - val_loss:
1.0037e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0182e-04 - val_loss:
1.0080e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0164e-04 - val_loss:
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1.0126e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0148e-04 - val_loss:
1.0175e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0135e-04 - val_loss:
1.0225e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0124e-04 - val_loss:
1.0278e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0116e-04 - val_loss:
1.0333e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0111e-04 - val_loss:
1.0391e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0110e-04 - val_loss:
1.0451e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0112e-04 - val_loss:
1.0513e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0120e-04 - val_loss:
1.0578e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0132e-04 - val_loss:
1.0645e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0149e-04 - val_loss:
1.0714e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.0173e-04 - val_loss:
1.0785e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0205e-04 - val_loss:
1.0858e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0245e-04 - val_loss:
1.0931e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0296e-04 - val_loss:
1.1005e-04
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.0358e-04 - val_loss:
1.1077e-04
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.0434e-04 - val_loss:
1.1146e-04
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Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0527e-04 - val_loss:
1.1208e-04
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0639e-04 - val_loss:
1.1260e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0774e-04 - val_loss:
1.1293e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0933e-04 - val_loss:
1.1299e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1120e-04 - val_loss:
1.1266e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1333e-04 - val_loss:
1.1177e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1568e-04 - val_loss:
1.1017e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1811e-04 - val_loss:
1.0774e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2035e-04 - val_loss:
1.0454e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2200e-04 - val_loss:
1.0087e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2259e-04 - val_loss:
9.7270e-05
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2177e-04 - val_loss:
9.4334e-05
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1955e-04 - val_loss:
9.2386e-05
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1635e-04 - val_loss:
9.1362e-05
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1281e-04 - val_loss:
9.0972e-05
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0943e-04 - val_loss:
9.0923e-05
Epoch 99/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0647e-04 - val_loss:
9.1027e-05
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0398e-04 - val_loss:
9.1191e-05
Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 5s 28ms/step - loss: 0.0187 - val_loss:
0.0012
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 19ms/step - loss: 0.0018 - val_loss:
3.0169e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 0.0013 - val_loss:
4.2497e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 0.0011 - val_loss:
2.3558e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 9.1488e-04 - val_loss:
2.0867e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 8.5681e-04 - val_loss:
2.0705e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 8.0746e-04 - val_loss:
1.9538e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.7083e-04 - val_loss:
1.7636e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 7.4555e-04 - val_loss:
1.6237e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 7.1840e-04 - val_loss:
1.5273e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.9417e-04 - val_loss:
1.4554e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.7301e-04 - val_loss:
1.4019e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 6.5426e-04 - val_loss:
1.3601e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.3747e-04 - val_loss:
1.3260e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.2221e-04 - val_loss:
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1.2973e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.0816e-04 - val_loss:
1.2726e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.9510e-04 - val_loss:
1.2508e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.8290e-04 - val_loss:
1.2311e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.7142e-04 - val_loss:
1.2129e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 5.6060e-04 - val_loss:
1.1956e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 5.5039e-04 - val_loss:
1.1791e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 5.4075e-04 - val_loss:
1.1631e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.3166e-04 - val_loss:
1.1475e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.2310e-04 - val_loss:
1.1324e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.1505e-04 - val_loss:
1.1178e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.0751e-04 - val_loss:
1.1036e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.0046e-04 - val_loss:
1.0900e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.9389e-04 - val_loss:
1.0770e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.8778e-04 - val_loss:
1.0647e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8212e-04 - val_loss:
1.0530e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 24ms/step - loss: 4.7688e-04 - val_loss:
1.0421e-04
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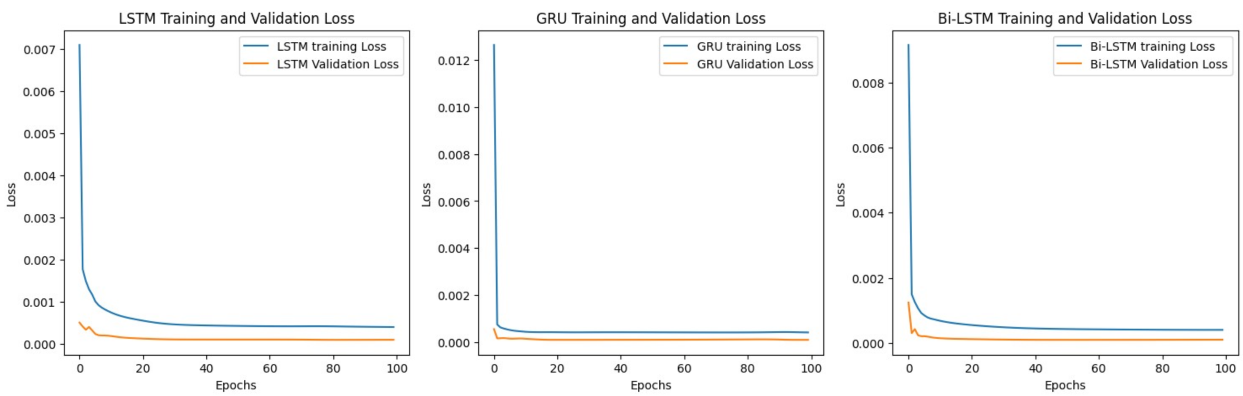
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 4.7204e-04 - val_loss:
1.0319e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.6757e-04 - val_loss:
1.0225e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.6345e-04 - val_loss:
1.0137e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.5965e-04 - val_loss:
1.0057e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.5615e-04 - val_loss:
9.9845e-05
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.5292e-04 - val_loss:
9.9185e-05
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.4994e-04 - val_loss:
9.8589e-05
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4717e-04 - val_loss:
9.8055e-05
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4461e-04 - val_loss:
9.7580e-05
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.4223e-04 - val_loss:
9.7160e-05
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.4002e-04 - val_loss:
9.6791e-05
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.3795e-04 - val_loss:
9.6470e-05
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.3603e-04 - val_loss:
9.6193e-05
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.3422e-04 - val_loss:
9.5957e-05
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.3253e-04 - val_loss:
9.5759e-05
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.3095e-04 - val_loss:
9.5595e-05
Epoch 48/100
```

```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2946e-04 - val_loss:
9.5463e-05
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.2806e-04 - val_loss:
9.5359e-05
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.2674e-04 - val_loss:
9.5281e-05
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2550e-04 - val_loss:
9.5226e-05
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2432e-04 - val_loss:
9.5191e-05
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.2320e-04 - val_loss:
9.5174e-05
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 4.2213e-04 - val_loss:
9.5174e-05
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2111e-04 - val_loss:
9.5188e-05
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2014e-04 - val_loss:
9.5214e-05
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1920e-04 - val_loss:
9.5251e-05
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1831e-04 - val_loss:
9.5298e-05
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1744e-04 - val_loss:
9.5352e-05
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1660e-04 - val_loss:
9.5414e-05
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1578e-04 - val_loss:
9.5482e-05
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1499e-04 - val_loss:
9.5555e-05
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1421e-04 - val_loss:
9.5633e-05
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1346e-04 - val_loss:
```

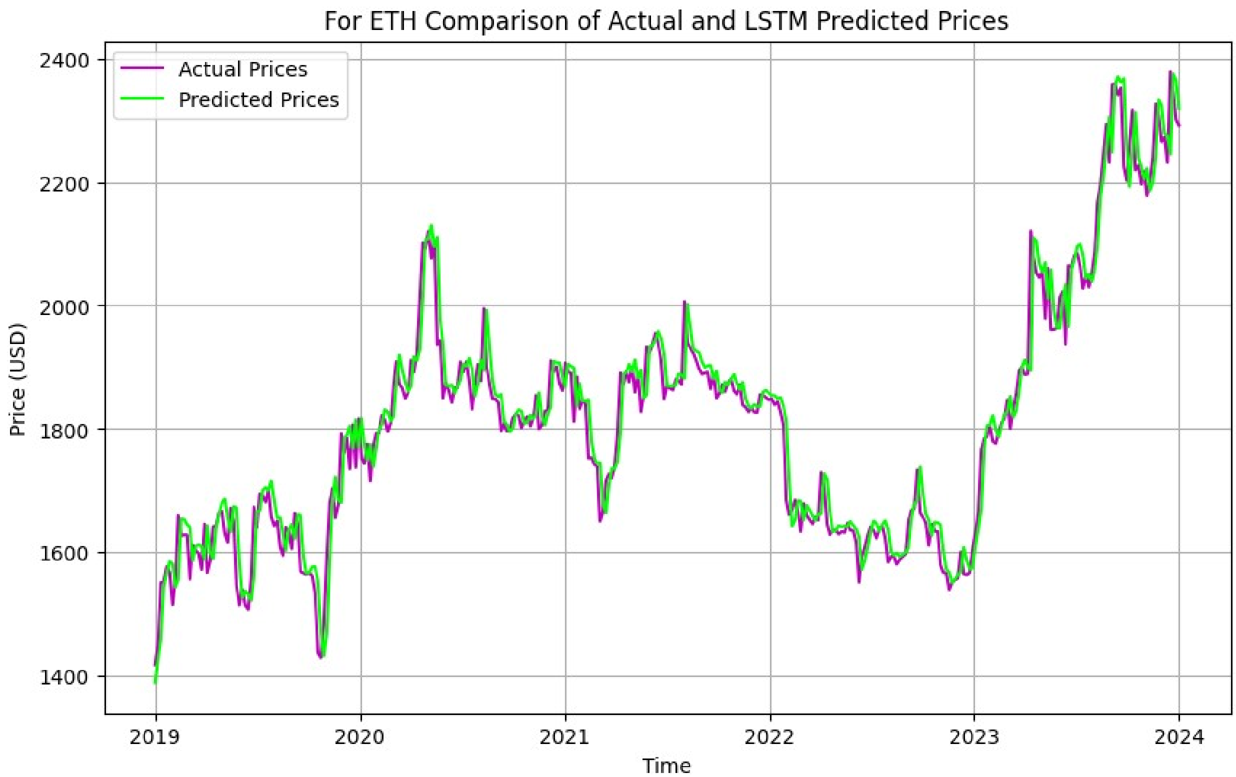
```
9.5715e-05
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1271e-04 - val_loss:
9.5799e-05
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 23ms/step - loss: 4.1198e-04 - val_loss:
9.5887e-05
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.1126e-04 - val_loss:
9.5977e-05
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.1056e-04 - val_loss:
9.6069e-05
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0986e-04 - val_loss:
9.6163e-05
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0917e-04 - val_loss:
9.6259e-05
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0849e-04 - val_loss:
9.6357e-05
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0781e-04 - val_loss:
9.6456e-05
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0715e-04 - val_loss:
9.6558e-05
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0650e-04 - val_loss:
9.6661e-05
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0586e-04 - val_loss:
9.6769e-05
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0524e-04 - val_loss:
9.6879e-05
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 22ms/step - loss: 4.0463e-04 - val_loss:
9.6994e-05
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.0405e-04 - val_loss:
9.7113e-05
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0348e-04 - val_loss:
9.7237e-05
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0294e-04 - val_loss:
9.7366e-05
```

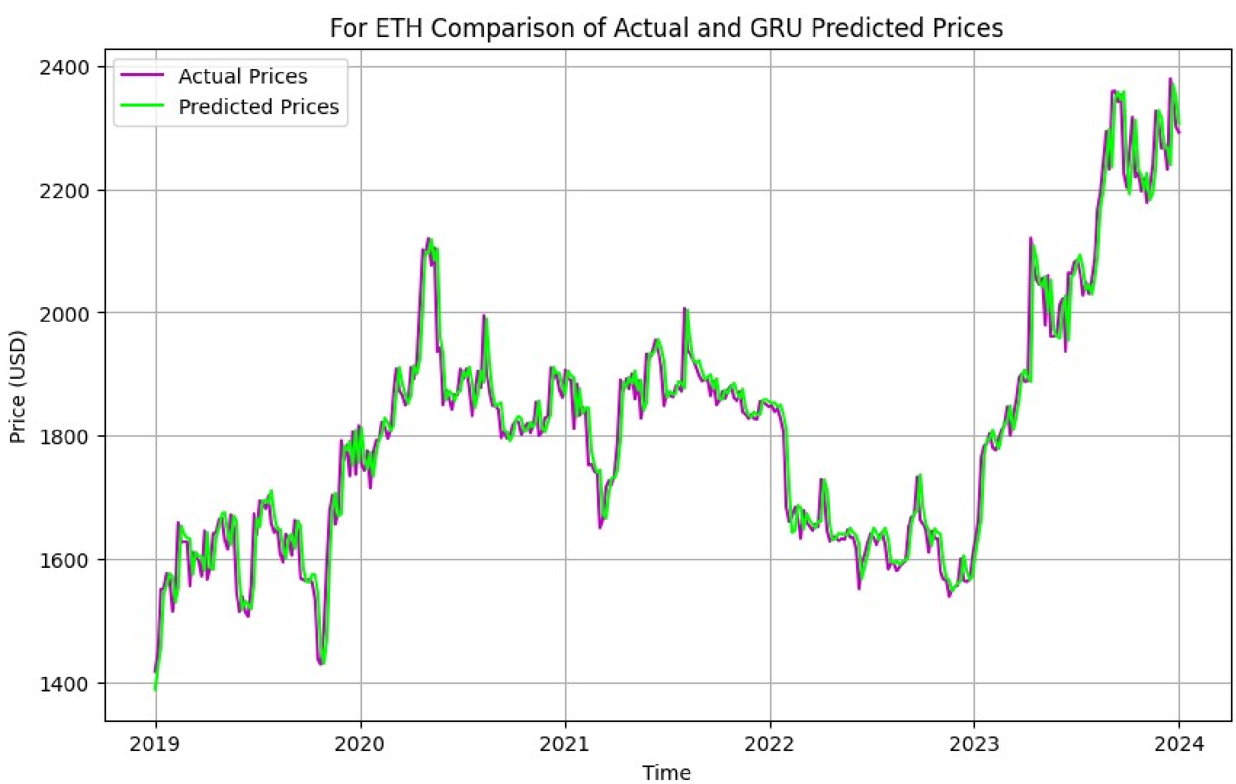
```
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0243e-04 - val_loss:
9.7500e-05
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0193e-04 - val_loss:
9.7641e-05
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.0147e-04 - val_loss:
9.7789e-05
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0102e-04 - val_loss:
9.7942e-05
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0060e-04 - val_loss:
9.8101e-05
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.0020e-04 - val_loss:
9.8268e-05
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9982e-04 - val_loss:
9.8441e-05
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 3.9946e-04 - val_loss:
9.8620e-05
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 3.9913e-04 - val_loss:
9.8806e-05
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.9882e-04 - val_loss:
9.8996e-05
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9853e-04 - val_loss:
9.9192e-05
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9827e-04 - val_loss:
9.9391e-05
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9805e-04 - val_loss:
9.9593e-05
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.9785e-04 - val_loss:
9.9795e-05
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9768e-04 - val_loss:
9.9996e-05
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.9756e-04 - val_loss:
1.0019e-04
Epoch 97/100
```

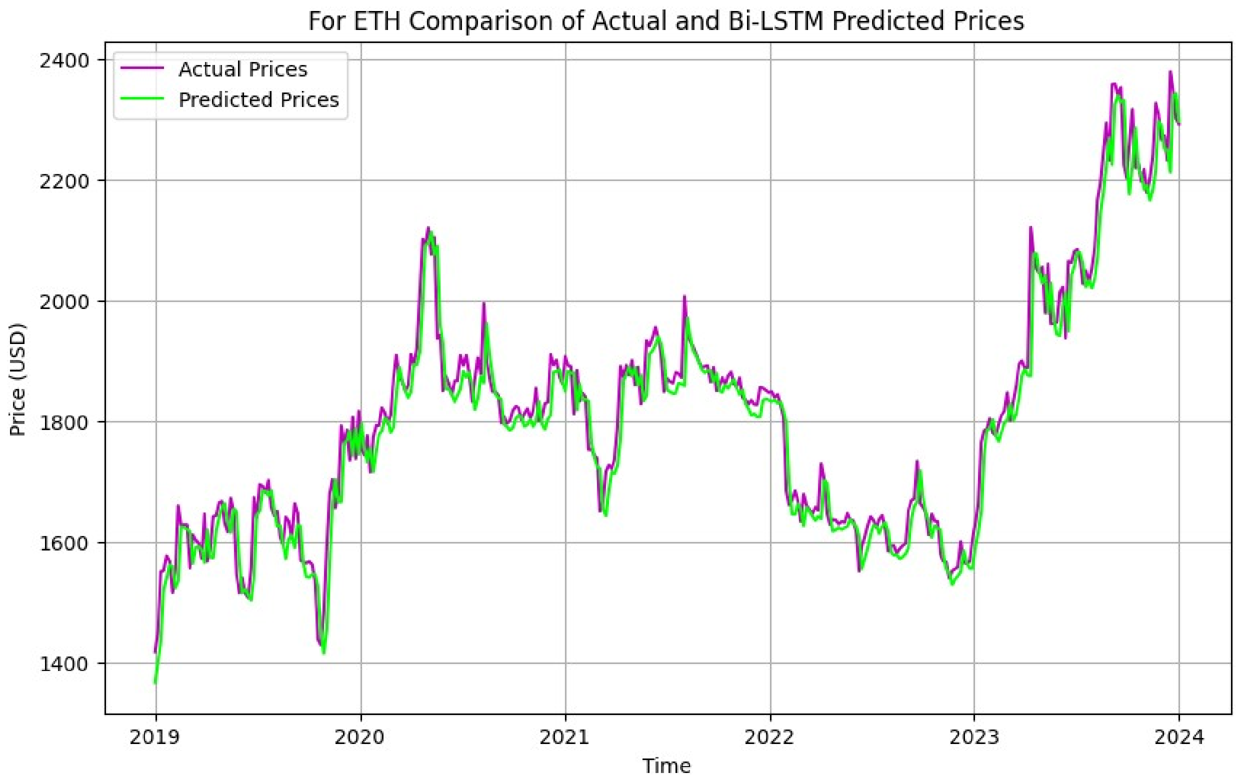
```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 3.9748e-04 - val_loss:
1.0038e-04
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 3.9744e-04 - val_loss:
1.0055e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 3.9745e-04 - val_loss:
1.0070e-04
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 3.9753e-04 - val_loss:
1.0083e-04
LSTM Test loss: 9.418311674380675e-05
GRU Test loss: 9.119144669966772e-05
BiLSTM Test loss: 0.00010082648077514023
```




```
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 1s 35ms/step
LSTM MSE: 9.418312279942257e-05, MAE: 0.00690689632307667
GRU MSE: 9.119144781079826e-05, MAE: 0.006710929154621598
BiLSTM MSE: 0.00010082648002455977, MAE: 0.007086421305006641
```


For ETH Comparison of Actual and LSTM Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
Time
1400
1600
1800
2000
2200
2400
2019
2020
2021
2022
2023
2024


For ETH Comparison of Actual and GRU Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
Time
1400
1600
1800
2000
2200
2400
2019
2020
2021
2022
2023
2024




```
LSTM RMSE: 0.010, MAPE: 1.91%
GRU RMSE: 0.010, MAPE: 1.85%
BiLSTM RMSE: 0.010, MAPE: 1.95%
Data preprocessed and ready for model training.

<ipython-input-1-11932f61a7e0>:546: FutureWarning: DataFrame.fillna
with 'method' is deprecated and will raise in a future version. Use
obj.ffill() or obj.bfill() instead.
  ltc_data.fillna(method='ffill', inplace=True)
/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/rnn.py:20
0: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a
layer. When using Sequential models, prefer using an `Input(shape)`
object as the first layer in the model instead.
  super().__init__(**kwargs)
/usr/local/lib/python3.11/dist-packages/keras/src/layers/rnn/bidirecti
onal.py:107: UserWarning: Do not pass an `input_shape`/`input_dim`
argument to a layer. When using Sequential models, prefer using an
`Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)

Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 19ms/step - loss: 0.0067 - val_loss:
4.3445e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 0.0015 - val_loss:
2.3623e-04
```

```
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 0.0012 - val_loss:
1.8183e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 0.0011 - val_loss:
1.7744e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 9.7333e-04 - val_loss:
1.5205e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 9.4309e-04 - val_loss:
1.4538e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 9.1258e-04 - val_loss:
1.4274e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 8.9886e-04 - val_loss:
1.4165e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 8.8982e-04 - val_loss:
1.4131e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 8.8233e-04 - val_loss:
1.4106e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 8.7641e-04 - val_loss:
1.4028e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 8.7142e-04 - val_loss:
1.3833e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.6638e-04 - val_loss:
1.3476e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.5988e-04 - val_loss:
1.2949e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.5027e-04 - val_loss:
1.2304e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 8.3584e-04 - val_loss:
1.1651e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 8.1538e-04 - val_loss:
1.1116e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.8895e-04 - val_loss:
1.0771e-04
Epoch 19/100
```

```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.5829e-04 - val_loss:
1.0609e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.2619e-04 - val_loss:
1.0564e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.9526e-04 - val_loss:
1.0570e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.6714e-04 - val_loss:
1.0590e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.4248e-04 - val_loss:
1.0612e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 6.2133e-04 - val_loss:
1.0640e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 6.0348e-04 - val_loss:
1.0682e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.8865e-04 - val_loss:
1.0748e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.7649e-04 - val_loss:
1.0842e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 5.6660e-04 - val_loss:
1.0965e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 5.5853e-04 - val_loss:
1.1115e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.5185e-04 - val_loss:
1.1287e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.4616e-04 - val_loss:
1.1473e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.4120e-04 - val_loss:
1.1667e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 5.3673e-04 - val_loss:
1.1867e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.3260e-04 - val_loss:
1.2069e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.2872e-04 - val_loss:
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1.2276e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.2501e-04 - val_loss:
1.2488e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.2144e-04 - val_loss:
1.2707e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.1799e-04 - val_loss:
1.2935e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.1464e-04 - val_loss:
1.3177e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.1139e-04 - val_loss:
1.3436e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.0824e-04 - val_loss:
1.3720e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.0518e-04 - val_loss:
1.4039e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.0223e-04 - val_loss:
1.4404e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.9939e-04 - val_loss:
1.4824e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.9668e-04 - val_loss:
1.5302e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.9413e-04 - val_loss:
1.5830e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.9173e-04 - val_loss:
1.6389e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.8943e-04 - val_loss:
1.6956e-04
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8719e-04 - val_loss:
1.7513e-04
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.8500e-04 - val_loss:
1.8043e-04
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.8285e-04 - val_loss:
1.8532e-04
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Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.8071e-04 - val_loss:
1.8963e-04
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7858e-04 - val_loss:
1.9330e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7649e-04 - val_loss:
1.9640e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7454e-04 - val_loss:
1.9901e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.7280e-04 - val_loss:
2.0109e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.7126e-04 - val_loss:
2.0255e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6984e-04 - val_loss:
2.0331e-04
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6851e-04 - val_loss:
2.0339e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6722e-04 - val_loss:
2.0277e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6593e-04 - val_loss:
2.0147e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6463e-04 - val_loss:
1.9954e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6330e-04 - val_loss:
1.9701e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6193e-04 - val_loss:
1.9394e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.6051e-04 - val_loss:
1.9040e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5900e-04 - val_loss:
1.8641e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.5729e-04 - val_loss:
1.8201e-04
Epoch 68/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.5531e-04 - val_loss:
1.7798e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.5362e-04 - val_loss:
1.7439e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.5199e-04 - val_loss:
1.6753e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.4750e-04 - val_loss:
1.6602e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4751e-04 - val_loss:
1.6309e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4585e-04 - val_loss:
1.6600e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.4619e-04 - val_loss:
1.6485e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4669e-04 - val_loss:
1.6126e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4525e-04 - val_loss:
1.5434e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.4249e-04 - val_loss:
1.4799e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3839e-04 - val_loss:
1.4688e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3672e-04 - val_loss:
1.4686e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3791e-04 - val_loss:
1.4672e-04
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3609e-04 - val_loss:
1.4471e-04
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3572e-04 - val_loss:
1.4013e-04
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3410e-04 - val_loss:
1.3710e-04
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3134e-04 - val_loss:
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1.3348e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2648e-04 - val_loss:
1.3114e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 4.2429e-04 - val_loss:
1.2711e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.2201e-04 - val_loss:
1.2727e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2082e-04 - val_loss:
1.2690e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1961e-04 - val_loss:
1.2594e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.1787e-04 - val_loss:
1.2511e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.1650e-04 - val_loss:
1.2386e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1566e-04 - val_loss:
1.2315e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1478e-04 - val_loss:
1.2366e-04
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.1397e-04 - val_loss:
1.2334e-04
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1226e-04 - val_loss:
1.2233e-04
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0927e-04 - val_loss:
1.2339e-04
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0777e-04 - val_loss:
1.2098e-04
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0549e-04 - val_loss:
1.2073e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.0285e-04 - val_loss:
1.1997e-04
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0095e-04 - val_loss:
1.1966e-04
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Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 3s 25ms/step - loss: 0.0087 - val_loss:
1.6569e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 7.7059e-04 - val_loss:
1.6390e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 7.2135e-04 - val_loss:
1.2274e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.2839e-04 - val_loss:
1.1315e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 7.7791e-04 - val_loss:
1.0945e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 7.6457e-04 - val_loss:
1.0659e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 7.1960e-04 - val_loss:
1.0190e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 6.9561e-04 - val_loss:
9.9011e-05
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 6.7703e-04 - val_loss:
9.7133e-05
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.5918e-04 - val_loss:
9.5873e-05
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.4420e-04 - val_loss:
9.5227e-05
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.3185e-04 - val_loss:
9.5117e-05
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.2149e-04 - val_loss:
9.5435e-05
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 6.1261e-04 - val_loss:
9.6080e-05
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 6.0483e-04 - val_loss:
9.6962e-05
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.9787e-04 - val_loss:
9.8015e-05
Epoch 17/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.9152e-04 - val_loss:
9.9192e-05
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.8567e-04 - val_loss:
1.0047e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 5.8024e-04 - val_loss:
1.0183e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 5.7518e-04 - val_loss:
1.0326e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 5.7045e-04 - val_loss:
1.0477e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - loss: 5.6602e-04 - val_loss:
1.0635e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.6186e-04 - val_loss:
1.0801e-04
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.5795e-04 - val_loss:
1.0973e-04
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.5425e-04 - val_loss:
1.1151e-04
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.5074e-04 - val_loss:
1.1335e-04
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.4740e-04 - val_loss:
1.1523e-04
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.4421e-04 - val_loss:
1.1715e-04
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.4114e-04 - val_loss:
1.1909e-04
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.3816e-04 - val_loss:
1.2104e-04
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.3526e-04 - val_loss:
1.2298e-04
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.3239e-04 - val_loss:
1.2489e-04
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 5.2953e-04 - val_loss:
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1.2674e-04
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.2663e-04 - val_loss:
1.2851e-04
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 5.2364e-04 - val_loss:
1.3012e-04
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.2048e-04 - val_loss:
1.3152e-04
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 5.1705e-04 - val_loss:
1.3257e-04
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 5.1322e-04 - val_loss:
1.3313e-04
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 5.0881e-04 - val_loss:
1.3295e-04
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 5.0362e-04 - val_loss:
1.3174e-04
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.9755e-04 - val_loss:
1.2927e-04
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.9071e-04 - val_loss:
1.2560e-04
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.8356e-04 - val_loss:
1.2126e-04
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.7678e-04 - val_loss:
1.1709e-04
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.7068e-04 - val_loss:
1.1371e-04
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.6470e-04 - val_loss:
1.1136e-04
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5847e-04 - val_loss:
1.1156e-04
Epoch 48/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.5505e-04 - val_loss:
1.1605e-04
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.5500e-04 - val_loss:
1.2155e-04
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Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.5418e-04 - val_loss:
1.2525e-04
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.5208e-04 - val_loss:
1.2638e-04
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4874e-04 - val_loss:
1.2537e-04
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.4509e-04 - val_loss:
1.2354e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.4180e-04 - val_loss:
1.2169e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.3884e-04 - val_loss:
1.2000e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3602e-04 - val_loss:
1.1845e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3325e-04 - val_loss:
1.1695e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.3047e-04 - val_loss:
1.1536e-04
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.2768e-04 - val_loss:
1.1347e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 14ms/step - loss: 4.2492e-04 - val_loss:
1.1117e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.2231e-04 - val_loss:
1.0854e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.2012e-04 - val_loss:
1.0589e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1905e-04 - val_loss:
1.0324e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 12ms/step - loss: 4.2044e-04 - val_loss:
9.9668e-05
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2582e-04 - val_loss:
9.4913e-05
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.3223e-04 - val_loss:
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1.0384e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1723e-04 - val_loss:
1.0411e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2157e-04 - val_loss:
1.0210e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.2268e-04 - val_loss:
1.0274e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.2110e-04 - val_loss:
1.0222e-04
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1972e-04 - val_loss:
1.0167e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1868e-04 - val_loss:
1.0117e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1785e-04 - val_loss:
1.0065e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 4.1704e-04 - val_loss:
1.0014e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1614e-04 - val_loss:
9.9590e-05
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1521e-04 - val_loss:
9.9006e-05
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1428e-04 - val_loss:
9.8401e-05
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 15ms/step - loss: 4.1336e-04 - val_loss:
9.7775e-05
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.1245e-04 - val_loss:
9.7126e-05
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1154e-04 - val_loss:
9.6447e-05
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.1063e-04 - val_loss:
9.5728e-05
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0969e-04 - val_loss:
9.4956e-05
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Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0871e-04 - val_loss:
9.4106e-05
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0765e-04 - val_loss:
9.3135e-05
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0640e-04 - val_loss:
9.1951e-05
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0472e-04 - val_loss:
9.0327e-05
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0172e-04 - val_loss:
8.6842e-05
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - loss: 3.9579e-04 - val_loss:
9.1755e-05
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.1258e-04 - val_loss:
8.8209e-05
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 4.0304e-04 - val_loss:
9.3834e-05
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.9754e-04 - val_loss:
8.4543e-05
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 4.0122e-04 - val_loss:
8.8789e-05
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9687e-04 - val_loss:
8.6071e-05
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9415e-04 - val_loss:
8.2186e-05
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8846e-04 - val_loss:
8.4307e-05
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - loss: 3.8219e-04 - val_loss:
8.0530e-05
Epoch 97/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - loss: 3.9344e-04 - val_loss:
8.4100e-05
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 4.0077e-04 - val_loss:
9.0249e-05
Epoch 99/100
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45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 3.9365e-04 - val_loss:
8.2897e-05
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 16ms/step - loss: 3.9435e-04 - val_loss:
7.8793e-05
Epoch 1/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 4s 30ms/step - loss: 0.0135 - val_loss:
2.7983e-04
Epoch 2/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 21ms/step - loss: 0.0013 - val_loss:
1.9479e-04
Epoch 3/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 0.0011 - val_loss:
1.5198e-04
Epoch 4/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 0.0011 - val_loss:
1.5188e-04
Epoch 5/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 0.0010 - val_loss:
1.4288e-04
Epoch 6/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 9.3134e-04 - val_loss:
1.3342e-04
Epoch 7/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 8.9857e-04 - val_loss:
1.2860e-04
Epoch 8/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 8.5966e-04 - val_loss:
1.2507e-04
Epoch 9/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 8.3624e-04 - val_loss:
1.2269e-04
Epoch 10/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 8.1906e-04 - val_loss:
1.2094e-04
Epoch 11/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 8.0412e-04 - val_loss:
1.1962e-04
Epoch 12/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 7.9099e-04 - val_loss:
1.1857e-04
Epoch 13/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.7907e-04 - val_loss:
1.1772e-04
Epoch 14/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 7.6809e-04 - val_loss:
1.1694e-04
Epoch 15/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.5786e-04 - val_loss:
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1.1613e-04
Epoch 16/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 7.4823e-04 - val_loss:
1.1514e-04
Epoch 17/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.3905e-04 - val_loss:
1.1385e-04
Epoch 18/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.3018e-04 - val_loss:
1.1215e-04
Epoch 19/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 7.2145e-04 - val_loss:
1.1002e-04
Epoch 20/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 7.1268e-04 - val_loss:
1.0753e-04
Epoch 21/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 7.0367e-04 - val_loss:
1.0487e-04
Epoch 22/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 6.9426e-04 - val_loss:
1.0225e-04
Epoch 23/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.8440e-04 - val_loss:
9.9807e-05
Epoch 24/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.7414e-04 - val_loss:
9.7614e-05
Epoch 25/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.6357e-04 - val_loss:
9.5677e-05
Epoch 26/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 6.5279e-04 - val_loss:
9.3982e-05
Epoch 27/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 6.4186e-04 - val_loss:
9.2509e-05
Epoch 28/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 6.3081e-04 - val_loss:
9.1241e-05
Epoch 29/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 6.1968e-04 - val_loss:
9.0167e-05
Epoch 30/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 6.0863e-04 - val_loss:
8.9289e-05
Epoch 31/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 25ms/step - loss: 5.9793e-04 - val_loss:
8.8626e-05
```

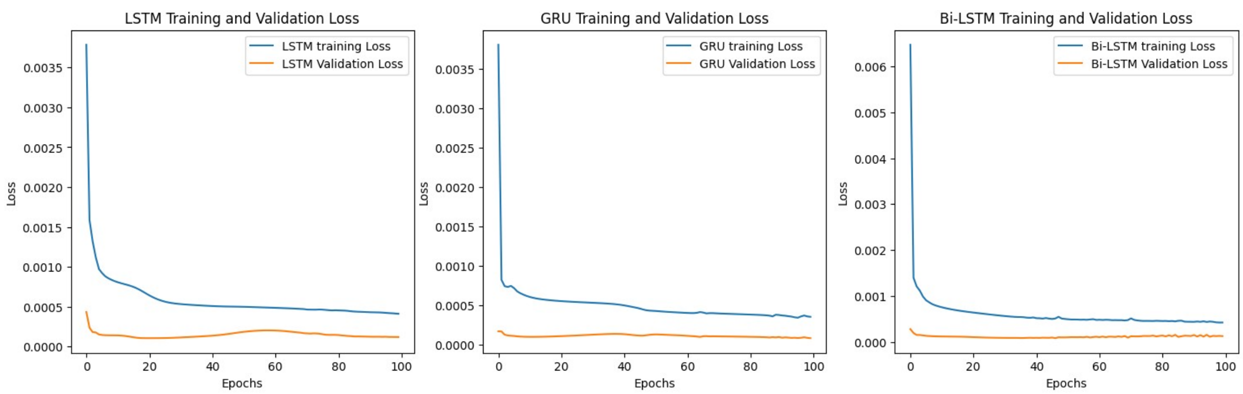
```
Epoch 32/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.8793e-04 - val_loss:
8.8200e-05
Epoch 33/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.7892e-04 - val_loss:
8.8029e-05
Epoch 34/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.7116e-04 - val_loss:
8.8118e-05
Epoch 35/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.6493e-04 - val_loss:
8.8240e-05
Epoch 36/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.6093e-04 - val_loss:
8.5697e-05
Epoch 37/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.6321e-04 - val_loss:
8.6138e-05
Epoch 38/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.5610e-04 - val_loss:
8.9552e-05
Epoch 39/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.4218e-04 - val_loss:
9.0751e-05
Epoch 40/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.4180e-04 - val_loss:
8.8081e-05
Epoch 41/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.3722e-04 - val_loss:
9.0087e-05
Epoch 42/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 5.2522e-04 - val_loss:
8.8170e-05
Epoch 43/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 5.2580e-04 - val_loss:
9.3047e-05
Epoch 44/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 26ms/step - loss: 5.1999e-04 - val_loss:
9.1102e-05
Epoch 45/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.1826e-04 - val_loss:
9.0542e-05
Epoch 46/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.1248e-04 - val_loss:
9.5760e-05
Epoch 47/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.0844e-04 - val_loss:
8.2278e-05
Epoch 48/100
```

```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 5.6750e-04 - val_loss: 
1.0150e-04
Epoch 49/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.2109e-04 - val_loss: 
9.9519e-05
Epoch 50/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 5.1093e-04 - val_loss: 
9.9026e-05
Epoch 51/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.0396e-04 - val_loss: 
1.0080e-04
Epoch 52/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.9618e-04 - val_loss: 
1.0465e-04
Epoch 53/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.9186e-04 - val_loss: 
1.0398e-04
Epoch 54/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 4.8840e-04 - val_loss: 
1.0325e-04
Epoch 55/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 25ms/step - loss: 4.8529e-04 - val_loss: 
1.0518e-04
Epoch 56/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8345e-04 - val_loss: 
1.0164e-04
Epoch 57/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8259e-04 - val_loss: 
1.1104e-04
Epoch 58/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.8177e-04 - val_loss: 
9.7397e-05
Epoch 59/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 5.0065e-04 - val_loss: 
1.0674e-04
Epoch 60/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.8004e-04 - val_loss: 
1.1316e-04
Epoch 61/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.7587e-04 - val_loss: 
1.0380e-04
Epoch 62/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.7771e-04 - val_loss: 
1.1707e-04
Epoch 63/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.7361e-04 - val_loss: 
1.0290e-04
Epoch 64/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.8161e-04 - val_loss: 
```

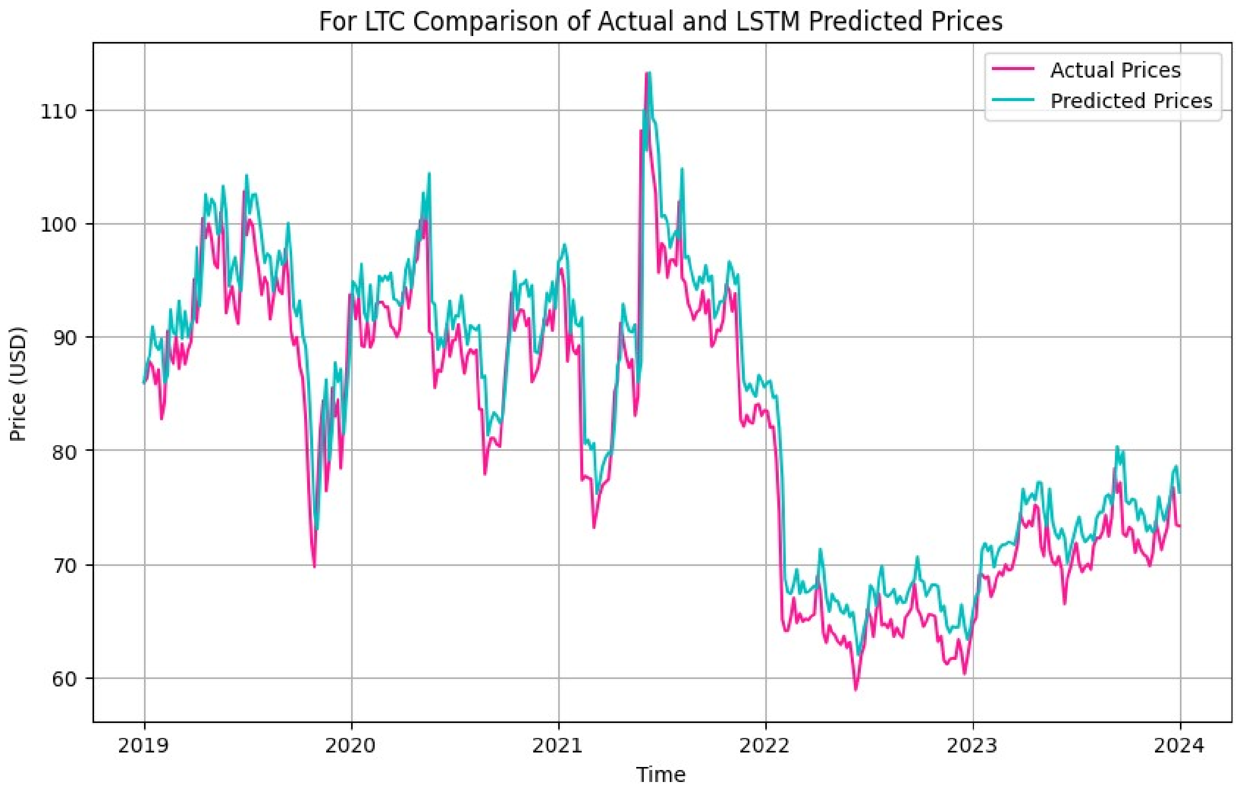
```
1.1591e-04
Epoch 65/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.6923e-04 - val_loss:
1.1407e-04
Epoch 66/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.6587e-04 - val_loss:
1.0887e-04
Epoch 67/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.7049e-04 - val_loss:
1.2115e-04
Epoch 68/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 24ms/step - loss: 4.6469e-04 - val_loss:
1.1126e-04
Epoch 69/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.6005e-04 - val_loss:
1.2902e-04
Epoch 70/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.6104e-04 - val_loss:
9.3779e-05
Epoch 71/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 5.1422e-04 - val_loss:
1.2411e-04
Epoch 72/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.7776e-04 - val_loss:
1.2260e-04
Epoch 73/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.6666e-04 - val_loss:
1.2127e-04
Epoch 74/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.5776e-04 - val_loss:
1.2347e-04
Epoch 75/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.5215e-04 - val_loss:
1.3100e-04
Epoch 76/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.5043e-04 - val_loss:
1.2926e-04
Epoch 77/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.4744e-04 - val_loss:
1.2917e-04
Epoch 78/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - loss: 4.4505e-04 - val_loss:
1.3921e-04
Epoch 79/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.4713e-04 - val_loss:
1.2002e-04
Epoch 80/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.5220e-04 - val_loss:
1.3205e-04
```

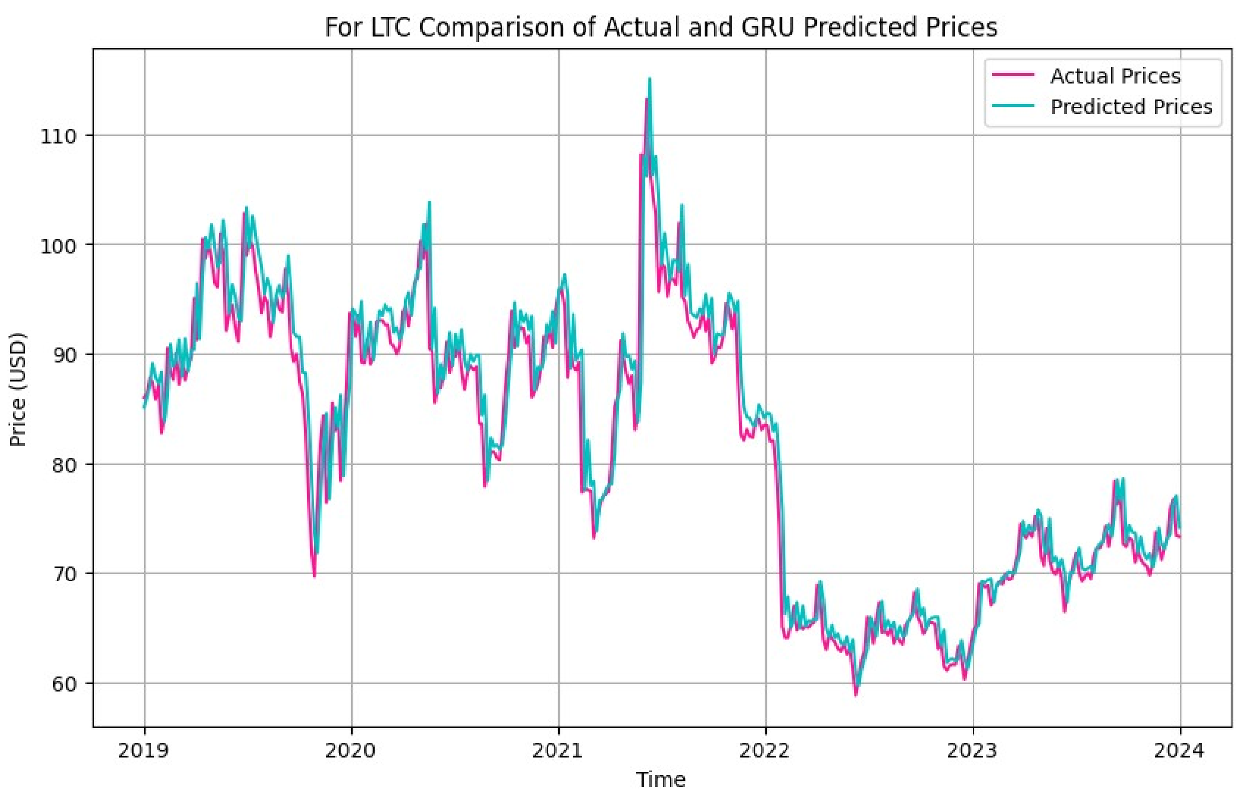
```
Epoch 81/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4549e-04 - val_loss:
1.3924e-04
Epoch 82/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.4412e-04 - val_loss:
1.2198e-04
Epoch 83/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4387e-04 - val_loss:
1.4410e-04
Epoch 84/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.4399e-04 - val_loss:
1.2472e-04
Epoch 85/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.3616e-04 - val_loss:
1.5383e-04
Epoch 86/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.4562e-04 - val_loss:
1.1018e-04
Epoch 87/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.5956e-04 - val_loss:
1.2449e-04
Epoch 88/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.3848e-04 - val_loss:
1.3626e-04
Epoch 89/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 2s 23ms/step - loss: 4.3268e-04 - val_loss:
1.3395e-04
Epoch 90/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 22ms/step - loss: 4.2953e-04 - val_loss:
1.2982e-04
Epoch 91/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 21ms/step - loss: 4.2791e-04 - val_loss:
1.5050e-04
Epoch 92/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.3356e-04 - val_loss:
1.1858e-04
Epoch 93/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.2921e-04 - val_loss:
1.4950e-04
Epoch 94/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.3574e-04 - val_loss:
1.1605e-04
Epoch 95/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.2721e-04 - val_loss:
1.5497e-04
Epoch 96/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 19ms/step - loss: 4.3256e-04 - val_loss:
1.1339e-04
Epoch 97/100
```

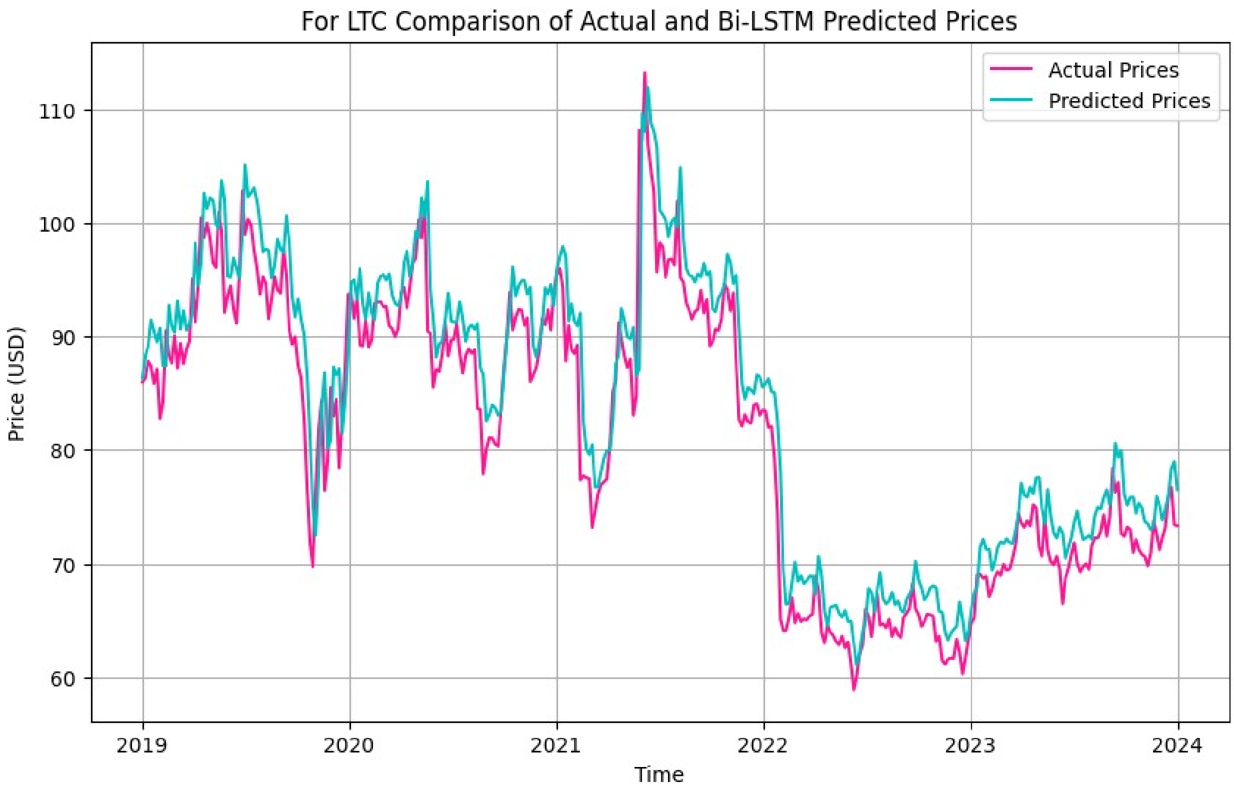
```
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.3590e-04 - val_loss:
1.3254e-04
Epoch 98/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 18ms/step - loss: 4.2069e-04 - val_loss:
1.2748e-04
Epoch 99/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 17ms/step - loss: 4.1576e-04 - val_loss:
1.3237e-04
Epoch 100/100
45/45 ━━━━━━━━━━━━━━━━━━━━ 1s 20ms/step - loss: 4.1499e-04 - val_loss:
1.2717e-04
LSTM Test loss: 0.00011965988960582763
GRU Test loss: 7.879322947701439e-05
BiLSTM Test loss: 0.0001271696964977309
```




```
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
12/12 ━━━━━━━━━━━━━━━━━━━━ 1s 36ms/step
LSTM MSE: 0.00011965987814683528, MAE: 0.00868452567123658
GRU MSE: 7.879322108244601e-05, MAE: 0.005997014748248105
BiLSTM MSE: 0.0001271696977900567, MAE: 0.00895174249978411
```


For LTC Comparison of Actual and LSTM Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
110
100
90
80
70
60
2019
2020
2021
2022
2023
2024
Time


For LTC Comparison of Actual and GRU Predicted Prices
Actual Prices
Predicted Prices
Price (USD)
110
100
90
80
70
60
2019
2020
2021
2022
2023
2024
Time




```
LSTM RMSE: 0.011, MAPE: 6.40%
GRU RMSE: 0.009, MAPE: 4.17%
BiLSTM RMSE: 0.011, MAPE: 6.54%
```