

LAB #5 - Redes Neuronales Recurrentes (RNN) para Series de Tiempo

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Link del repositorio: <https://github.com/alee2602/LAB5-DS>

Importación de Librerías

```
In [14]: import os, sys, math, warnings, json, random
warnings.filterwarnings("ignore")

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from datetime import datetime
from pandas_datareader import data as pdr

from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import mean_absolute_error, mean_squared_error

import tensorflow as tf
from tensorflow.keras import layers, models, callbacks
from tensorflow.keras.preprocessing.sequence import TimeseriesGenerator
from tensorflow.keras import regularizers

# Semillas para reproducibilidad
SEED = 8
random.seed(SEED)
np.random.seed(SEED)
tf.random.set_seed(SEED)
```

1. Carga y exploración de datos

```
In [9]: SERIE = "IPN31152N" # Ice cream & frozen dessert production index (2012=100, mensual)
START = "1985-01-01" # fecha inicial amplia para historia
END   = None          # hasta hoy

def load_fred_series(serie=SERIE, start=START, end=END):
    try:
        df = pdr.DataReader(serie, "fred", start=start, end=end)
        df = df.rename(columns={serie: "value"})
        df.index.name = "date"
        print(f"Descarga exitosa desde FRED: {serie} | filas={len(df)} rango={df.index.min()} - {df.index.max()}")
        return df
    except Exception as e:
        print("No se pudo descargar desde FRED. Intentando CSV local...", e)
```

```

# CSV de respaldo en el mismo folder del notebook
local = f"./{serie}.csv"
if not os.path.exists(local):
    raise FileNotFoundError(f"No hay internet ni archivo local '{local}'. C
df = pd.read_csv(local)
# normaliza columnas
cols = {c.lower(): c for c in df.columns}
date_col = cols.get("date", None)
value_col = cols.get("value", None)
if date_col is None or value_col is None:

    date_col = "DATE" if "DATE" in df.columns else list(df.columns)[0]
    value_col = "VALUE" if "VALUE" in df.columns else list(df.columns)[1]
df = df.rename(columns={date_col: "date", value_col: "value"})
df["date"] = pd.to_datetime(df["date"])
df = df.set_index("date").sort_index()
print(f"Carga local desde CSV: {local} | filas={len(df)} rango={df.index.m
return df

df = load_fred_series()
display(df.head(3))
display(df.tail(3))

print(df.describe().T)
print("\nFrecuencia inferida:", pd.infer_freq(df.index))

plt.figure(figsize=(10,4))
plt.plot(df.index, df["value"], lw=1.5)
plt.title("Producción industrial: helados y postres congelados (Índice 2012=100, me
plt.xlabel("Fecha"); plt.ylabel("Índice")
plt.grid(True, alpha=0.3)
plt.show()

```

Descarga exitosa desde FRED: IPN31152N | filas=486 rango=1985-01-01..2025-06-01

| | value |
|-------------------|----------|
| | date |
| 1985-01-01 | 76.4150 |
| 1985-02-01 | 86.8838 |
| 1985-03-01 | 101.5509 |

| | value |
|-------------------|----------|
| | date |
| 2025-04-01 | 116.9527 |
| 2025-05-01 | 118.2192 |
| 2025-06-01 | 127.0128 |

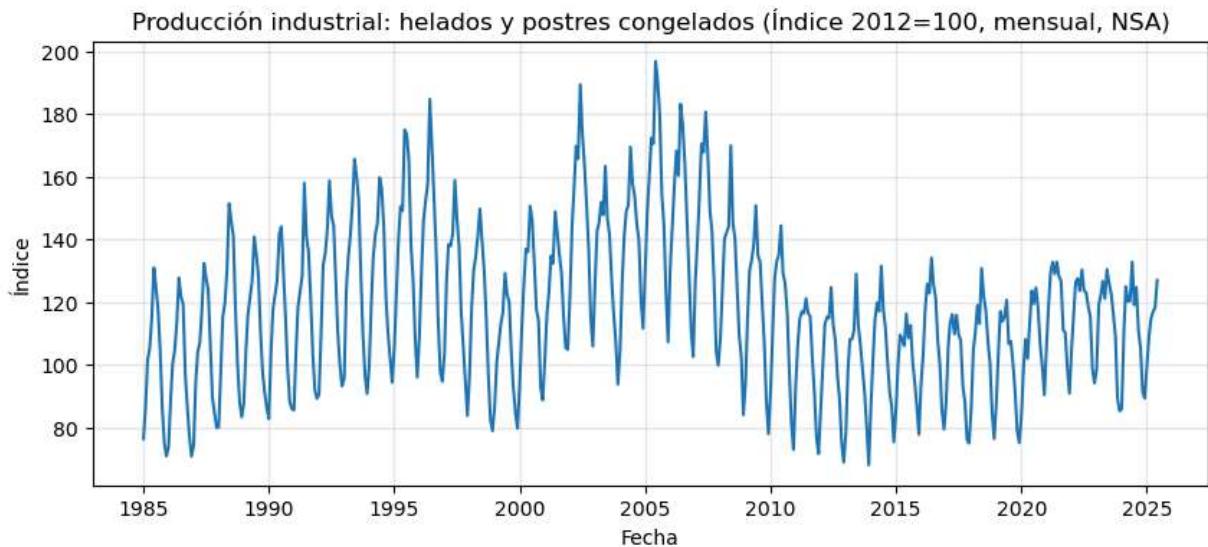
```

      count        mean       std       min     25%     50%     75%  \
value  486.0  118.226987  24.82883  68.0609  100.4178  116.6211  133.038675

                           max
value                      196.8174

```

Frecuencia inferida: MS



2. División de conjuntos

```
In [ ]: test_months = 24

# Asegurarnos de que el índice esté ordenado y con frecuencia mensual
df = df.sort_index()
if pd.infer_freq(df.index) is None:
    # Si la frecuencia no se infiere, reindexamos a meses
    df = df.asfreq('MS')

n_total = len(df)
n_test = test_months
n_train = n_total - n_test

train = df.iloc[:n_train].copy()
test = df.iloc[n_train:].copy()

print(f"Filas totales: {n_total}, Entrenamiento: {len(train)}, Prueba: {len(test)}")
print("Rango train:", train.index.min().date(), "->", train.index.max().date())
print("Rango test :", test.index.min().date(), "->", test.index.max().date())
```

Filas totales: 486, Entrenamiento: 462, Prueba: 24

Rango train: 1985-01-01 -> 2023-06-01

Rango test : 2023-07-01 -> 2025-06-01

3. Normalización y preparación

```
In [ ]: scaler = MinMaxScaler(feature_range=(0, 1))
train_vals = train['value'].values.reshape(-1,1)
test_vals = test['value'].values.reshape(-1,1)
```

```

scaler.fit(train_vals)                      # ajustar solo con datos de entrenamiento
train_scaled = scaler.transform(train_vals)
test_scaled = scaler.transform(test_vals)

# Parametrización del generador de secuencias (Lookback)
lookback = 12
batch_size = 32

train_gen = TimeseriesGenerator(train_scaled, train_scaled,
                                length=lookback, sampling_rate=1, stride=1,
                                batch_size=batch_size)

# Para evaluación/predicción, creamos un generador que permita predecir sobre la ve
combined = np.vstack([train_scaled[-lookback:], test_scaled])
test_gen = TimeseriesGenerator(combined, combined,
                               length=lookback, batch_size=1)

print("Ejemplos en train_gen:", len(train_gen))
print("Ejemplos en test_gen :", len(test_gen))
print("shape ejemplo X:", train_gen[0][0].shape, "y shape:", train_gen[0][1].shape)

```

Ejemplos en train_gen: 15
Ejemplos en test_gen : 24
shape ejemplo X: (32, 12, 1) y shape: (32, 1)

4. Construcción del modelo

```

In [ ]: import tensorflow as tf
from tensorflow.keras import layers, models, callbacks, regularizers
from tensorflow.keras.preprocessing.sequence import TimeseriesGenerator

# 1 LSTM con return_sequences=False, capa densa final
model_lstm = models.Sequential([
    layers.Input(shape=(lookback, 1)),
    layers.LSTM(64, activation='tanh', return_sequences=False,
               kernel_regularizer=regularizers.l2(1e-4)),
    layers.Dropout(0.2),
    layers.Dense(32, activation='relu', kernel_regularizer=regularizers.l2(1e-4)),
    layers.Dropout(0.1),
    layers.Dense(1, activation='linear')
])

model_lstm.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=0.001),
                    loss='mse',
                    metrics=['mae'])

model_lstm.summary()

```

Model: "sequential_4"

| Layer (type) | Output Shape | Param # |
|--------------------------|--------------|---------|
| <hr/> | | |
| lstm_4 (LSTM) | (None, 64) | 16896 |
| dropout_8 (Dropout) | (None, 64) | 0 |
| dense_8 (Dense) | (None, 32) | 2080 |
| dropout_9 (Dropout) | (None, 32) | 0 |
| dense_9 (Dense) | (None, 1) | 33 |
| <hr/> | | |
| Total params: 19,009 | | |
| Trainable params: 19,009 | | |
| Non-trainable params: 0 | | |

5. Entrenamiento y evaluación

```
In [ ]: es = callbacks.EarlyStopping(monitor='val_loss', patience=8, restore_best_weights=True)
ck = callbacks.ModelCheckpoint('best_lstm.keras', monitor='val_loss', save_best_only=True)

# Preparar validación: usar 10% del train para validación durante fit
history_lstm = model_lstm.fit(
    train_gen,
    epochs=200,                      # se detendrá por EarlyStopping si no mejora
    validation_data=None,
    batch_size=None,
    callbacks=[es, ck],
    verbose=2
)

# Guardar tiempo y resultados
print("Entrenamiento finalizado. Épocas entrenadas:", len(history_lstm.history['los
```

Epoch 1/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 3s - loss: 0.0782 - mae: 0.2202 - 3s/epoch - 196ms/step
Epoch 2/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0420 - mae: 0.1567 - 122ms/epoch - 8ms/step
Epoch 3/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0375 - mae: 0.1501 - 135ms/epoch - 9ms/step
Epoch 4/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0340 - mae: 0.1417 - 127ms/epoch - 8ms/step
Epoch 5/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0333 - mae: 0.1408 - 124ms/epoch - 8ms/step
Epoch 6/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0339 - mae: 0.1408 - 134ms/epoch - 9ms/step
Epoch 7/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0328 - mae: 0.1405 - 118ms/epoch - 8ms/step
Epoch 8/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0320 - mae: 0.1368 - 144ms/epoch - 10ms/step
Epoch 9/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0327 - mae: 0.1387 - 130ms/epoch - 9ms/step
Epoch 10/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0282 - mae: 0.1279 - 129ms/epoch - 9ms/step
Epoch 11/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0286 - mae: 0.1301 - 127ms/epoch - 8ms/step
Epoch 12/200

```
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0264 - mae: 0.1222 - 113ms/epoch - 8ms/step
Epoch 13/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0239 - mae: 0.1147 - 113ms/epoch - 8ms/step
Epoch 14/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0207 - mae: 0.1038 - 117ms/epoch - 8ms/step
Epoch 15/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0160 - mae: 0.0903 - 120ms/epoch - 8ms/step
Epoch 16/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0159 - mae: 0.0846 - 118ms/epoch - 8ms/step
Epoch 17/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0124 - mae: 0.0747 - 111ms/epoch - 7ms/step
Epoch 18/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0119 - mae: 0.0746 - 130ms/epoch - 9ms/step
Epoch 19/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0114 - mae: 0.0683 - 139ms/epoch - 9ms/step
Epoch 20/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0110 - mae: 0.0692 - 139ms/epoch - 9ms/step
Epoch 21/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0104 - mae: 0.0665 - 157ms/epoch - 10ms/step
Epoch 22/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0107 - mae: 0.0657 - 159ms/epoch - 11ms/step
Epoch 23/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not avai
```

lable. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0107 - mae: 0.0671 - 130ms/epoch - 9ms/step
Epoch 24/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0103 - mae: 0.0661 - 146ms/epoch - 10ms/step
Epoch 25/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0096 - mae: 0.0619 - 147ms/epoch - 10ms/step
Epoch 26/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0096 - mae: 0.0634 - 139ms/epoch - 9ms/step
Epoch 27/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0088 - mae: 0.0591 - 221ms/epoch - 15ms/step
Epoch 28/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0092 - mae: 0.0620 - 150ms/epoch - 10ms/step
Epoch 29/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0086 - mae: 0.0597 - 136ms/epoch - 9ms/step
Epoch 30/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0102 - mae: 0.0662 - 134ms/epoch - 9ms/step
Epoch 31/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0108 - mae: 0.0695 - 129ms/epoch - 9ms/step
Epoch 32/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0098 - mae: 0.0623 - 133ms/epoch - 9ms/step
Epoch 33/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0092 - mae: 0.0622 - 126ms/epoch - 8ms/step
Epoch 34/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae

```
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0089 - mae: 0.0615 - 130ms/epoch - 9ms/step  
Epoch 35/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0100 - mae: 0.0677 - 128ms/epoch - 9ms/step  
Epoch 36/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0097 - mae: 0.0639 - 125ms/epoch - 8ms/step  
Epoch 37/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0082 - mae: 0.0582 - 120ms/epoch - 8ms/step  
Epoch 38/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0090 - mae: 0.0628 - 117ms/epoch - 8ms/step  
Epoch 39/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0081 - mae: 0.0585 - 121ms/epoch - 8ms/step  
Epoch 40/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0091 - mae: 0.0602 - 115ms/epoch - 8ms/step  
Epoch 41/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0086 - mae: 0.0609 - 118ms/epoch - 8ms/step  
Epoch 42/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0089 - mae: 0.0615 - 138ms/epoch - 9ms/step  
Epoch 43/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0082 - mae: 0.0581 - 108ms/epoch - 7ms/step  
Epoch 44/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0078 - mae: 0.0579 - 111ms/epoch - 7ms/step  
Epoch 45/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
```

```
15/15 - 0s - loss: 0.0078 - mae: 0.0574 - 126ms/epoch - 8ms/step
Epoch 46/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0084 - mae: 0.0606 - 134ms/epoch - 9ms/step
Epoch 47/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0088 - mae: 0.0635 - 132ms/epoch - 9ms/step
Epoch 48/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0085 - mae: 0.0621 - 127ms/epoch - 8ms/step
Epoch 49/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0574 - 131ms/epoch - 9ms/step
Epoch 50/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0082 - mae: 0.0590 - 117ms/epoch - 8ms/step
Epoch 51/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0083 - mae: 0.0607 - 128ms/epoch - 9ms/step
Epoch 52/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0082 - mae: 0.0600 - 130ms/epoch - 9ms/step
Epoch 53/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0566 - 134ms/epoch - 9ms/step
Epoch 54/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0583 - 167ms/epoch - 11ms/step
Epoch 55/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0567 - 134ms/epoch - 9ms/step
Epoch 56/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0070 - mae: 0.0569 - 121ms/epoch - 8ms/step
```

Epoch 57/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0581 - 122ms/epoch - 8ms/step
Epoch 58/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0078 - mae: 0.0595 - 163ms/epoch - 11ms/step
Epoch 59/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0075 - mae: 0.0587 - 132ms/epoch - 9ms/step
Epoch 60/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0073 - mae: 0.0568 - 122ms/epoch - 8ms/step
Epoch 61/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0072 - mae: 0.0563 - 133ms/epoch - 9ms/step
Epoch 62/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0084 - mae: 0.0632 - 133ms/epoch - 9ms/step
Epoch 63/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0077 - mae: 0.0588 - 127ms/epoch - 8ms/step
Epoch 64/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0070 - mae: 0.0574 - 128ms/epoch - 9ms/step
Epoch 65/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0070 - mae: 0.0566 - 121ms/epoch - 8ms/step
Epoch 66/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0073 - mae: 0.0568 - 114ms/epoch - 8ms/step
Epoch 67/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0066 - mae: 0.0541 - 140ms/epoch - 9ms/step
Epoch 68/200

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WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0078 - mae: 0.0611 - 134ms/epoch - 9ms/step
Epoch 69/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0072 - mae: 0.0576 - 122ms/epoch - 8ms/step
Epoch 70/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0072 - mae: 0.0584 - 143ms/epoch - 10ms/step
Epoch 71/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0068 - mae: 0.0565 - 122ms/epoch - 8ms/step
Epoch 72/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0074 - mae: 0.0572 - 121ms/epoch - 8ms/step
Epoch 73/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0603 - 131ms/epoch - 9ms/step
Epoch 74/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0072 - mae: 0.0573 - 153ms/epoch - 10ms/step
Epoch 75/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0066 - mae: 0.0555 - 164ms/epoch - 11ms/step
Epoch 76/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0066 - mae: 0.0554 - 133ms/epoch - 9ms/step
Epoch 77/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0073 - mae: 0.0585 - 175ms/epoch - 12ms/step
Epoch 78/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0070 - mae: 0.0572 - 128ms/epoch - 9ms/step
Epoch 79/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not avai
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lable. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0071 - mae: 0.0587 - 241ms/epoch - 16ms/step
Epoch 80/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0066 - mae: 0.0555 - 170ms/epoch - 11ms/step
Epoch 81/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0067 - mae: 0.0547 - 142ms/epoch - 9ms/step
Epoch 82/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0073 - mae: 0.0597 - 118ms/epoch - 8ms/step
Epoch 83/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0065 - mae: 0.0562 - 129ms/epoch - 9ms/step
Epoch 84/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0076 - mae: 0.0613 - 143ms/epoch - 10ms/step
Epoch 85/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0071 - mae: 0.0595 - 186ms/epoch - 12ms/step
Epoch 86/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0063 - mae: 0.0540 - 150ms/epoch - 10ms/step
Epoch 87/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0072 - mae: 0.0603 - 173ms/epoch - 12ms/step
Epoch 88/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0066 - mae: 0.0562 - 145ms/epoch - 10ms/step
Epoch 89/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0064 - mae: 0.0541 - 172ms/epoch - 11ms/step
Epoch 90/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae

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WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0065 - mae: 0.0550 - 160ms/epoch - 11ms/step  
Epoch 91/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0066 - mae: 0.0572 - 132ms/epoch - 9ms/step  
Epoch 92/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0068 - mae: 0.0559 - 133ms/epoch - 9ms/step  
Epoch 93/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0067 - mae: 0.0569 - 128ms/epoch - 9ms/step  
Epoch 94/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0064 - mae: 0.0545 - 128ms/epoch - 9ms/step  
Epoch 95/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0064 - mae: 0.0531 - 140ms/epoch - 9ms/step  
Epoch 96/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0063 - mae: 0.0553 - 152ms/epoch - 10ms/step  
Epoch 97/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0067 - mae: 0.0563 - 158ms/epoch - 11ms/step  
Epoch 98/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0065 - mae: 0.0566 - 129ms/epoch - 9ms/step  
Epoch 99/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0067 - mae: 0.0579 - 148ms/epoch - 10ms/step  
Epoch 100/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0065 - mae: 0.0551 - 135ms/epoch - 9ms/step  
Epoch 101/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
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15/15 - 0s - loss: 0.0058 - mae: 0.0523 - 138ms/epoch - 9ms/step
Epoch 102/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0518 - 134ms/epoch - 9ms/step
Epoch 103/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0534 - 130ms/epoch - 9ms/step
Epoch 104/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0060 - mae: 0.0530 - 131ms/epoch - 9ms/step
Epoch 105/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0529 - 129ms/epoch - 9ms/step
Epoch 106/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0058 - mae: 0.0523 - 136ms/epoch - 9ms/step
Epoch 107/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0532 - 135ms/epoch - 9ms/step
Epoch 108/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0062 - mae: 0.0544 - 134ms/epoch - 9ms/step
Epoch 109/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0067 - mae: 0.0567 - 137ms/epoch - 9ms/step
Epoch 110/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0056 - mae: 0.0524 - 155ms/epoch - 10ms/step
Epoch 111/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0064 - mae: 0.0577 - 134ms/epoch - 9ms/step
Epoch 112/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0060 - mae: 0.0548 - 132ms/epoch - 9ms/step
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Epoch 113/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0062 - mae: 0.0550 - 151ms/epoch - 10ms/step
Epoch 114/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0058 - mae: 0.0529 - 144ms/epoch - 10ms/step
Epoch 115/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0058 - mae: 0.0530 - 151ms/epoch - 10ms/step
Epoch 116/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0060 - mae: 0.0539 - 151ms/epoch - 10ms/step
Epoch 117/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0536 - 148ms/epoch - 10ms/step
Epoch 118/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0504 - 141ms/epoch - 9ms/step
Epoch 119/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0062 - mae: 0.0547 - 138ms/epoch - 9ms/step
Epoch 120/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0055 - mae: 0.0521 - 139ms/epoch - 9ms/step
Epoch 121/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0056 - mae: 0.0522 - 176ms/epoch - 12ms/step
Epoch 122/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0511 - 136ms/epoch - 9ms/step
Epoch 123/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0061 - mae: 0.0550 - 138ms/epoch - 9ms/step
Epoch 124/200

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WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0515 - 139ms/epoch - 9ms/step
Epoch 125/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0543 - 155ms/epoch - 10ms/step
Epoch 126/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0514 - 138ms/epoch - 9ms/step
Epoch 127/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0519 - 132ms/epoch - 9ms/step
Epoch 128/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0531 - 134ms/epoch - 9ms/step
Epoch 129/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0058 - mae: 0.0529 - 132ms/epoch - 9ms/step
Epoch 130/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0052 - mae: 0.0510 - 122ms/epoch - 8ms/step
Epoch 131/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0530 - 123ms/epoch - 8ms/step
Epoch 132/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0512 - 129ms/epoch - 9ms/step
Epoch 133/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0508 - 120ms/epoch - 8ms/step
Epoch 134/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0056 - mae: 0.0512 - 121ms/epoch - 8ms/step
Epoch 135/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not avai
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lable. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0059 - mae: 0.0541 - 119ms/epoch - 8ms/step
Epoch 136/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0052 - mae: 0.0506 - 124ms/epoch - 8ms/step
Epoch 137/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0058 - mae: 0.0528 - 120ms/epoch - 8ms/step
Epoch 138/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0055 - mae: 0.0533 - 126ms/epoch - 8ms/step
Epoch 139/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0543 - 132ms/epoch - 9ms/step
Epoch 140/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0052 - mae: 0.0503 - 124ms/epoch - 8ms/step
Epoch 141/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0055 - mae: 0.0525 - 126ms/epoch - 8ms/step
Epoch 142/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0055 - mae: 0.0523 - 124ms/epoch - 8ms/step
Epoch 143/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0055 - mae: 0.0516 - 135ms/epoch - 9ms/step
Epoch 144/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0057 - mae: 0.0518 - 151ms/epoch - 10ms/step
Epoch 145/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0061 - mae: 0.0575 - 161ms/epoch - 11ms/step
Epoch 146/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae

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WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0058 - mae: 0.0544 - 160ms/epoch - 11ms/step  
Epoch 147/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0057 - mae: 0.0523 - 130ms/epoch - 9ms/step  
Epoch 148/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0058 - mae: 0.0542 - 133ms/epoch - 9ms/step  
Epoch 149/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0058 - mae: 0.0559 - 159ms/epoch - 11ms/step  
Epoch 150/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0054 - mae: 0.0523 - 147ms/epoch - 10ms/step  
Epoch 151/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0057 - mae: 0.0538 - 132ms/epoch - 9ms/step  
Epoch 152/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0053 - mae: 0.0526 - 131ms/epoch - 9ms/step  
Epoch 153/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0056 - mae: 0.0540 - 129ms/epoch - 9ms/step  
Epoch 154/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0051 - mae: 0.0518 - 125ms/epoch - 8ms/step  
Epoch 155/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0051 - mae: 0.0513 - 122ms/epoch - 8ms/step  
Epoch 156/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.  
15/15 - 0s - loss: 0.0060 - mae: 0.0565 - 125ms/epoch - 8ms/step  
Epoch 157/200  
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae  
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
```

```
15/15 - 0s - loss: 0.0062 - mae: 0.0550 - 124ms/epoch - 8ms/step
Epoch 158/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0515 - 190ms/epoch - 13ms/step
Epoch 159/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0050 - mae: 0.0502 - 162ms/epoch - 11ms/step
Epoch 160/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0056 - mae: 0.0541 - 184ms/epoch - 12ms/step
Epoch 161/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0533 - 138ms/epoch - 9ms/step
Epoch 162/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0528 - 139ms/epoch - 9ms/step
Epoch 163/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0052 - mae: 0.0505 - 138ms/epoch - 9ms/step
Epoch 164/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0521 - 132ms/epoch - 9ms/step
Epoch 165/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0522 - 131ms/epoch - 9ms/step
Epoch 166/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0523 - 128ms/epoch - 9ms/step
Epoch 167/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0505 - 129ms/epoch - 9ms/step
Epoch 168/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0046 - mae: 0.0485 - 133ms/epoch - 9ms/step
```

Epoch 169/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0051 - mae: 0.0506 - 137ms/epoch - 9ms/step
Epoch 170/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0511 - 130ms/epoch - 9ms/step
Epoch 171/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0519 - 130ms/epoch - 9ms/step
Epoch 172/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0520 - 135ms/epoch - 9ms/step
Epoch 173/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0050 - mae: 0.0511 - 136ms/epoch - 9ms/step
Epoch 174/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0505 - 121ms/epoch - 8ms/step
Epoch 175/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0051 - mae: 0.0521 - 127ms/epoch - 8ms/step
Epoch 176/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0050 - mae: 0.0498 - 128ms/epoch - 9ms/step
Epoch 177/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0516 - 128ms/epoch - 9ms/step
Epoch 178/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0497 - 123ms/epoch - 8ms/step
Epoch 179/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0048 - mae: 0.0498 - 133ms/epoch - 9ms/step
Epoch 180/200

```
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0519 - 140ms/epoch - 9ms/step
Epoch 181/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0488 - 131ms/epoch - 9ms/step
Epoch 182/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0051 - mae: 0.0504 - 131ms/epoch - 9ms/step
Epoch 183/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0048 - mae: 0.0492 - 140ms/epoch - 9ms/step
Epoch 184/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0050 - mae: 0.0511 - 157ms/epoch - 10ms/step
Epoch 185/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0056 - mae: 0.0546 - 125ms/epoch - 8ms/step
Epoch 186/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0052 - mae: 0.0521 - 129ms/epoch - 9ms/step
Epoch 187/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0053 - mae: 0.0535 - 129ms/epoch - 9ms/step
Epoch 188/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0491 - 124ms/epoch - 8ms/step
Epoch 189/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0050 - mae: 0.0511 - 125ms/epoch - 8ms/step
Epoch 190/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0491 - 125ms/epoch - 8ms/step
Epoch 191/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not avai
```

```

lable. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0529 - 146ms/epoch - 10ms/step
Epoch 192/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0054 - mae: 0.0550 - 130ms/epoch - 9ms/step
Epoch 193/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0048 - mae: 0.0504 - 125ms/epoch - 8ms/step
Epoch 194/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0047 - mae: 0.0499 - 125ms/epoch - 8ms/step
Epoch 195/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0051 - mae: 0.0508 - 134ms/epoch - 9ms/step
Epoch 196/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0048 - mae: 0.0508 - 129ms/epoch - 9ms/step
Epoch 197/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0046 - mae: 0.0496 - 126ms/epoch - 8ms/step
Epoch 198/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0049 - mae: 0.0489 - 151ms/epoch - 10ms/step
Epoch 199/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0051 - mae: 0.0513 - 143ms/epoch - 10ms/step
Epoch 200/200
WARNING:tensorflow:Early stopping conditioned on metric `val_loss` which is not available. Available metrics are: loss,mae
WARNING:tensorflow:Can save best model only with val_loss available, skipping.
15/15 - 0s - loss: 0.0047 - mae: 0.0498 - 122ms/epoch - 8ms/step
Entrenamiento finalizado. Épocas entrenadas: 200

```

```

In [ ]: # Cargar mejor modelo si existe
try:
    model_lstm = models.load_model('best_lstm.keras')
    print("Modelo restaurado desde checkpoint.")
except Exception:
    print("Usando modelo entrenado en memoria.")

```

```

# Predecir todo el conjunto combinado a partir del test_gen
pred_scaled = model_lstm.predict(test_gen, verbose=0)
pred_scaled = pred_scaled.reshape(-1,1)

# Solo tomar las predicciones correspondientes al periodo de test (Len(test) valore
pred_test_scaled = pred_scaled[:len(test)]
pred_test = scaler.inverse_transform(pred_test_scaled)

# Series para comparar
pred_index = test.index
pred_series = pd.Series(pred_test.flatten(), index=pred_index, name='pred')
actual_series = test['value']

# Mostrar primeras predicciones
display(pd.DataFrame({'actual': actual_series.values.flatten(), "pred": pred_series

```

Usando modelo entrenado en memoria.

| | actual | pred |
|---|----------|------------|
| 0 | 126.0569 | 127.366661 |
| 1 | 122.6748 | 122.362015 |
| 2 | 116.2177 | 115.799820 |
| 3 | 109.3279 | 107.806320 |
| 4 | 89.3353 | 101.253929 |

6. Resultados

In [20]:

```

# Métricas
mae = mean_absolute_error(actual_series, pred_series)
rmse = math.sqrt(mean_squared_error(actual_series, pred_series))
print(f"MAE: {mae:.4f}, RMSE: {rmse:.4f}")

# Gráfica: serie real vs predicción
plt.figure(figsize=(12,5))
plt.plot(df.index, df['value'], label='Serie completa', color='lightgray')
plt.plot(train.index, train['value'], label='Train', color='tab:blue')
plt.plot(test.index, test['value'], label='Test (real)', color='tab:orange')
plt.plot(pred_series.index, pred_series.values, label='Predicción LSTM', color='tab:red')
plt.axvline(test.index[0], color='k', linestyle=':', alpha=0.6)
plt.legend()
plt.title("Predicción LSTM vs realidad (Ice cream & frozen dessert IP index)")
plt.xlabel("Fecha"); plt.ylabel("Índice")
plt.grid(alpha=0.3)
plt.show()

# Residuos
resid = actual_series - pred_series
plt.figure(figsize=(10,3))
plt.plot(resid.index, resid.values)
plt.title("Residuos (actual - predicción)")

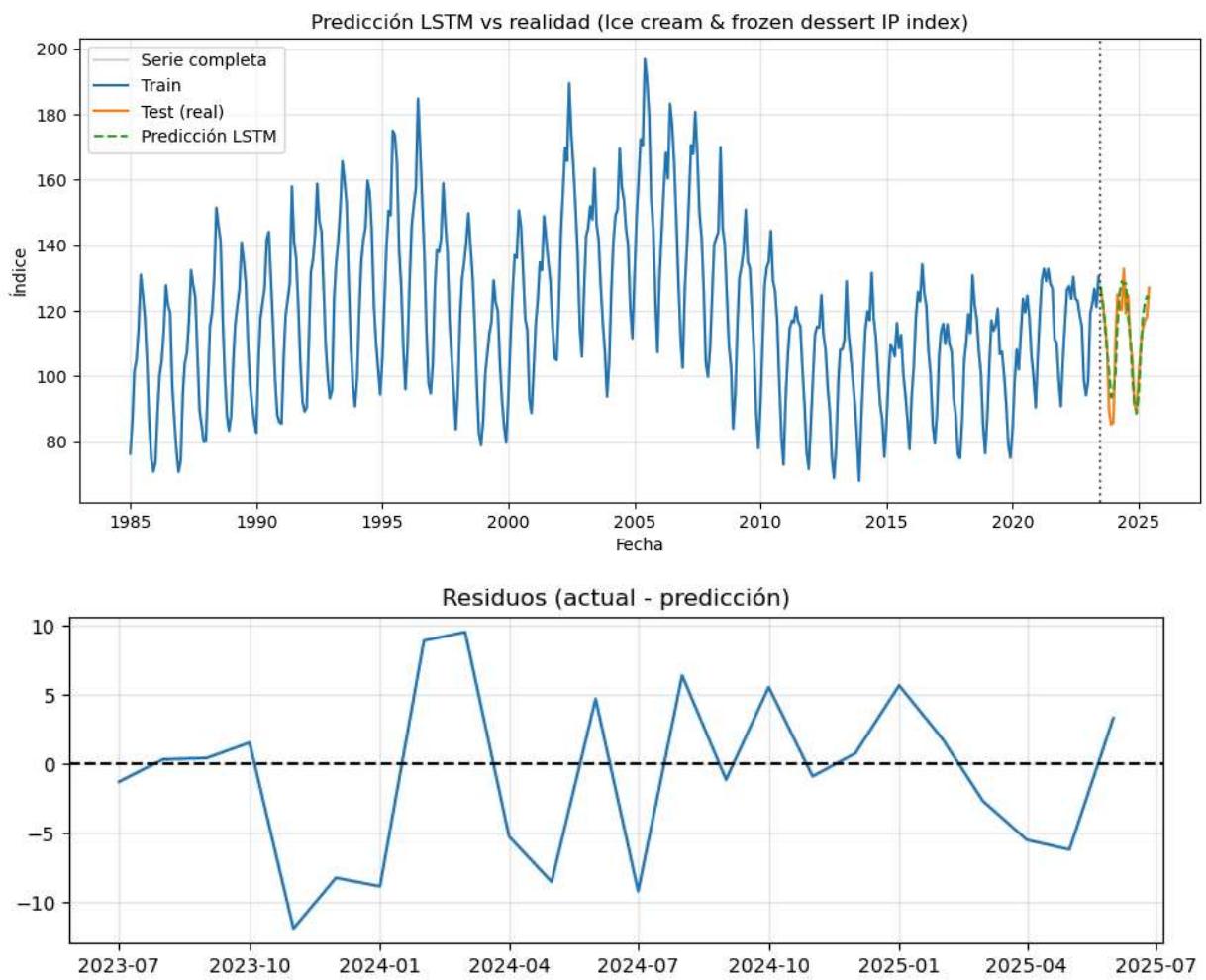
```

```

plt.axhline(0, color='k', linestyle='--')
plt.grid(alpha=0.3)
plt.show()

```

MAE: 4.9406, RMSE: 6.0097



Análisis y Discusión

La serie temporal analizada corresponde a la producción industrial de helados y postres congelados en Estados Unidos, medida como un índice mensual con base 2012=100. Los datos brindados abarcan de **enero de 1985 a junio de 2025**, con un total de **486**

observaciones. La estadística descriptiva inicial muestra un **valor promedio de 118.2**, con una **desviación estándar de 24.8** y un rango que va desde un **mínimo de 68.0** hasta un **máximo de 196.8**. La frecuencia inferida es mensual (MS), lo cual confirma la estructura temporal de la serie.

El conjunto se dividió en **462 observaciones** para **entrenamiento** (1985–2023) y **24 observaciones** para **prueba** (2023–2025). El generador de secuencias se configuró con ventanas de **12 pasos**, lo que permite al modelo aprender dependencias anuales dentro de la serie. La estructura final del modelo LSTM fue relativamente compacta, con **19,009** parámetros entrenables distribuidos en una capa LSTM de 64 unidades, seguida de capas densas y regularización con *dropout*.

Durante el entrenamiento, el modelo mostró una reducción progresiva de la pérdida y del error absoluto medio (MAE), alcanzando valores cercanos a **0.005** en escala normalizada. Sin embargo, se debe destacar que el **callback** de `EarlyStopping` no funcionó como se esperaba, ya que no se definió un conjunto de validación explícito. Esto llevó a que el entrenamiento se prolongara por las **200 épocas máximas**, lo que, aunque no resultó en sobreajuste evidente, pudo incrementar el tiempo de cómputo innecesariamente.

En la etapa de predicción sobre el conjunto de prueba, el modelo logró un **MAE de 4.94** y un **RMSE de 6.01** en la escala original de la serie. Estos valores indican un error promedio de entre 5 y 6 puntos del índice, lo cual representa una desviación moderada considerando la magnitud de la serie (promedio ≈ 118). Los primeros resultados muestran que las predicciones capturan la tendencia general, aunque en algunos puntos de quiebre como el caso donde el valor real de 89.3 tuvo una predicción de 101.2, el modelo subestima o sobreestima con mayor amplitud.

En conclusión, el modelo **LSTM** implementado demuestra una **buenas capacidades de generalización** en series con estacionalidad anual, logrando **errores relativamente bajos** en comparación con la variabilidad natural de la serie. Sin embargo, el rendimiento podría mejorarse al incorporar un conjunto de validación para detener el entrenamiento oportunamente, ajustar hiperparámetros como el número de unidades LSTM o la tasa de **dropout**, y explorar arquitecturas más profundas o híbridas como lo sería **LSTM + capas convolucionales**. Asimismo, sería recomendable analizar los residuos de manera más detallada para identificar si persisten patrones estacionales que el modelo no logra capturar completamente.