Fase 1: Importación de librerías necesarias

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```
# ------------------------------
# MÓDULOS PARA MANIPULACIÓN Y VISUALIZACIÓN DE DATOS
# ------------------------------
import numpy as np  # Operaciones numéricas de alto rendimiento
import pandas as pd  # Manipulación de datos estructurados (opcional
si se usa DataFrame)
import matplotlib.pyplot as plt  # Visualización de métricas y
resultados
import seaborn as sns  # Visualizaciones más atractivas
import re

# ------------------------------
# MÓDULOS DE PREPROCESAMIENTO Y UTILIDADES DE KERAS
# ------------------------------
from tensorflow.keras.datasets import imdb  # Dataset IMDB
preprocesado de Keras
from tensorflow.keras.preprocessing.sequence import pad_sequences  #
Padding para secuencias
from tensorflow.keras.preprocessing.text import Tokenizer  # (Si
decides usar texto original en lugar de índices)
# ------------------------------
# MÓDULOS PARA DEFINIR EL MODELO EN KERAS
# ------------------------------
from tensorflow.keras.models import Model  # API funcional para
modelos complejos
from tensorflow.keras.layers import Input, Embedding, Dense, Dropout,
LayerNormalization
from tensorflow.keras.layers import GlobalAveragePooling1D, Add,
Embedding
# ------------------------------
# MÓDULOS DE LA ARQUITECTURA TRANSFORMER (capas de atención y más)
# ------------------------------
from tensorflow.keras.layers import MultiHeadAttention  # Mecanismo de
atención multiparte
from tensorflow.keras.optimizers import Adam  # Optimizador popular en
NLP
from tensorflow.keras.losses import BinaryCrossentropy  # Pérdida para
clasificación binaria
from tensorflow.keras.callbacks import EarlyStopping,
ReduceLROnPlateau, ModelCheckpoint
from tensorflow.keras.callbacks import TensorBoard, Callback
```

```
# ------------------------------
# MÓDULOS PARA MÉTRICAS Y ANÁLISIS
# ------------------------------
from sklearn.metrics import classification_report, confusion_matrix  # Métricas de rendimiento
from sklearn.model_selection import train_test_split
# ------------------------------
# UTILIDADES ADICIONALES
# ------------------------------
import tensorflow as tf  # Librería base para modelos de deep learning
import os  # Para gestionar rutas de guardado de modelos/logs
```

Fase 2: Exploración del Dataset IMDB

```
# Cargamos el dataset IMDB desde Keras.
# Este dataset ya viene tokenizado: las palabras han sido reemplazadas por índices enteros.
# num_words=10000 indica que se conservarán las 10,000 palabras más frecuentes.
(X_train, y_train), (X_test, y_test) = imdb.load_data(num_words=10000)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/imdb.npz
17464789/17464789 ━━━━━━━━━━━━━━━━━━━━ 1s 0us/step
```

```
# Revisamos la cantidad de muestras en entrenamiento y prueba
print("Tamaño del set de entrenamiento:", len(X_train))
print("Tamaño del set de prueba:", len(X_test))
```

```
Tamaño del set de entrenamiento: 25000
Tamaño del set de prueba: 25000
```

```
# Mostramos una reseña en su forma tokenizada (índices de palabras)
print("Ejemplo de reseña (tokenizada):", X_train[0])

# Mostramos la etiqueta asociada (0 = negativa, 1 = positiva)
print("Etiqueta de la reseña:", y_train[0])
```

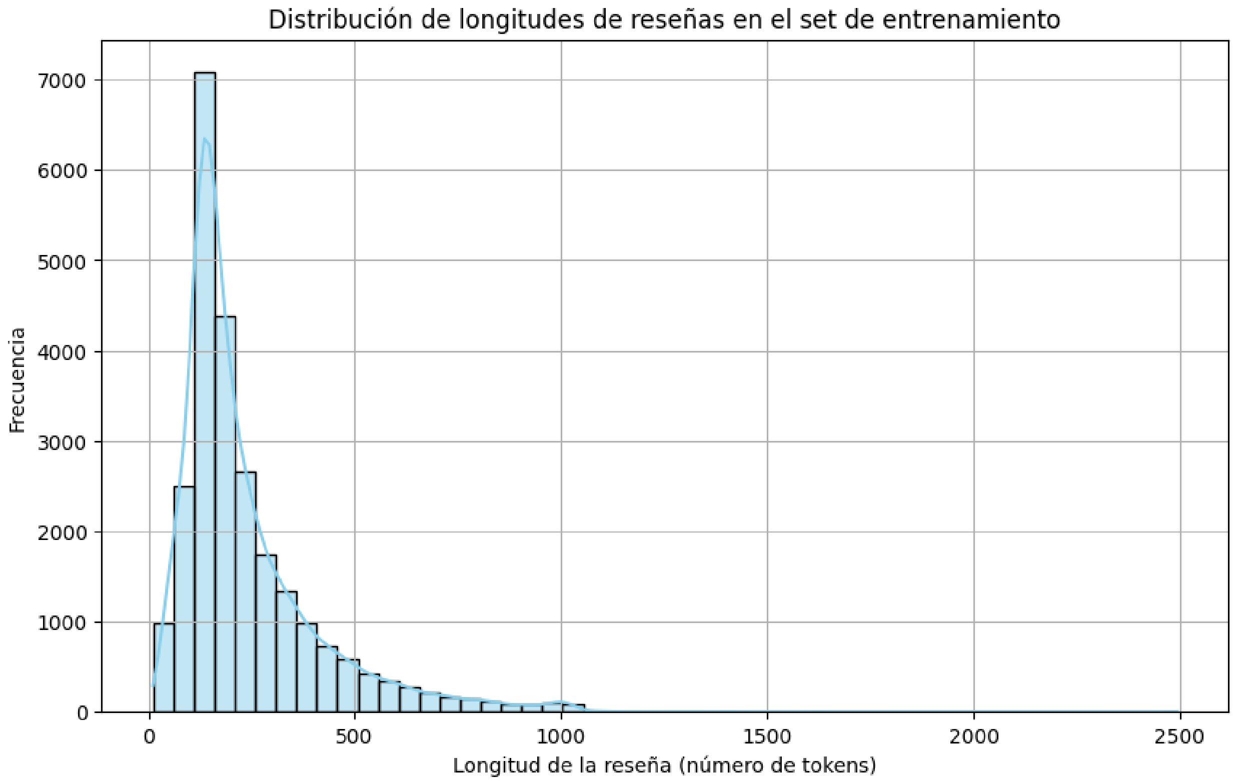
```
Ejemplo de reseña (tokenizada): [1, 14, 22, 16, 43, 530, 973, 1622,
1385, 65, 458, 4468, 66, 3941, 4, 173, 36, 256, 5, 25, 100, 43, 838,
112, 50, 670, 2, 9, 35, 480, 284, 5, 150, 4, 172, 112, 167, 2, 336,
385, 39, 4, 172, 4536, 1111, 17, 546, 38, 13, 447, 4, 192, 50, 16, 6,
147, 2025, 19, 14, 22, 4, 1920, 4613, 469, 4, 22, 71, 87, 12, 16, 43,
530, 38, 76, 15, 13, 1247, 4, 22, 17, 515, 17, 12, 16, 626, 18, 2, 5,
62, 386, 12, 8, 316, 8, 106, 5, 4, 2223, 5244, 16, 480, 66, 3785, 33,
4, 130, 12, 16, 38, 619, 5, 25, 124, 51, 36, 135, 48, 25, 1415, 33, 6,
22, 12, 215, 28, 77, 52, 5, 14, 407, 16, 82, 2, 8, 4, 107, 117, 5952,
15, 256, 4, 2, 7, 3766, 5, 723, 36, 71, 43, 530, 476, 26, 400, 317,
46, 7, 4, 2, 1029, 13, 104, 88, 4, 381, 15, 297, 98, 32, 2071, 56, 26,
141, 6, 194, 7486, 18, 4, 226, 22, 21, 134, 476, 26, 480, 5, 144, 30,
5535, 18, 51, 36, 28, 224, 92, 25, 104, 4, 226, 65, 16, 38, 1334, 88,
12, 16, 283, 5, 16, 4472, 113, 103, 32, 15, 16, 5345, 19, 178, 32]
Etiqueta de la reseña: 1
```

```
# Calculamos la longitud de cada reseña
review_lengths = [len(review) for review in X_train]

# Estadísticas descriptivas sobre la longitud de las reseñas
print("Longitud mínima:", np.min(review_lengths))
print("Longitud máxima:", np.max(review_lengths))
print("Longitud promedio:", np.mean(review_lengths))
```

```
Longitud mínima: 11
Longitud máxima: 2494
Longitud promedio: 238.71364
```

```
# Visualizamos la distribución de las longitudes para decidir un valor
razonable de padding
plt.figure(figsize=(10, 6))
sns.histplot(review_lengths, bins=50, kde=True, color='skyblue')
plt.title("Distribución de longitudes de reseñas en el set de
entrenamiento")
plt.xlabel("Longitud de la reseña (número de tokens)")
plt.ylabel("Frecuencia")
plt.grid(True)
plt.show()
```



```python
# Obtenemos el diccionario que mapea palabras a índices
word_index = imdb.get_word_index()

# Revertimos el diccionario: de índice a palabra
index_to_word = {index + 3: word for word, index in
word_index.items()}
index_to_word[0] = "[PAD]"
index_to_word[1] = "[START]"
index_to_word[2] = "[UNK]"
index_to_word[3] = "[UNUSED]"

# Función para decodificar una reseña
def decode_review(encoded_review):
    return ' '.join([index_to_word.get(i, "?") for i in
encoded_review])

# Visualizamos la reseña decodificada
print("Reseña decodificada:\n", decode_review(X_train[0]))
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/imdb_word_index.json
1641221/1641221 ━━━━━━━━━━━━━━━━━━━━ 1s 0us/step
Reseña decodificada:
 [START] this film was just brilliant casting location scenery story
direction everyone's really suited the part they played and you could
just imagine being there robert [UNK] is an amazing actor and now the
```

```
same being director [UNK] father came from the same scottish island as
myself so i loved the fact there was a real connection with this film
the witty remarks throughout the film were great it was just brilliant
so much that i bought the film as soon as it was released for [UNK]
and would recommend it to everyone to watch and the fly fishing was
amazing really cried at the end it was so sad and you know what they
say if you cry at a film it must have been good and this definitely
was also [UNK] to the two little boy's that played the [UNK] of norman
and paul they were just brilliant children are often left out of the
[UNK] list i think because the stars that play them all grown up are
such a big profile for the whole film but these children are amazing
and should be praised for what they have done don't you think the
whole story was so lovely because it was true and was someone's life
after all that was shared with us all
```

Fase 3: Preprocesamiento del Dataset IMDB

Paso 1: Definir la longitud máxima de las secuencias

```python
# Longitud máxima de las reseñas para padding/truncamiento
MAX_LEN = 250  # Puedes ajustarlo si quieres probar con más/menos
contexto
```

Paso 2: Aplicar padding a las secuencias

```python
# Pad o trunca las reseñas para que todas tengan la misma longitud
X_train_pad = pad_sequences(X_train, maxlen=MAX_LEN, padding='post',
truncating='post')
X_test_pad = pad_sequences(X_test, maxlen=MAX_LEN, padding='post',
truncating='post')

# Verificamos que todas las reseñas ahora tengan la misma longitud
print("Nueva forma de las reseñas:", X_train_pad.shape)
```

```
Nueva forma de las reseñas: (25000, 250)
```

Paso 3: Conversión de etiquetas a float32

```python
# Convertimos las etiquetas a float32 para compatibilidad con la
función de pérdida
y_train = np.array(y_train).astype("float32")
y_test = np.array(y_test).astype("float32")
```

Paso 4: Crear un conjunto de validación

```python
# Separamos un pequeño conjunto de validación del set de entrenamiento
X_train_pad, X_val_pad, y_train, y_val = train_test_split(
    X_train_pad, y_train, test_size=0.15, random_state=42)

print("Train shape:", X_train_pad.shape)
print("Validation shape:", X_val_pad.shape)
```

```
Train shape: (21250, 250)
Validation shape: (3750, 250)
```

Paso 5: Revisar una reseña tras el padding

```python
# Mostrar la reseña decodificada después del padding
print("Reseña con padding:\n", decode_review(X_train_pad[0]))
```

```
Reseña con padding:
 [START] i love buying those cheap lousy dvd's from [UNK] video one
day i happened to buy this one it's the perfect silly science fiction
film of the 50's all [UNK] up [UNK] with [UNK] everything scantily
clad girls and plenty of melodrama it's an enjoyable film to those who
appreciate this kind of stuff and if you can [UNK] your [UNK] enough
you can actually get [UNK] out not just by the psychotic head or by
the beating of the thing in the closet but toward the end with the
character of 'the perfect [UNK] it's so what's another word for [UNK]
ing [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD]
[PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD]
[PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD]
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[PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD] [PAD]
[PAD] [PAD] [PAD]
```

3.1 Validación de los Datos Procesados

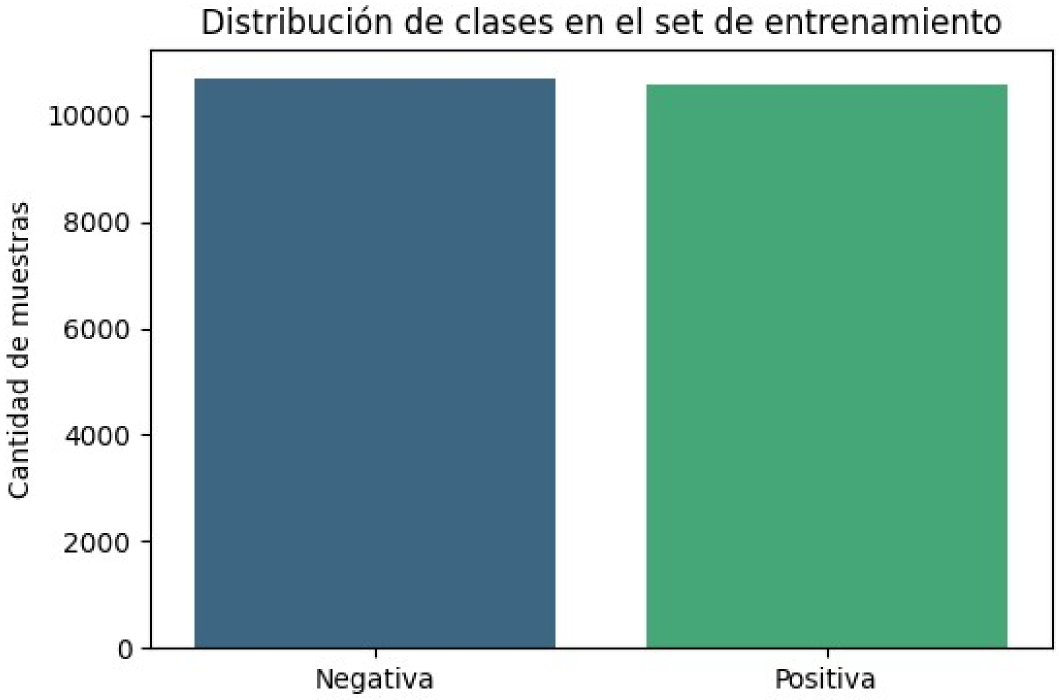
1. Verificar la distribución de clases (positivas vs negativas)

```python
# Conteo de clases en el set de entrenamiento
unique, counts = np.unique(y_train, return_counts=True)

# Mapeo a etiquetas legibles
labels = ['Negativa', 'Positiva']
for label, count in zip(labels, counts):
    print(f"{label}: {count} muestras")
```

```
# Visualización con gráfico de barras
plt.figure(figsize=(6, 4))
sns.barplot(x=labels, y=counts, palette='viridis')
plt.title("Distribución de clases en el set de entrenamiento")
plt.ylabel("Cantidad de muestras")
plt.show()
```

```
Negativa: 10686 muestras
Positiva: 10564 muestras
```

```
/tmp/ipython-input-14-90149018.py:11: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be
removed in v0.14.0. Assign the `x` variable to `hue` and set
`legend=False` for the same effect.

  sns.barplot(x=labels, y=counts, palette='viridis')
```



1. Confirmar que todas las secuencias tengan el mismo largo

```
# Verificamos que todas las secuencias sean de longitud MAX_LEN
train_lengths = [len(seq) for seq in X_train_pad]
print("¿Todas las reseñas tienen longitud MAX_LEN?:", all(l == MAX_LEN
for l in train_lengths))
```

```
¿Todas las reseñas tienen longitud MAX_LEN?: True
```

1. Mostrar un ejemplo post-padding y su etiqueta

```python
# Seleccionamos una reseña y mostramos su contenido
idx = 1
print("Etiqueta:", "Positiva" if y_train[idx] == 1.0 else "Negativa")
print("Secuencia tokenizada (con padding):\n", X_train_pad[idx])

# Decodificamos (excluyendo ceros del padding para mayor claridad)
print("Reseña decodificada:\n", decode_review([i for i in
X_train_pad[idx] if i != 0]))
```

```
Etiqueta: Negativa
Secuencia tokenizada (con padding):
 [   1   48   13 1869  332   27  403   23    4  288 1108   13  115
62
   28 6677   15   14  247    2    5  154 3357  621   16   93   34    6
  132   38 3280 3445   19    4  785  162 2869   11  192    4   22    9
   38  230   39   15   15   13  594   48  145   11    4 4867    5 3352
  162 2869    2   62   28  427 1800   14  552    7   22   45   38   38
 4928    5   12  186    8   28  117    8   81   19   38  111    7   27
  960  108   14  218 2707    6   78  155   43    6   55 1767  155   10
   10   51   13   82  258    6  227 1767   16    4 1166    7 2822   49
    7    4 1989  520   14   22  262   54   50   26   38  111  128  785
 2769   46   50    4  690   11   14   22   71  331   24  572  221    5
    4  105   32  468   38 1904    5 2749   48   13   69    8   67  160
 1026  415   37    2   44   89  254   12    9    8   30 1026   42   79
    6   52 6388 1866   23    6 5417 4267   13   16  170    8    2   10
   10    4 1324  347    9   15   40  298 2769   24  175  785  621    9
 1818   14   22    9   24  160 5271    2  852    2    2    7    2   42
    2    2 2310  372    5  466    4 1369    7 5860    2   13  191   67
   76  282    8  386   12   17  233   85   74    6  753    2    0    0
    0    0    0    0    0    0    0    0    0    0    0    0]
Reseña decodificada:
 [START] if i hadn't read his name on the dvd cover i never would have
suspected that this rather [UNK] and old fashioned musical was made by
a man so closely associated with the french new wave in fact the film
is so far from that that i wonder if back in the 50s and 60s new wave
[UNK] would have absolutely hated this type of film it's so so unreal
and it seems to have little to do with so many of his previous films
this isn't necessarily a bad thing just a very surprising thing br br
what i also found a bit surprising was the amount of praise some of
the reviewers gave this film especially when there are so many better
french musicals out there the songs in this film were simply not
particularly interesting and the characters all seemed so bland and
stereotypical if i had to see another rich person who [UNK] about how
hard it is to be rich or get a good sale price on a designer outfit i
was going to [UNK] br br the bottom line is that like american
musicals not every french musical is gold this film is not another les
[UNK] de [UNK] [UNK] of [UNK] or [UNK] [UNK] eight women and despite
the presence of audrey [UNK] i can't see much reason to recommend it
as anything other than a dull [UNK]
```

1. Comprobar distribución de clases en validación y test

```
# Validación
val_labels, val_counts = np.unique(y_val, return_counts=True)
print("Distribución en Validación:", dict(zip(val_labels,
val_counts)))

# Test
test_labels, test_counts = np.unique(y_test, return_counts=True)
print("Distribución en Test:", dict(zip(test_labels, test_counts)))

Distribución en Validación: {np.float32(0.0): np.int64(1814),
np.float32(1.0): np.int64(1936)}
Distribución en Test: {np.float32(0.0): np.int64(12500),
np.float32(1.0): np.int64(12500)}
```

1. Confirmar tipos y dimensiones finales

```
print("Tipo de datos de X_train_pad:", X_train_pad.dtype)
print("Forma de X_train_pad:", X_train_pad.shape)
print("Forma de y_train:", y_train.shape)

Tipo de datos de X_train_pad: int32
Forma de X_train_pad: (21250, 250)
Forma de y_train: (21250,)
```

Fase 4: Diseño del Modelo Transformer Encoder-Decoder

```
# Dimensiones del modelo Transformer
VOCAB_SIZE = 10000          # Número de palabras únicas
MAX_LEN = 250               # Longitud máxima de las secuencias (ya
definido)
EMBED_DIM = 128             # Dimensión del embedding
NUM_HEADS = 4               # Número de cabezas de atención
FF_DIM = 128                # Dimensión interna del feed-forward
NUM_ENCODER_BLOCKS = 2      # Número de bloques en el encoder
NUM_DECODER_BLOCKS = 2      # Número de bloques en el decoder
DROPOUT_RATE = 0.1

# Capa de embedding con mask_zero=True para soportar padding
embedding_layer = Embedding(input_dim=VOCAB_SIZE,
                            output_dim=EMBED_DIM,
                            input_length=MAX_LEN,
                            mask_zero=True)

/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/
embedding.py:90: UserWarning: Argument `input_length` is deprecated.
```

```
Just remove it.
  warnings.warn(
```

```python
# Bloque del encoder
def transformer_encoder(inputs):
    # Multi-head self-attention
    attention = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(inputs, inputs)
    attention = Dropout(DROPOUT_RATE)(attention)
    out1 = LayerNormalization(epsilon=1e-6)(inputs + attention)

    # Feed-forward
    ff = Dense(FF_DIM, activation="relu")(out1)
    ff = Dense(EMBED_DIM)(ff)
    ff = Dropout(DROPOUT_RATE)(ff)
    return LayerNormalization(epsilon=1e-6)(out1 + ff)

# Bloque del decoder (simplificado para clasificación)
def transformer_decoder(inputs, encoder_output):
    # Masked self-attention del decoder
    attention1 = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(inputs, inputs)
    attention1 = Dropout(DROPOUT_RATE)(attention1)
    out1 = LayerNormalization(epsilon=1e-6)(inputs + attention1)

    # Atención sobre la salida del encoder
    attention2 = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(out1, encoder_output)
    attention2 = Dropout(DROPOUT_RATE)(attention2)
    out2 = LayerNormalization(epsilon=1e-6)(out1 + attention2)

    # Feed-forward
    ff = Dense(FF_DIM, activation="relu")(out2)
    ff = Dense(EMBED_DIM)(ff)
    ff = Dropout(DROPOUT_RATE)(ff)
    return LayerNormalization(epsilon=1e-6)(out2 + ff)

# Input del encoder y decoder
encoder_inputs = Input(shape=(MAX_LEN,), name="encoder_input")
decoder_inputs = Input(shape=(MAX_LEN,), name="decoder_input")

# Embedding compartido para encoder y decoder
x_enc = embedding_layer(encoder_inputs)
x_dec = embedding_layer(decoder_inputs)

# Aplicamos bloques encoder
for _ in range(NUM_ENCODER_BLOCKS):
    x_enc = transformer_encoder(x_enc)

# Aplicamos bloques decoder
```

```
for _ in range(NUM_DECODER_BLOCKS):
    x_dec = transformer_decoder(x_dec, x_enc)

# Pooling + Capa de salida
x = GlobalAveragePooling1D()(x_dec)
x = Dropout(DROPOUT_RATE)(x)
outputs = Dense(1, activation="sigmoid")(x)

# Modelo final
transformer_model = Model(inputs=[encoder_inputs, decoder_inputs],
outputs=outputs)

# Resumen del modelo
transformer_model.summary()
```

```
Model: "functional"

┏━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━┳━━━━━━━━━━━━━━━
━━━━━┓
┃ Layer (type)        ┃ Output Shape      ┃    Param # ┃ Connected to

┡━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━╇━━━━━━━━━━━━━━━
━━━━━┩
│ decoder_input       │ (None, 250)       │          0 │ -

│ (InputLayer)        │                   │            │

├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ encoder_input       │ (None, 250)       │          0 │ -

│ (InputLayer)        │                   │            │

├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ embedding           │ (None, 250, 128)  │  1,280,000 │
encoder_input[0]… │
│ (Embedding)         │                   │            │
decoder_input[0]… │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ not_equal           │ (None, 250)       │          0 │
encoder_input[0]… │
│ (NotEqual)          │                   │            │

├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │ embedding[0]
[0],   │
│ (MultiHeadAttentio… │                   │            │ embedding[0]
[0],  │
│                     │                    │             │ not_equal[0]
[0],  │
│                     │                    │             │ not_equal[0]
[0]   │
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ dropout_1 (Dropout) │ (None, 250, 128)   │           0 │
multi_head_atten… │
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ add (Add)           │ (None, 250, 128)   │           0 │ embedding[0]
[0],  │
│                     │                    │             │ dropout_1[0]
[0]   │
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ layer_normalization │ (None, 250, 128)   │         256 │ add[0][0]
│
│ (LayerNormalizatio… │                    │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ dense (Dense)       │ (None, 250, 128)   │      16,512 │
layer_normalizat… │
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ dense_1 (Dense)     │ (None, 250, 128)   │      16,512 │ dense[0][0]
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ dropout_2 (Dropout) │ (None, 250, 128)   │           0 │ dense_1[0][0]
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ add_1 (Add)         │ (None, 250, 128)   │           0 │
layer_normalizat… │
│                     │                    │             │ dropout_2[0]
[0]   │
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)   │         256 │ add_1[0][0]
│
│ (LayerNormalizatio… │                    │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────
──────┤
│ multi_head_attenti… │ (None, 250, 128)   │     263,808 │
layer_normalizat… │
```

```
│ (MultiHeadAttentio… │                   │            │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_4 (Dropout) │ (None, 250, 128)  │          0 │
multi_head_atten… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_2 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_4[0]
[0]    │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_2[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ not_equal_1         │ (None, 250)       │          0 │
decoder_input[0]… │
│ (NotEqual)          │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dense_2 (Dense)     │ (None, 250, 128)  │     16,512 │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │ embedding[1]
[0],   │
│ (MultiHeadAttentio… │                   │            │ embedding[1]
[0],   │
│                     │                   │            │
not_equal_1[0][0… │
│                     │                   │            │
not_equal_1[0][0] │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dense_3 (Dense)     │ (None, 250, 128)  │     16,512 │ dense_2[0][0]
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_7 (Dropout) │ (None, 250, 128)  │          0 │
multi_head_atten… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_5 (Dropout) │ (None, 250, 128)  │          0 │ dense_3[0][0]
```

```
│
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ add_4 (Add)         │ (None, 250, 128)   │          0 │ embedding[1]
[0],  │
│                     │                    │            │ dropout_7[0]
[0]   │
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ add_3 (Add)         │ (None, 250, 128)   │          0 │
layer_normalizat… │
│                     │                    │            │ dropout_5[0]
[0]   │
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_4[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_3[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)   │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                    │            │
layer_normalizat… │
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ dropout_9 (Dropout) │ (None, 250, 128)   │          0 │
multi_head_atten… │
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ add_5 (Add)         │ (None, 250, 128)   │          0 │
layer_normalizat… │
│                     │                    │            │ dropout_9[0]
[0]   │
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_5[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
─────┤
```

```
│ dense_4 (Dense)     │ (None, 250, 128)  │     16,512 │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dense_5 (Dense)     │ (None, 250, 128)  │     16,512 │ dense_4[0][0]
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_10          │ (None, 250, 128)  │          0 │ dense_5[0][0]
│
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_6 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_10[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_6[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                   │            │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_12          │ (None, 250, 128)  │          0 │
multi_head_atten… │
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_7 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_12[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_7[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
```

```
──────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                   │            │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ dropout_14          │ (None, 250, 128)  │          0 │
multi_head_atten… │
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ add_8 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_14[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_8[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ dense_6 (Dense)     │ (None, 250, 128)  │     16,512 │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ dense_7 (Dense)     │ (None, 250, 128)  │     16,512 │ dense_6[0][0]
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ dropout_15          │ (None, 250, 128)  │          0 │ dense_7[0][0]
│
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ add_9 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_15[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_9[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
```

```
├─────────────────────┼──────────────────────┼─────────────┼──────────────
─────┤
│ global_average_poo… │ (None, 128)          │           0 │
layer_normalizat… │
│ (GlobalAveragePool… │                      │             │
│
├─────────────────────┼──────────────────────┼─────────────┼──────────────
─────┤
│ dropout_16          │ (None, 128)          │           0 │
global_average_p… │
│ (Dropout)           │                      │             │
│
├─────────────────────┼──────────────────────┼─────────────┼──────────────
─────┤
│ dense_8 (Dense)     │ (None, 1)            │         129 │ dropout_16[0]
[0]   │
└─────────────────────┴──────────────────────┴─────────────┴──────────────
─────┘

 Total params: 2,997,633 (11.44 MB)

 Trainable params: 2,997,633 (11.44 MB)

 Non-trainable params: 0 (0.00 B)

transformer_model.compile(
    optimizer=Adam(learning_rate=1e-4),
    loss=BinaryCrossentropy(),
    metrics=["accuracy"]
)
```

Fase 5: Entrenamiento del Modelo Transformer

```
# Rutas definidas
CHECKPOINT_DIR = "/content/drive/MyDrive/Transformer/Checkpoint"
LOG_DIR = "/content/drive/MyDrive/Transformer/Log"
CHECKPOINT_PATH = os.path.join(CHECKPOINT_DIR, "best_model.h5")
EPOCH_TRACKER_PATH = os.path.join(CHECKPOINT_DIR, "last_epoch.txt")

# ⚠ Validación robusta de existencia y contenido
def is_checkpoint_valid(model_path):
    return os.path.isfile(model_path) and os.path.getsize(model_path)
> 0

def is_epoch_file_valid(epoch_path):
    return os.path.isfile(epoch_path) and os.path.getsize(epoch_path)
> 0

# Epoch inicial
```

```
initial_epoch = 0

# Cargar pesos si ambos archivos son válidos
if is_checkpoint_valid(CHECKPOINT_PATH) and
is_epoch_file_valid(EPOCH_TRACKER_PATH):
    try:
        print("□ Checkpoint encontrado. Intentando cargar pesos del
modelo...")
        transformer_model.load_weights(CHECKPOINT_PATH)
        with open(EPOCH_TRACKER_PATH, "r") as f:
            initial_epoch = int(f.read().strip()) + 1
        print(f"Reanudando desde la época {initial_epoch}")
    except Exception as e:
        print("⚠ Error al cargar los pesos del checkpoint. Se ignorará
y se entrenará desde cero.")
        print(f"Detalles del error: {e}")
        initial_epoch = 0
else:
    print("ℹ No se encontró checkpoint válido. Entrenamiento comenzará
desde la época 0.")
```

```
ℹ No se encontró checkpoint válido. Entrenamiento comenzará desde la
época 0.
```

```
# Callback personalizado para guardar el número de la última época
completada
class EpochTrackerCallback(Callback):
    def on_epoch_end(self, epoch, logs=None):
        with open(EPOCH_TRACKER_PATH, "w") as f:
            f.write(str(epoch))

callbacks = [
    EarlyStopping(monitor="val_loss", patience=2,
restore_best_weights=True, verbose=1),
    ReduceLROnPlateau(monitor="val_loss", factor=0.5, patience=2,
min_lr=1e-6, verbose=1),
    ModelCheckpoint(
        filepath=CHECKPOINT_PATH,
        monitor="val_loss",
        save_best_only=True,
        verbose=1
    ),
    TensorBoard(log_dir=LOG_DIR),
    EpochTrackerCallback()
]

history = transformer_model.fit(
    [X_train_pad, X_train_pad],   # input_encoder, input_decoder
    y_train,
    validation_data=([X_val_pad, X_val_pad], y_val),
    epochs=60,
    initial_epoch=initial_epoch,
    batch_size=64,
    callbacks=callbacks
)
```

```
Epoch 1/60
333/333 ━━━━━━━━━━━━━━━━━━━━ 0s 185ms/step - accuracy: 0.6553 - loss:
0.5878
Epoch 1: val_loss improved from inf to 0.34477, saving model to
/content/drive/MyDrive/Transformer/Checkpoint/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

333/333 ━━━━━━━━━━━━━━━━━━━━ 96s 205ms/step - accuracy: 0.6556 - loss:
0.5874 - val_accuracy: 0.8509 - val_loss: 0.3448 - learning_rate:
1.0000e-04
Epoch 2/60
332/333 ━━━━━━━━━━━━━━━━━━━━ 0s 155ms/step - accuracy: 0.9009 - loss:
0.2524
Epoch 2: val_loss improved from 0.34477 to 0.31059, saving model to
/content/drive/MyDrive/Transformer/Checkpoint/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

333/333 ━━━━━━━━━━━━━━━━━━━━ 115s 167ms/step - accuracy: 0.9009 -
loss: 0.2524 - val_accuracy: 0.8688 - val_loss: 0.3106 -
learning_rate: 1.0000e-04
Epoch 3/60
332/333 ━━━━━━━━━━━━━━━━━━━━ 0s 155ms/step - accuracy: 0.9324 - loss:
0.1841
Epoch 3: val_loss did not improve from 0.31059
333/333 ━━━━━━━━━━━━━━━━━━━━ 80s 163ms/step - accuracy: 0.9324 - loss:
0.1842 - val_accuracy: 0.8707 - val_loss: 0.3344 - learning_rate:
1.0000e-04
Epoch 4/60
332/333 ━━━━━━━━━━━━━━━━━━━━ 0s 155ms/step - accuracy: 0.9523 - loss:
0.1377
Epoch 4: ReduceLROnPlateau reducing learning rate to
4.999999873689376e-05.

Epoch 4: val_loss did not improve from 0.31059
```

```
333/333 ━━━━━━━━━━━━━━━━━━━━ 84s 170ms/step - accuracy: 0.9523 - loss:
0.1377 - val_accuracy: 0.8440 - val_loss: 0.4359 - learning_rate:
1.0000e-04
Epoch 4: early stopping
Restoring model weights from the end of the best epoch: 2.
```

Fase 6: Evaluación del Modelo

```python
# Cargar los mejores pesos del entrenamiento
transformer_model.load_weights("/content/drive/MyDrive/Transformer/
Checkpoint/best_model.h5")
print("□ Pesos del mejor modelo cargados exitosamente.")
```

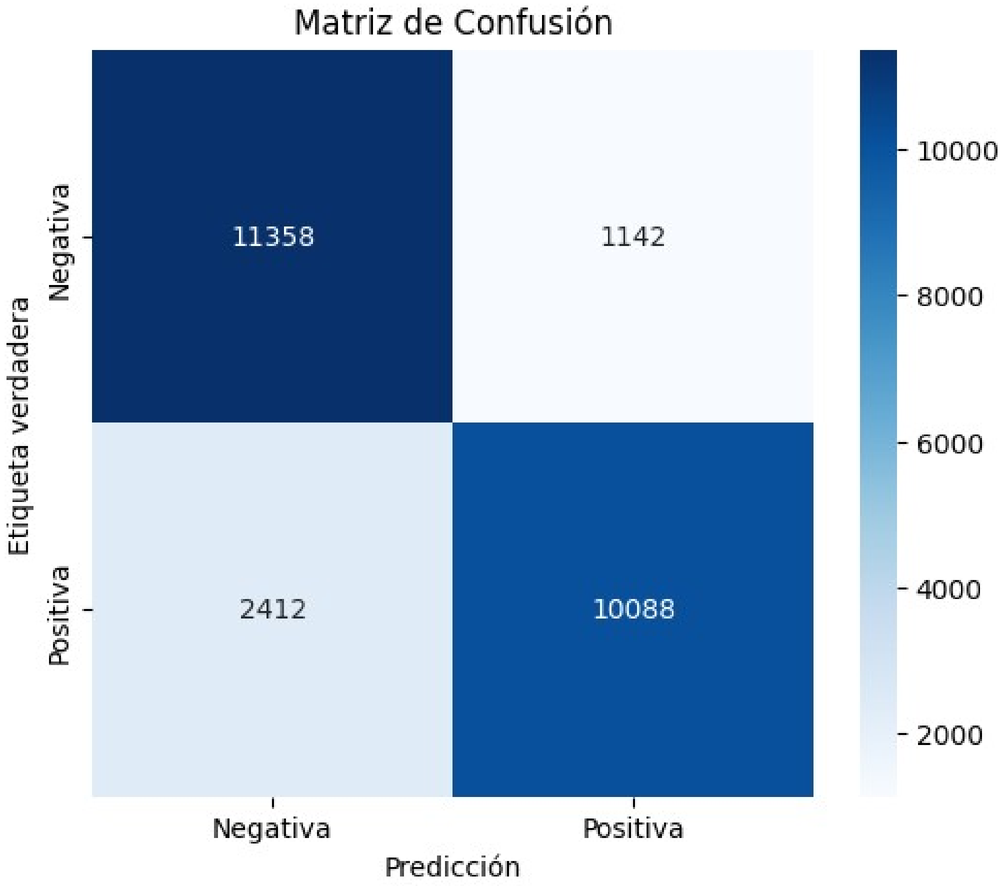
```
□ Pesos del mejor modelo cargados exitosamente.
```

```python
# Evaluación del modelo en el conjunto de test
test_loss, test_accuracy = transformer_model.evaluate([X_test_pad,
X_test_pad], y_test, verbose=1)
print(f"□ Evaluación en test - Accuracy: {test_accuracy:.4f} | Loss:
{test_loss:.4f}")
```

```
782/782 ━━━━━━━━━━━━━━━━━━━━ 23s 27ms/step - accuracy: 0.8571 - loss:
0.3339
□ Evaluación en test - Accuracy: 0.8578 | Loss: 0.3344
```

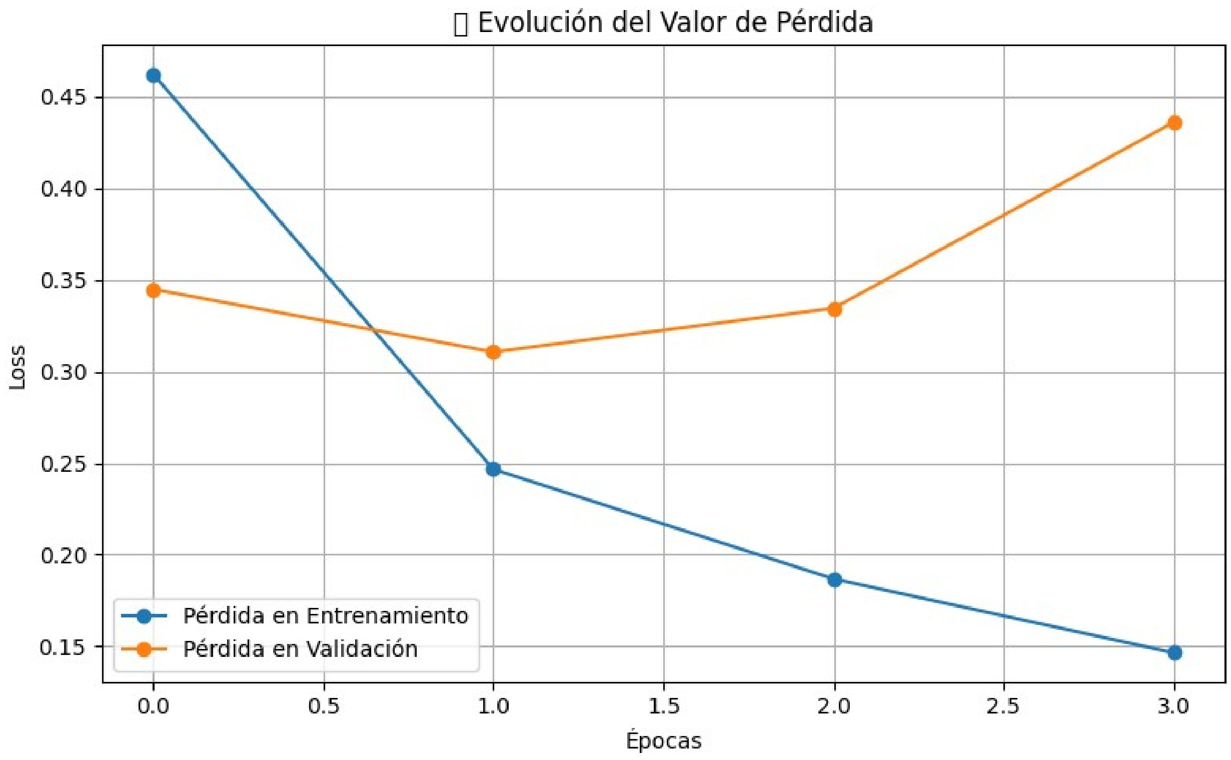
```python
# Predicciones (probabilidades)
y_pred_prob = transformer_model.predict([X_test_pad, X_test_pad])
# Convertir a clases (0 o 1)
y_pred = (y_pred_prob >= 0.5).astype(int)

# Reporte de clasificación
print("□ Reporte de Clasificación:\n")
print(classification_report(y_test, y_pred, target_names=["Negativa",
"Positiva"]))

# Matriz de confusión
cm = confusion_matrix(y_test, y_pred)

# Visualización
plt.figure(figsize=(6,5))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
xticklabels=["Negativa", "Positiva"], yticklabels=["Negativa",
"Positiva"])
plt.xlabel("Predicción")
plt.ylabel("Etiqueta verdadera")
plt.title("Matriz de Confusión")
plt.show()
```

```
782/782 ━━━━━━━━━━━━━━━━━━━━ 23s 27ms/step
□ Reporte de Clasificación:

              precision    recall  f1-score   support

    Negativa       0.82      0.91      0.86     12500
    Positiva       0.90      0.81      0.85     12500

    accuracy                           0.86     25000
   macro avg       0.86      0.86      0.86     25000
weighted avg       0.86      0.86      0.86     25000
```



```python
# Gráfico del valor de pérdida durante el entrenamiento
def plot_loss(history):
    plt.figure(figsize=(8, 5))
    plt.plot(history.history['loss'], label='Pérdida en
Entrenamiento', marker='o')
    plt.plot(history.history['val_loss'], label='Pérdida en
Validación', marker='o')
    plt.title('□ Evolución del Valor de Pérdida')
    plt.xlabel('Épocas')
    plt.ylabel('Loss')
    plt.legend()
    plt.grid(True)
    plt.tight_layout()
    plt.show()

# Llamamos a la función
plot_loss(history)
```

```
/tmp/ipython-input-32-2417583913.py:11: UserWarning: Glyph 128201 (\
N{CHART WITH DOWNWARDS TREND}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151
: UserWarning: Glyph 128201 (\N{CHART WITH DOWNWARDS TREND}) missing
from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



```
# Si estás en Google Colab, ejecuta esta celda para cargar el tablero
de TensorBoard
%load_ext tensorboard
%tensorboard --logdir /content/drive/MyDrive/Transformer/Log
```

```
<IPython.core.display.Javascript object>
```

Fase 7 predicciones

```
# Reconstruye el modelo exactamente igual que durante el entrenamiento
# (con los bloques encoder, decoder, embeddings, pooling y demás definidos)

transformer_model.load_weights("/content/drive/MyDrive/Transformer/Checkpoint/best_model.h5")
print("□ Modelo cargado correctamente.")
```

```
□ Modelo cargado correctamente.
```

```
sample_reviews = [
    "This movie was a masterpiece with stunning visuals and strong performances",
    "Absolutely terrible. I can't believe I wasted two hours on this",
    "It was okay, not bad but not great either",
    "One of the best films I've seen in years!",
    "The plot made no sense and the acting was wooden",
    "I laughed, I cried, and I loved every minute of it",
    "Completely overrated. Don't understand the hype",
    "An emotional rollercoaster with brilliant writing",
    "Boring and predictable from start to finish",
    "This is a bad movie"
]

# Cargar diccionario de palabras
word_index = imdb.get_word_index()
word_index = {k: (v + 3) for k, v in word_index.items()}
word_index["[PAD]"] = 0
word_index["[START]"] = 1
word_index["[UNK]"] = 2
word_index["[UNUSED]"] = 3

def encode_review(text, max_len=250):
    text = text.lower()
    text = re.sub(r"[^a-zA-Z0-9\s]", "", text)
    tokens = text.split()
    encoded = [1]  # [START]
    for word in tokens:
        encoded.append(word_index.get(word, 2))
    padded = pad_sequences([encoded], maxlen=max_len, padding='post', truncating='post')
    return padded

print("□ PREDICCIONES DETALLADAS DEL MODELO TRANSFORMER:\n")

for i, review in enumerate(sample_reviews):
    encoded = encode_review(review, max_len=250)
    prediction = transformer_model.predict([encoded, encoded])[0][0]
    predicted_class = int(prediction >= 0.5)

    predicted_sentiment = "Positiva □" if predicted_class == 1 else
"Negativa □"
    probability_percent = prediction * 100  # Convertimos a porcentaje

    print(f"{i+1}. Reseña: \"{review}\"\n")
    print(f"   □ Predicción del modelo: {predicted_sentiment}")
    print(f"   □ Probabilidad: {probability_percent:.2f}%\n")
```

```
□ PREDICCIONES DETALLADAS DEL MODELO TRANSFORMER:

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 35ms/step
1. Reseña: "This movie was a masterpiece with stunning visuals and
strong performances"

   □ Predicción del modelo: Positiva □
   □ Probabilidad: 99.95%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 41ms/step
2. Reseña: "Absolutely terrible. I can't believe I wasted two hours on
this"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 0.26%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step
3. Reseña: "It was okay, not bad but not great either"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 1.18%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step
4. Reseña: "One of the best films I've seen in years!"

   □ Predicción del modelo: Positiva □
   □ Probabilidad: 99.94%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step
5. Reseña: "The plot made no sense and the acting was wooden"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 0.15%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 35ms/step
6. Reseña: "I laughed, I cried, and I loved every minute of it"

   □ Predicción del modelo: Positiva □
   □ Probabilidad: 99.87%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step
```

```
7. Reseña: "Completely overrated. Don't understand the hype"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 0.47%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 35ms/step
8. Reseña: "An emotional rollercoaster with brilliant writing"

   □ Predicción del modelo: Positiva □
   □ Probabilidad: 99.89%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 35ms/step
9. Reseña: "Boring and predictable from start to finish"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 0.19%

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step
10. Reseña: "This is a bad movie"

   □ Predicción del modelo: Negativa □
   □ Probabilidad: 0.52%
```

Fase 8: Exploración del Dataset Fashion-MNIST

Carga del dataset de imágenes (Fashion-MNIST).

```
from tensorflow.keras.datasets import fashion_mnist

# Cargar el dataset
(X_train, y_train), (X_test, y_test) = fashion_mnist.load_data()

# Ver las dimensiones de los datos
print("Forma de X_train:", X_train.shape)
print("Forma de X_test:", X_test.shape)
print("Forma de y_train:", y_train.shape)
print("Forma de y_test:", y_test.shape)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-labels-idx1-ubyte.gz
29515/29515 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-images-idx3-ubyte.gz
26421880/26421880 ━━━━━━━━━━━━━━━━━━━━ 1s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-labels-idx1-ubyte.gz
5148/5148 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-images-idx3-ubyte.gz
4422102/4422102 ━━━━━━━━━━━━━━━━━━━━ 1s 0us/step
Forma de X_train: (60000, 28, 28)
Forma de X_test: (10000, 28, 28)
Forma de y_train: (60000,)
Forma de y_test: (10000,)
```

Exploración visual de algunas imágenes

```python
import matplotlib.pyplot as plt

# Mostrar algunas imágenes
def plot_images(X, y, labels, num_images=5):
    plt.figure(figsize=(10, 5))
    for i in range(num_images):
        plt.subplot(1, num_images, i + 1)
        plt.imshow(X[i], cmap="gray")
        plt.title(f"Clase: {labels[y[i]]}")
        plt.axis('off')
    plt.show()

# Etiquetas de las clases
labels = ["T-shirt/top", "Trouser", "Pullover", "Dress", "Coat",
"Sandal", "Shirt", "Sneaker", "Bag", "Ankle boot"]

# Visualizar las primeras 5 imágenes
plot_images(X_train, y_train, labels)
```

Preprocesamiento de los datos

```python
# Normalización de las imágenes
X_train = X_train.astype('float32') / 255.0
X_test = X_test.astype('float32') / 255.0

# Verificación de la normalización (deberían estar entre 0 y 1)
print("Valor máximo de X_train:", X_train.max())
print("Valor mínimo de X_train:", X_train.min())
```

```
Valor máximo de X_train: 1.0
Valor mínimo de X_train: 0.0
```

```python
# Redimensionar para que el formato sea (num_samples, 28, 28, 1)
X_train = X_train.reshape(-1, 28, 28, 1)
X_test = X_test.reshape(-1, 28, 28, 1)

# Verificación de la nueva forma
print("Nueva forma de X_train:", X_train.shape)
print("Nueva forma de X_test:", X_test.shape)
```

```
Nueva forma de X_train: (60000, 28, 28, 1)
Nueva forma de X_test: (10000, 28, 28, 1)
```

```python
from tensorflow.keras.utils import to_categorical

# Codificación one-hot de las etiquetas
y_train = to_categorical(y_train, 10)
y_test = to_categorical(y_test, 10)

# Verificación de la codificación
print("Primeras etiquetas codificadas:", y_train[:5])
```

```
Primeras etiquetas codificadas: [[0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]]
```

Fase 9: Diseño de la Arquitectura del Modelo CNN

Definición de la arquitectura de la red convolucional (CNN)

```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten,
Dense, Dropout

# Definir la arquitectura del modelo CNN
model = Sequential()

# Capa convolucional 1
model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28,
1)))
model.add(MaxPooling2D((2, 2)))

# Capa convolucional 2
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
```

```python
# Capa convolucional 3
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))

# Aplanado de la salida
model.add(Flatten())

# Capa densa completamente conectada
model.add(Dense(128, activation='relu'))

# Capa de Dropout para evitar overfitting
model.add(Dropout(0.5))

# Capa de salida (10 clases)
model.add(Dense(10, activation='softmax'))

# Resumen del modelo
model.summary()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/
convolutional/base_conv.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__(activity_regularizer=activity_regularizer,
**kwargs)

Model: "sequential"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ conv2d (Conv2D)                 │ (None, 26, 26, 32)     │
320 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d (MaxPooling2D)    │ (None, 13, 13, 32)     │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ conv2d_1 (Conv2D)               │ (None, 11, 11, 64)     │
18,496 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_1 (MaxPooling2D)  │ (None, 5, 5, 64)       │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
```

```
─────┤
│ conv2d_2 (Conv2D)               │ (None, 3, 3, 128)       │
73,856 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_2 (MaxPooling2D)  │ (None, 1, 1, 128)       │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ flatten (Flatten)               │ (None, 128)             │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense (Dense)                   │ (None, 128)             │
16,512 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dropout (Dropout)               │ (None, 128)             │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense_1 (Dense)                 │ (None, 10)              │
1,290 │
└─────────────────────────────────┴────────────────────────┴──────────
─────┘

 Total params: 110,474 (431.54 KB)

 Trainable params: 110,474 (431.54 KB)

 Non-trainable params: 0 (0.00 B)
```

Fase 10: Entrenamiento del Modelo CNN

Preparación para el entrenamiento

```
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.losses import CategoricalCrossentropy
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint,
TensorBoard

# Compilación del modelo con la función de pérdida correcta
model.compile(
    optimizer=Adam(learning_rate=0.001),
    loss=CategoricalCrossentropy(from_logits=False),
    metrics=['accuracy']
)
```

Definir los Callbacks

```
from google.colab import drive
drive.mount('/content/drive')

Drive already mounted at /content/drive; to attempt to forcibly
remount, call drive.mount("/content/drive", force_remount=True).

# Directorios para guardar los modelos y logs
CHECKPOINT_DIR = "/content/drive/MyDrive/Modelo CNN/checkpoints"
LOG_DIR = "/content/drive/MyDrive/Modelo CNN/logs"

# Callback para guardar el mejor modelo
checkpoint_callback = ModelCheckpoint(
    filepath=f"{CHECKPOINT_DIR}/best_model.h5",
    monitor='val_loss',
    save_best_only=True,
    verbose=1
)

# Callback para detener el entrenamiento si no hay mejoras
early_stopping_callback = EarlyStopping(
    monitor='val_loss',
    patience=3,  # Número de épocas sin mejora antes de parar
    restore_best_weights=True,
    verbose=1
)

# Callback para TensorBoard
tensorboard_callback = TensorBoard(
    log_dir=LOG_DIR,
    histogram_freq=1,
    write_graph=True
)
```

Entrenar el Modelo

```
# Entrenamiento del modelo
history_cnn = model.fit(
    X_train, y_train,  # Datos de entrenamiento
    validation_data=(X_test, y_test),  # Datos de validación
    epochs=30,  # Número de épocas
    batch_size=64,  # Tamaño del batch
    callbacks=[checkpoint_callback, early_stopping_callback,
tensorboard_callback]
)

Epoch 1/30
938/938 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.6417 - loss:
0.9738
```

```
Epoch 1: val_loss improved from inf to 0.49951, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 13s 8ms/step - accuracy: 0.6418 - loss:
0.9735 - val_accuracy: 0.8081 - val_loss: 0.4995
Epoch 2/30
930/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8245 - loss:
0.4860
Epoch 2: val_loss improved from 0.49951 to 0.40828, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 15s 6ms/step - accuracy: 0.8246 - loss:
0.4858 - val_accuracy: 0.8483 - val_loss: 0.4083
Epoch 3/30
927/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.8553 - loss:
0.4045
Epoch 3: val_loss improved from 0.40828 to 0.36573, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.8553 - loss:
0.4044 - val_accuracy: 0.8668 - val_loss: 0.3657
Epoch 4/30
937/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.8683 - loss:
0.3637
Epoch 4: val_loss improved from 0.36573 to 0.34029, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.
```

```
 938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.8683 - loss:
0.3637 - val_accuracy: 0.8761 - val_loss: 0.3403
Epoch 5/30
926/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8777 - loss:
0.3344
Epoch 5: val_loss did not improve from 0.34029
938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 6ms/step - accuracy: 0.8778 - loss:
0.3343 - val_accuracy: 0.8742 - val_loss: 0.3427
Epoch 6/30
938/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.8891 - loss:
0.3066
Epoch 6: val_loss improved from 0.34029 to 0.32448, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.8891 - loss:
0.3066 - val_accuracy: 0.8780 - val_loss: 0.3245
Epoch 7/30
934/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8994 - loss:
0.2788
Epoch 7: val_loss improved from 0.32448 to 0.31536, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 6s 6ms/step - accuracy: 0.8994 - loss:
0.2788 - val_accuracy: 0.8877 - val_loss: 0.3154
Epoch 8/30
928/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9041 - loss:
0.2619
Epoch 8: val_loss improved from 0.31536 to 0.31226, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.9041 - loss:
0.2619 - val_accuracy: 0.8890 - val_loss: 0.3123
Epoch 9/30
```

```
937/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9132 - loss:
0.2395
Epoch 9: val_loss improved from 0.31226 to 0.30478, saving model to
/content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.9132 - loss:
0.2396 - val_accuracy: 0.8917 - val_loss: 0.3048
Epoch 10/30
927/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.9166 - loss:
0.2284
Epoch 10: val_loss did not improve from 0.30478
938/938 ━━━━━━━━━━━━━━━━━━━━ 6s 6ms/step - accuracy: 0.9166 - loss:
0.2284 - val_accuracy: 0.8929 - val_loss: 0.3209
Epoch 11/30
934/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.9217 - loss:
0.2132
Epoch 11: val_loss improved from 0.30478 to 0.30063, saving model
to /content/drive/MyDrive/Modelo CNN/checkpoints/best_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 938/938 ━━━━━━━━━━━━━━━━━━━━ 10s 6ms/step - accuracy: 0.9217 - loss:
0.2133 - val_accuracy: 0.8952 - val_loss: 0.3006
Epoch 12/30
931/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9238 - loss:
0.2049
Epoch 12: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 9s 5ms/step - accuracy: 0.9238 - loss:
0.2049 - val_accuracy: 0.8939 - val_loss: 0.3127
Epoch 13/30
928/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.9298 - loss:
0.1933
Epoch 13: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 6s 6ms/step - accuracy: 0.9298 - loss:
0.1934 - val_accuracy: 0.8914 - val_loss: 0.3161
Epoch 14/30
935/938 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9308 - loss:
0.1836
Epoch 14: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 5s 5ms/step - accuracy: 0.9308 - loss:
```

```
0.1837 - val_accuracy: 0.8966 - val_loss: 0.3265
Epoch 14: early stopping
Restoring model weights from the end of the best epoch: 11.
```

Fase 11: Evaluación del Modelo CNN

Evaluación del modelo en el conjunto de test

```
# Evaluación del modelo en el conjunto de test
test_loss, test_accuracy = model.evaluate(X_test, y_test, verbose=1)
print(f"□ Evaluación en test - Accuracy: {test_accuracy:.4f} | Loss:
{test_loss:.4f}")

313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 4ms/step - accuracy: 0.8931 - loss:
0.3110
□ Evaluación en test - Accuracy: 0.8952 | Loss: 0.3006
```

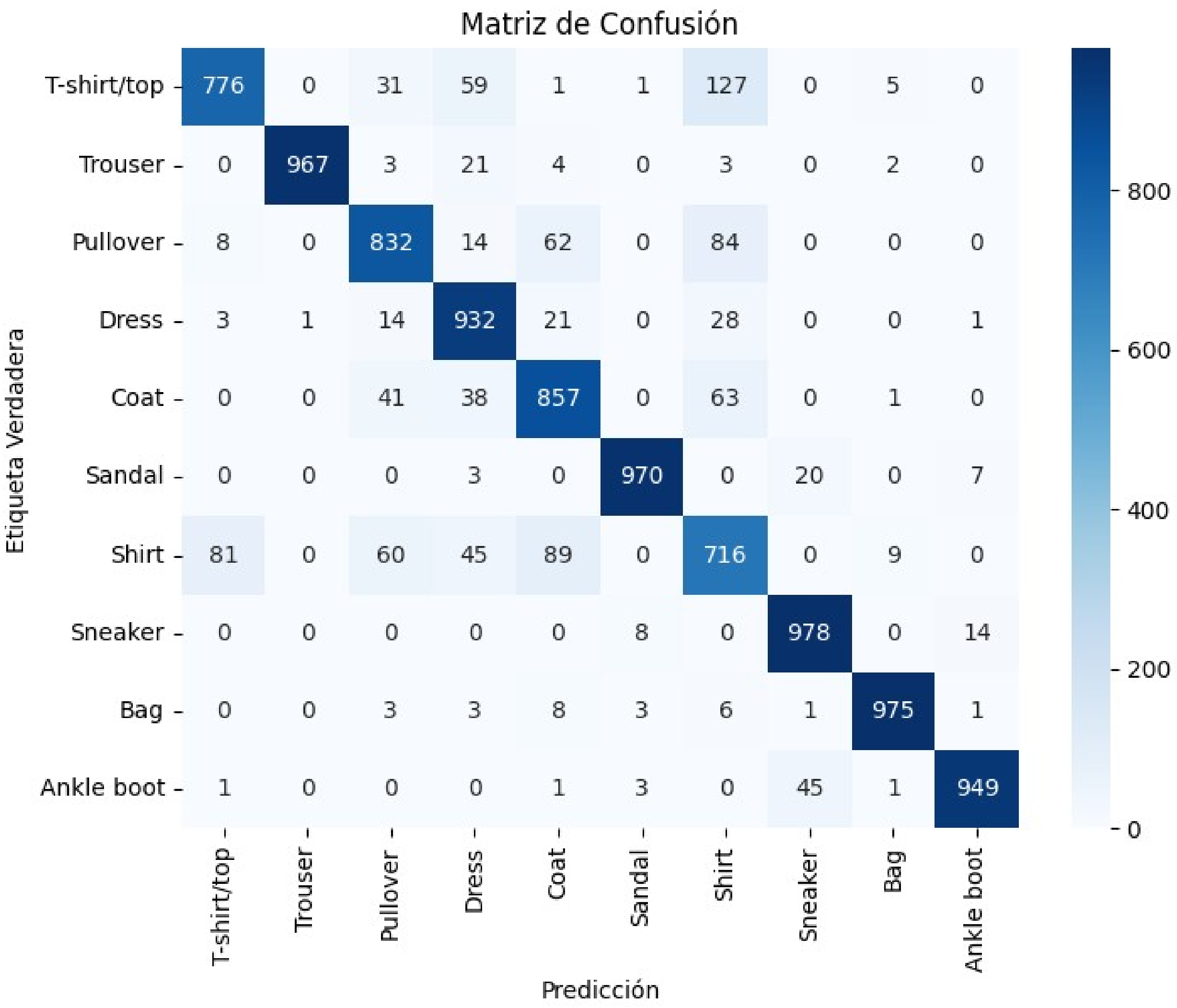
Análisis de métricas

```
from sklearn.metrics import classification_report

# Obtener las predicciones
y_pred_prob = model.predict(X_test)
y_pred = np.argmax(y_pred_prob, axis=1)  # Convertir probabilidades a
clases

# Reporte de clasificación
print("□ Reporte de Clasificación:\n")
print(classification_report(np.argmax(y_test, axis=1), y_pred,
target_names=labels))

313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
□ Reporte de Clasificación:

              precision    recall  f1-score   support

 T-shirt/top       0.89      0.78      0.83      1000
     Trouser       1.00      0.97      0.98      1000
    Pullover       0.85      0.83      0.84      1000
       Dress       0.84      0.93      0.88      1000
        Coat       0.82      0.86      0.84      1000
      Sandal       0.98      0.97      0.98      1000
       Shirt       0.70      0.72      0.71      1000
     Sneaker       0.94      0.98      0.96      1000
         Bag       0.98      0.97      0.98      1000
  Ankle boot       0.98      0.95      0.96      1000

    accuracy                           0.90     10000
```

```
   macro avg       0.90      0.90      0.90     10000
weighted avg       0.90      0.90      0.90     10000
```

Visualización de resultados

```
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

# Matriz de confusión
cm = confusion_matrix(np.argmax(y_test, axis=1), y_pred)

# Visualización de la matriz de confusión
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=labels,
yticklabels=labels)
plt.xlabel("Predicción")
plt.ylabel("Etiqueta Verdadera")
plt.title("Matriz de Confusión")
plt.show()
```

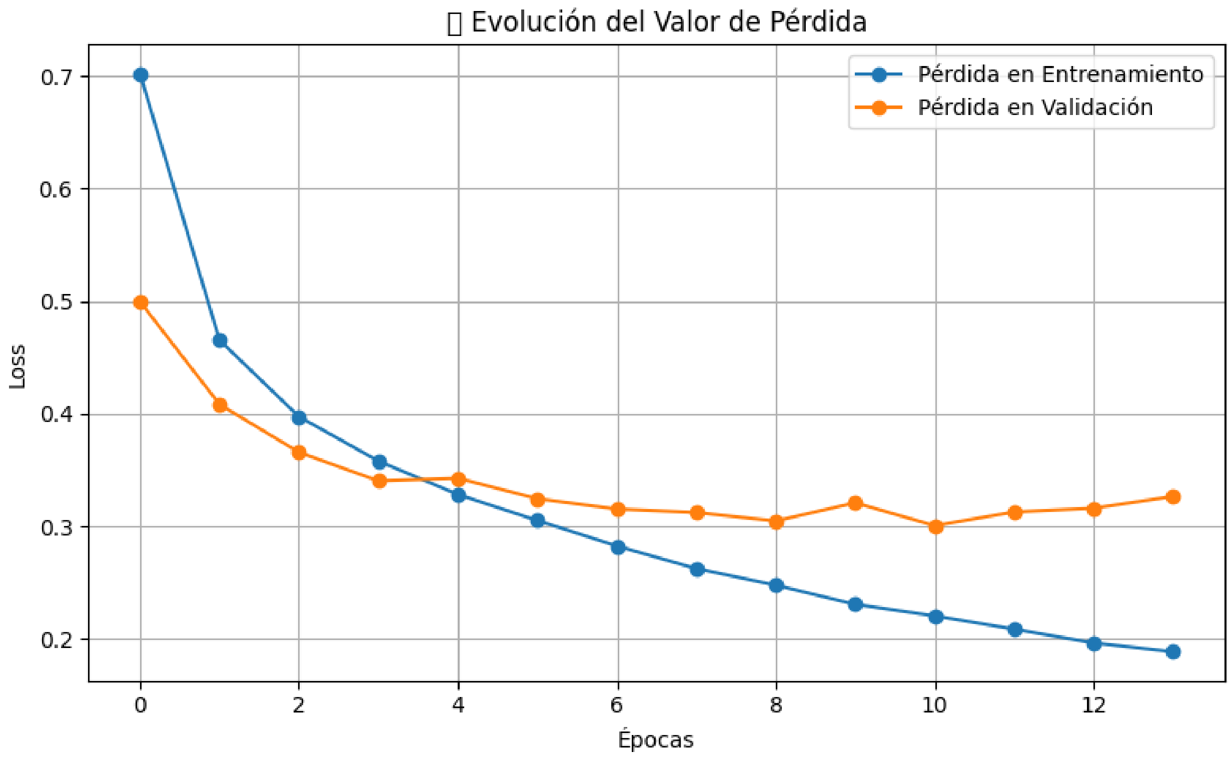


Matriz de Confusión

Etiqueta Verdadera \ Predicción	T-shirt/top	Trouser	Pullover	Dress	Coat	Sandal	Shirt	Sneaker	Bag	Ankle boot
T-shirt/top	776	0	31	59	1	1	127	0	5	0
Trouser	0	967	3	21	4	0	3	0	2	0
Pullover	8	0	832	14	62	0	84	0	0	0
Dress	3	1	14	932	21	0	28	0	0	1
Coat	0	0	41	38	857	0	63	0	1	0
Sandal	0	0	0	3	0	970	0	20	0	7
Shirt	81	0	60	45	89	0	716	0	9	0
Sneaker	0	0	0	0	0	8	0	978	0	14
Bag	0	0	3	3	8	3	6	1	975	1
Ankle boot	1	0	0	0	1	3	0	45	1	949

```python
# Gráfico del valor de pérdida durante el entrenamiento
def plot_loss(history):
    plt.figure(figsize=(8, 5))
    plt.plot(history.history['loss'], label='Pérdida en 
Entrenamiento', marker='o')
    plt.plot(history.history['val_loss'], label='Pérdida en 
Validación', marker='o')
    plt.title('□ Evolución del Valor de Pérdida')
    plt.xlabel('Épocas')
    plt.ylabel('Loss')
    plt.legend()
    plt.grid(True)
    plt.tight_layout()
    plt.show()

# Llamamos a la función para visualizar el gráfico
plot_loss(history_cnn)
```

```
/tmp/ipython-input-24-3940220300.py:11: UserWarning: Glyph 128201 (\
N{CHART WITH DOWNWARDS TREND}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151
: UserWarning: Glyph 128201 (\N{CHART WITH DOWNWARDS TREND}) missing
from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



Fase 12: Ajuste de Hiperparámetros y Regularización

Ajuste de hiperparámetros del modelo

```
# Definir la arquitectura del modelo CNN con BatchNormalization
model = Sequential()

# Capa convolucional 1
model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28,
1)))
model.add(BatchNormalization())  # Normalización por lotes
model.add(MaxPooling2D((2, 2)))

# Capa convolucional 2
```

```
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(BatchNormalization())  # Normalización por lotes
model.add(MaxPooling2D((2, 2)))

# Capa convolucional 3
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(BatchNormalization())  # Normalización por lotes
model.add(MaxPooling2D((2, 2)))

# Aplanado de la salida
model.add(Flatten())

# Capa densa completamente conectada
model.add(Dense(128, activation='relu'))

# Capa de Dropout
model.add(Dropout(0.5))

# Capa de salida (10 clases)
model.add(Dense(10, activation='softmax'))
```

Regularización

```
# Ahora compilamos el modelo después de definir su arquitectura
model.compile(
    optimizer=Adam(learning_rate=0.001),  # Ajustar el learning rate
    loss=CategoricalCrossentropy(from_logits=False),
    metrics=['accuracy']
)
```

Entrenamiento con nuevos parametros

```
history_cnn_new = model.fit(
    X_train, y_train,  # Datos de entrenamiento
    validation_data=(X_test, y_test),  # Datos de validación
    epochs=30,  # Número de épocas ajustado
    batch_size=64,  # Tamaño del batch ajustado
    callbacks=[checkpoint_callback, early_stopping_callback,
tensorboard_callback]
)

Epoch 1/30
938/938 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.7503 - loss:
0.7319
Epoch 1: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 15s 8ms/step - accuracy: 0.7503 - loss:
0.7317 - val_accuracy: 0.8564 - val_loss: 0.4074
Epoch 2/30
935/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8615 - loss:
```

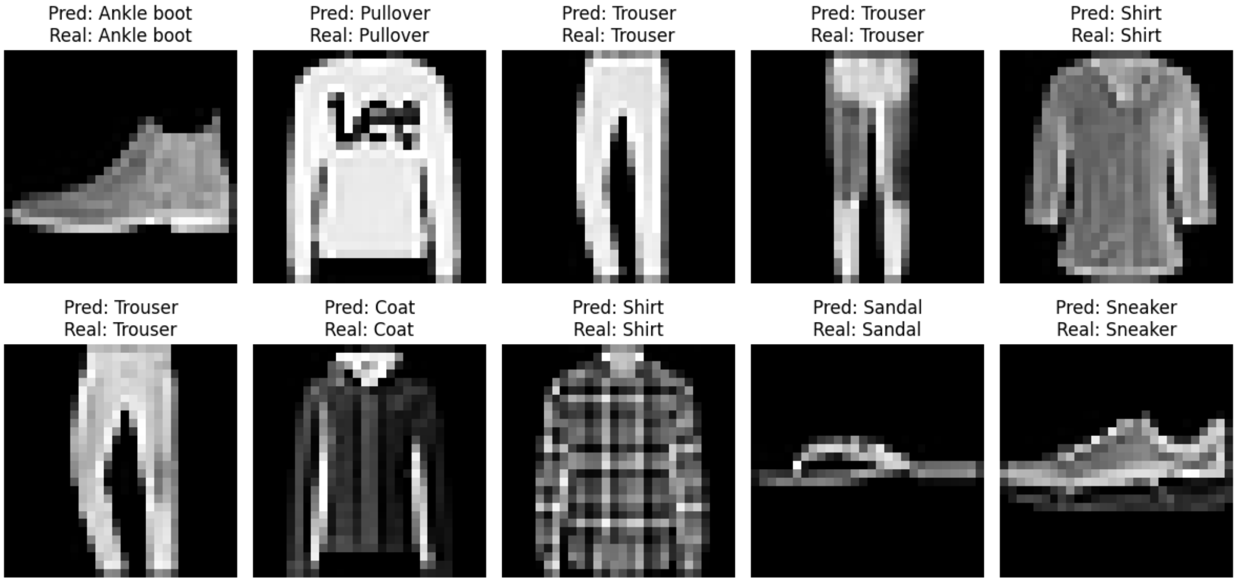
```
0.3862
Epoch 2: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 16s 6ms/step - accuracy: 0.8615 - loss:
0.3862 - val_accuracy: 0.8474 - val_loss: 0.3981
Epoch 3/30
937/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8785 - loss:
0.3339
Epoch 3: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 10s 5ms/step - accuracy: 0.8785 - loss:
0.3339 - val_accuracy: 0.8783 - val_loss: 0.3312
Epoch 4/30
936/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8938 - loss:
0.2932
Epoch 4: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 6s 6ms/step - accuracy: 0.8938 - loss:
0.2933 - val_accuracy: 0.8807 - val_loss: 0.3371
Epoch 5/30
938/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.8996 - loss:
0.2716
Epoch 5: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 10s 6ms/step - accuracy: 0.8996 - loss:
0.2716 - val_accuracy: 0.8733 - val_loss: 0.3578
Epoch 6/30
931/938 ━━━━━━━━━━━━━━━━━━━━ 0s 5ms/step - accuracy: 0.9084 - loss:
0.2515
Epoch 6: val_loss did not improve from 0.30063
938/938 ━━━━━━━━━━━━━━━━━━━━ 10s 6ms/step - accuracy: 0.9084 - loss:
0.2515 - val_accuracy: 0.8714 - val_loss: 0.3429
Epoch 6: early stopping
Restoring model weights from the end of the best epoch: 3.
```

Fase 13: Predicciones y Reporte Final

Generación de predicciones sobre nuevas imágenes

```python
import matplotlib.pyplot as plt

# Función para mostrar imágenes junto con las predicciones y las
clases reales
def plot_images_with_predictions(X, y_true, y_pred, labels,
num_images=10):
    plt.figure(figsize=(12, 6))
    for i in range(num_images):
        plt.subplot(2, 5, i + 1)  # 2 filas, 5 columnas
        plt.imshow(X[i].reshape(28, 28), cmap='gray')  #
Redimensionamos la imagen a 28x28
        plt.title(f"Pred: {labels[y_pred[i]]}\nReal:
```

```python
{labels[np.argmax(y_true[i])]}")
        plt.axis('off')
    plt.tight_layout()
    plt.show()

# Mostrar las primeras 10 imágenes con las predicciones y clases
reales
plot_images_with_predictions(X_test, y_test, y_pred, labels,
num_images=10)
```



Reporte de Clasificación

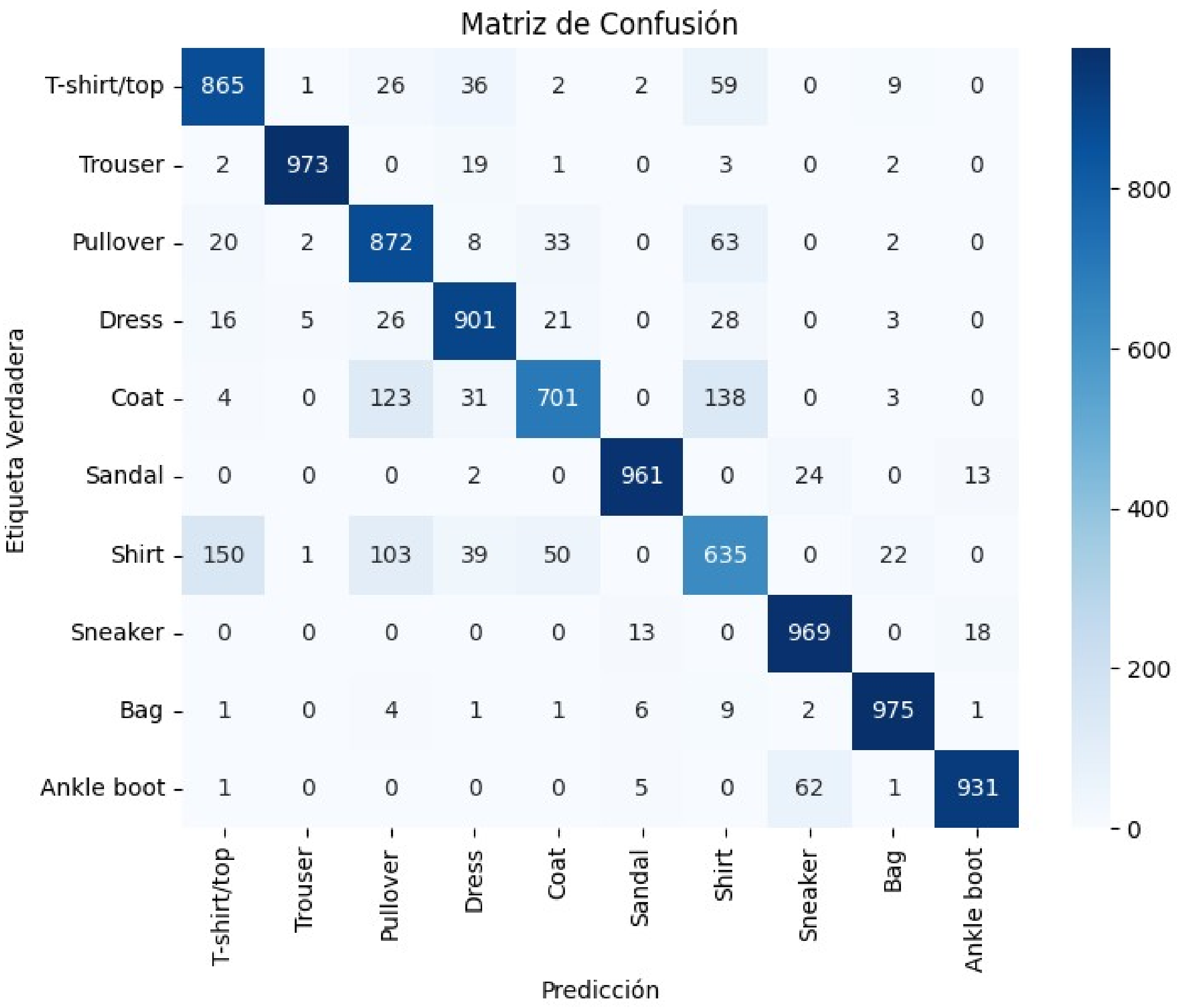
```python
from sklearn.metrics import classification_report

# Reporte de clasificación
print("□ Reporte de Clasificación:\n")
print(classification_report(np.argmax(y_test, axis=1), y_pred,
target_names=labels))
```

```
□ Reporte de Clasificación:

              precision    recall  f1-score   support

 T-shirt/top       0.82      0.86      0.84      1000
     Trouser       0.99      0.97      0.98      1000
    Pullover       0.76      0.87      0.81      1000
       Dress       0.87      0.90      0.88      1000
        Coat       0.87      0.70      0.78      1000
      Sandal       0.97      0.96      0.97      1000
       Shirt       0.68      0.64      0.66      1000
     Sneaker       0.92      0.97      0.94      1000
```

```
         Bag       0.96      0.97      0.97      1000
  Ankle boot       0.97      0.93      0.95      1000

    accuracy                           0.88     10000
   macro avg       0.88      0.88      0.88     10000
weighted avg       0.88      0.88      0.88     10000
```

Matriz de Confusión

```python
from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

# Matriz de confusión
cm = confusion_matrix(np.argmax(y_test, axis=1), y_pred)

# Visualización de la matriz de confusión
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=labels,
yticklabels=labels)
plt.xlabel("Predicción")
plt.ylabel("Etiqueta Verdadera")
plt.title("Matriz de Confusión")
plt.show()
```

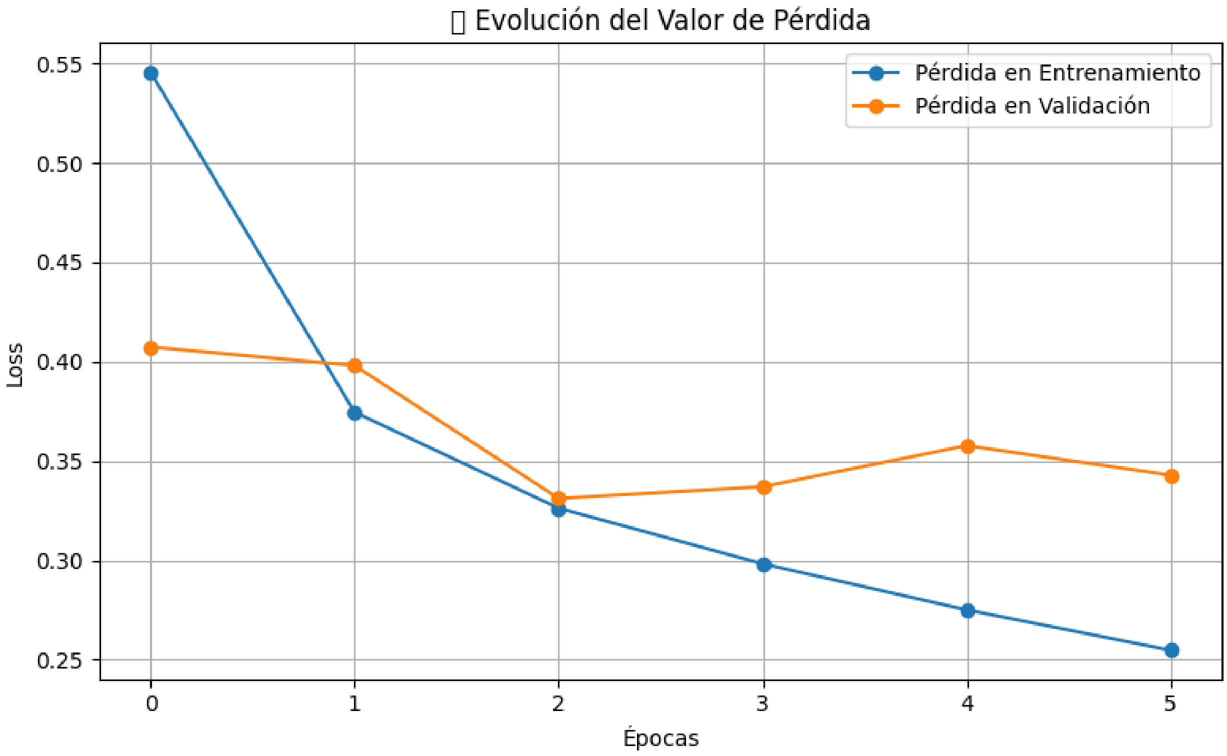

Matriz de Confusión

	T-shirt/top	Trouser	Pullover	Dress	Coat	Sandal	Shirt	Sneaker	Bag	Ankle boot
T-shirt/top	865	1	26	36	2	2	59	0	9	0
Trouser	2	973	0	19	1	0	3	0	2	0
Pullover	20	2	872	8	33	0	63	0	2	0
Dress	16	5	26	901	21	0	28	0	3	0
Coat	4	0	123	31	701	0	138	0	3	0
Sandal	0	0	0	2	0	961	0	24	0	13
Shirt	150	1	103	39	50	0	635	0	22	0
Sneaker	0	0	0	0	0	13	0	969	0	18
Bag	1	0	4	1	1	6	9	2	975	1
Ankle boot	1	0	0	0	0	5	0	62	1	931

Gráfico de la Evolución de la Pérdida

```
# Gráfico del valor de pérdida durante el entrenamiento
def plot_loss(history):
    plt.figure(figsize=(8, 5))
    plt.plot(history.history['loss'], label='Pérdida en
Entrenamiento', marker='o')
    plt.plot(history.history['val_loss'], label='Pérdida en
Validación', marker='o')
    plt.title('□ Evolución del Valor de Pérdida')
    plt.xlabel('Épocas')
    plt.ylabel('Loss')
    plt.legend()
    plt.grid(True)
    plt.tight_layout()
    plt.show()
```

```
# Llamamos a la función para visualizar el gráfico
plot_loss(history_cnn_new)

/tmp/ipython-input-38-1574992072.py:11: UserWarning: Glyph 128201 (\
N{CHART WITH DOWNWARDS TREND}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151
: UserWarning: Glyph 128201 (\N{CHART WITH DOWNWARDS TREND}) missing
from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



Guardar modelo final

```
# Guardar el modelo entrenado
model.save('/content/drive/MyDrive/Modelo
CNN/modelo/fashion_mnist_cnn_model.h5')

print("Modelo guardado exitosamente.")

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

Modelo guardado exitosamente.
```

Codigo para carga modelo guardado (Solo referencial)

```
from tensorflow.keras.models import load_model

# Cargar el modelo previamente guardado
loaded_model = load_model('/content/drive/MyDrive/Modelo
CNN/modelo/fashion_mnist_cnn_model.h5')

print("Modelo cargado exitosamente.")
```

Fase 14: Evaluación con imagenes reales por usuario

Implementación Gradio

```
pip install gradio
```

```
Requirement already satisfied: gradio in
/usr/local/lib/python3.11/dist-packages (5.31.0)
Requirement already satisfied: aiofiles<25.0,>=22.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (24.1.0)
Requirement already satisfied: anyio<5.0,>=3.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (4.9.0)
Requirement already satisfied: fastapi<1.0,>=0.115.2 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.116.0)
Requirement already satisfied: ffmpy in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.6.0)
Requirement already satisfied: gradio-client==1.10.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (1.10.1)
Requirement already satisfied: groovy~=0.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.1.2)
Requirement already satisfied: httpx>=0.24.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.28.1)
Requirement already satisfied: huggingface-hub>=0.28.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.33.2)
Requirement already satisfied: jinja2<4.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.1.6)
Requirement already satisfied: markupsafe<4.0,>=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.0.2)
Requirement already satisfied: numpy<3.0,>=1.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.0.2)
Requirement already satisfied: orjson~=3.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.10.18)
Requirement already satisfied: packaging in
/usr/local/lib/python3.11/dist-packages (from gradio) (24.2)
Requirement already satisfied: pandas<3.0,>=1.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.2.2)
```

```
Requirement already satisfied: pillow<12.0,>=8.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (11.2.1)
Requirement already satisfied: pydantic<2.12,>=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.11.7)
Requirement already satisfied: pydub in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.25.1)
Requirement already satisfied: python-multipart>=0.0.18 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.0.20)
Requirement already satisfied: pyyaml<7.0,>=5.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (6.0.2)
Requirement already satisfied: ruff>=0.9.3 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.12.2)
Requirement already satisfied: safehttpx<0.2.0,>=0.1.6 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.1.6)
Requirement already satisfied: semantic-version~=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.10.0)
Requirement already satisfied: starlette<1.0,>=0.40.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.46.2)
Requirement already satisfied: tomlkit<0.14.0,>=0.12.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.13.3)
Requirement already satisfied: typer<1.0,>=0.12 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.16.0)
Requirement already satisfied: typing-extensions~=4.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (4.14.1)
Requirement already satisfied: uvicorn>=0.14.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.35.0)
Requirement already satisfied: fsspec in
/usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.1-
>gradio) (2025.3.2)
Requirement already satisfied: websockets<16.0,>=10.0 in
/usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.1-
>gradio) (15.0.1)
Requirement already satisfied: idna>=2.8 in
/usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio)
(3.10)
Requirement already satisfied: sniffio>=1.1 in
/usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio)
(1.3.1)
Requirement already satisfied: certifi in
/usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio)
(2025.7.9)
Requirement already satisfied: httpcore==1.* in
/usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio)
(1.0.9)
Requirement already satisfied: h11>=0.16 in
/usr/local/lib/python3.11/dist-packages (from httpcore==1.*-
>httpx>=0.24.1->gradio) (0.16.0)
Requirement already satisfied: filelock in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (3.18.0)
Requirement already satisfied: requests in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (2.32.3)
Requirement already satisfied: tqdm>=4.42.1 in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (4.67.1)
Requirement already satisfied: hf-xet<2.0.0,>=1.1.2 in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (1.1.5)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2025.2)
Requirement already satisfied: annotated-types>=0.6.0 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.2 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (2.33.2)
Requirement already satisfied: typing-inspection>=0.4.0 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (0.4.1)
Requirement already satisfied: click>=8.0.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (8.2.1)
Requirement already satisfied: shellingham>=1.3.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (1.5.4)
Requirement already satisfied: rich>=10.11.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (13.9.4)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.8.2-
>pandas<3.0,>=1.0->gradio) (1.17.0)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.11/dist-packages (from rich>=10.11.0-
>typer<1.0,>=0.12->gradio) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/usr/local/lib/python3.11/dist-packages (from rich>=10.11.0-
>typer<1.0,>=0.12->gradio) (2.19.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.11/dist-packages (from requests->huggingface-
hub>=0.28.1->gradio) (3.4.2)
```

```
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests->huggingface-
hub>=0.28.1->gradio) (2.4.0)
Requirement already satisfied: mdurl~=0.1 in
/usr/local/lib/python3.11/dist-packages (from markdown-it-py>=2.2.0-
>rich>=10.11.0->typer<1.0,>=0.12->gradio) (0.1.2)
```

```python
import gradio as gr
import numpy as np
from tensorflow.keras.models import load_model
from PIL import Image

# Cargar el modelo guardado
model = load_model('/content/drive/MyDrive/Modelo
CNN/modelo/fashion_mnist_cnn_model.h5')

# Función para preprocesar la imagen y hacer la predicción
def predict_image(img):
    try:
        # Verificar si la entrada es None
        if img is None:
            return "Error: No se ha proporcionado ninguna imagen"

        # Convertir a PIL Image si es necesario
        if isinstance(img, np.ndarray):
            # Si es un array numpy, convertirlo a PIL Image
            img = Image.fromarray(img.astype('uint8'))

        # Convertir a escala de grises
        if img.mode != 'L':
            img = img.convert('L')

        # Redimensionar a 28x28 píxeles
        img = img.resize((28, 28), Image.Resampling.LANCZOS)

        # Convertir a array numpy
        img_array = np.array(img)

        # Verificar el tamaño del array
        print(f"Tamaño de la imagen procesada: {img_array.shape}")

        # Normalizar la imagen a escala [0, 1]
        img_array = img_array.astype('float32') / 255.0

        # Añadir dimensiones para el modelo: (1, 28, 28, 1)
        img_array = np.expand_dims(img_array, axis=-1)  # (28, 28, 1)
        img_array = np.expand_dims(img_array, axis=0)   # (1, 28, 28,
1)

        # Verificar que la forma del array es la correcta
        print(f"Forma del array para el modelo: {img_array.shape}")

        # Realizar la predicción
        prediction = model.predict(img_array, verbose=0)

        # Obtener la clase con la mayor probabilidad
        predicted_class = np.argmax(prediction)
        confidence = np.max(prediction)

        # Etiquetas de las clases
        labels = ['T-shirt/top', 'Trouser', 'Pullover', 'Dress',
'Coat',
                 'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot']

        # Retornar el resultado con confianza
        return f"Predicción: {labels[predicted_class]} (Confianza:
{confidence:.2%})"

    except Exception as e:
        return f"Error al procesar la imagen: {str(e)}"

# Crear la interfaz con Gradio
interface = gr.Interface(
    fn=predict_image,
    inputs=gr.Image(type="pil"),  # Usar type="pil" para recibir PIL
Image
    outputs=gr.Text(),
    title="Clasificador Fashion-MNIST CNN",
    description="Sube una imagen de una prenda de vestir y el modelo
predecirá qué tipo de prenda es.",
    examples=None  # Puedes agregar ejemplos aquí si tienes imágenes
de prueba
)

# Lanzar la interfaz
if __name__ == "__main__":
    interface.launch(debug=True)
```

Fase 15: Fusionar Modelos

Cargar los modelos ya entrenados

```
from google.colab import drive
from tensorflow.keras.models import load_model
import os

drive.mount('/content/drive')
```

```
def check_model_loaded(model, model_name):
    try:
        model.summary()
        print(f"{model_name} □")
    except Exception as e:
        print(f"{model_name} □ - Error: {str(e)}")

cnn_model_path = '/content/drive/My Drive/fashion_mnist_cnn_model.h5'
transformer_model_path = '/content/drive/My Drive/best_model.h5'

if os.path.exists(cnn_model_path):
    try:
        cnn_model = load_model(cnn_model_path)
        check_model_loaded(cnn_model, "CNN Model")
    except Exception as e:
        print(f"CNN Model □ - Error al cargar el modelo: {str(e)}")
else:
    print(f"CNN Model □ - No se encontró el archivo en
{cnn_model_path}")

if os.path.exists(transformer_model_path):
    try:
        transformer_model = load_model(transformer_model_path)
        check_model_loaded(transformer_model, "Transformer Model")
    except Exception as e:
        print(f"Transformer Model □ - Error al cargar el modelo:
{str(e)}")
else:
    print(f"Transformer Model □ - No se encontró el archivo en
{transformer_model_path}")
```

```
Drive already mounted at /content/drive; to attempt to forcibly
remount, call drive.mount("/content/drive", force_remount=True).

WARNING:absl:Compiled the loaded model, but the compiled metrics have
yet to be built. `model.compile_metrics` will be empty until you train
or evaluate the model.

Model: "sequential_3"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape            ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ conv2d_9 (Conv2D)                │ (None, 26, 26, 32)      │
320 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
```

```
│ batch_normalization_6           │ (None, 26, 26, 32)     │
128 │
│ (BatchNormalization)            │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_9 (MaxPooling2D)  │ (None, 13, 13, 32)     │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ conv2d_10 (Conv2D)              │ (None, 11, 11, 64)     │
18,496 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ batch_normalization_7           │ (None, 11, 11, 64)     │
256 │
│ (BatchNormalization)            │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_10 (MaxPooling2D) │ (None, 5, 5, 64)       │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ conv2d_11 (Conv2D)              │ (None, 3, 3, 128)      │
73,856 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ batch_normalization_8           │ (None, 3, 3, 128)      │
512 │
│ (BatchNormalization)            │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_11 (MaxPooling2D) │ (None, 1, 1, 128)      │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ flatten_3 (Flatten)             │ (None, 128)            │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense_6 (Dense)                 │ (None, 128)            │
16,512 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dropout_3 (Dropout)             │ (None, 128)            │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
```

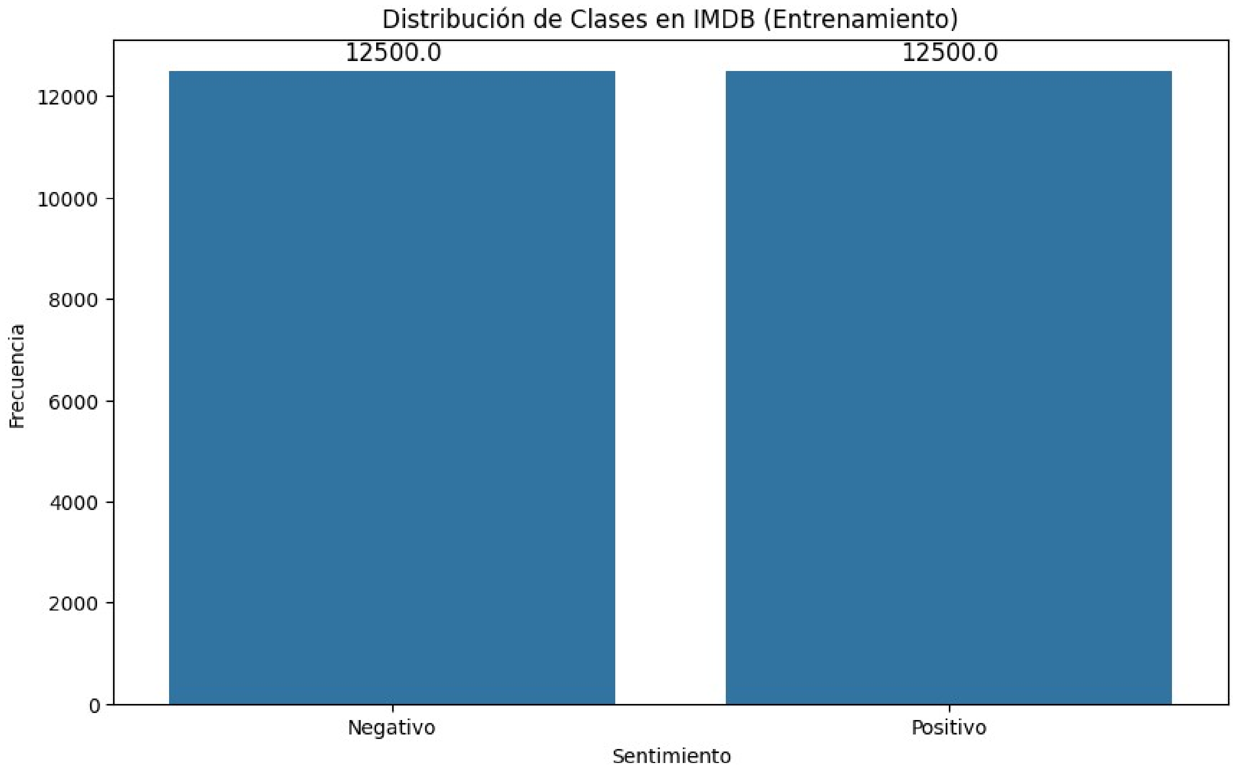
```
─────┤
│ dense_7 (Dense)                 │ (None, 10)             │
1,290 │
└─────────────────────────────────┴────────────────────────┴──────────
─────┘

 Total params: 111,372 (435.05 KB)

 Trainable params: 110,922 (433.29 KB)

 Non-trainable params: 448 (1.75 KB)

 Optimizer params: 2 (12.00 B)

CNN Model □

WARNING:absl:Compiled the loaded model, but the compiled metrics have
yet to be built. `model.compile_metrics` will be empty until you train
or evaluate the model.

Model: "sequential"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ conv2d (Conv2D)                 │ (None, 26, 26, 32)     │
320 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d (MaxPooling2D)    │ (None, 13, 13, 32)     │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ conv2d_1 (Conv2D)               │ (None, 11, 11, 64)     │
18,496 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_1 (MaxPooling2D)  │ (None, 5, 5, 64)       │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ conv2d_2 (Conv2D)               │ (None, 3, 3, 128)      │
73,856 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ max_pooling2d_2 (MaxPooling2D)  │ (None, 1, 1, 128)      │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
```

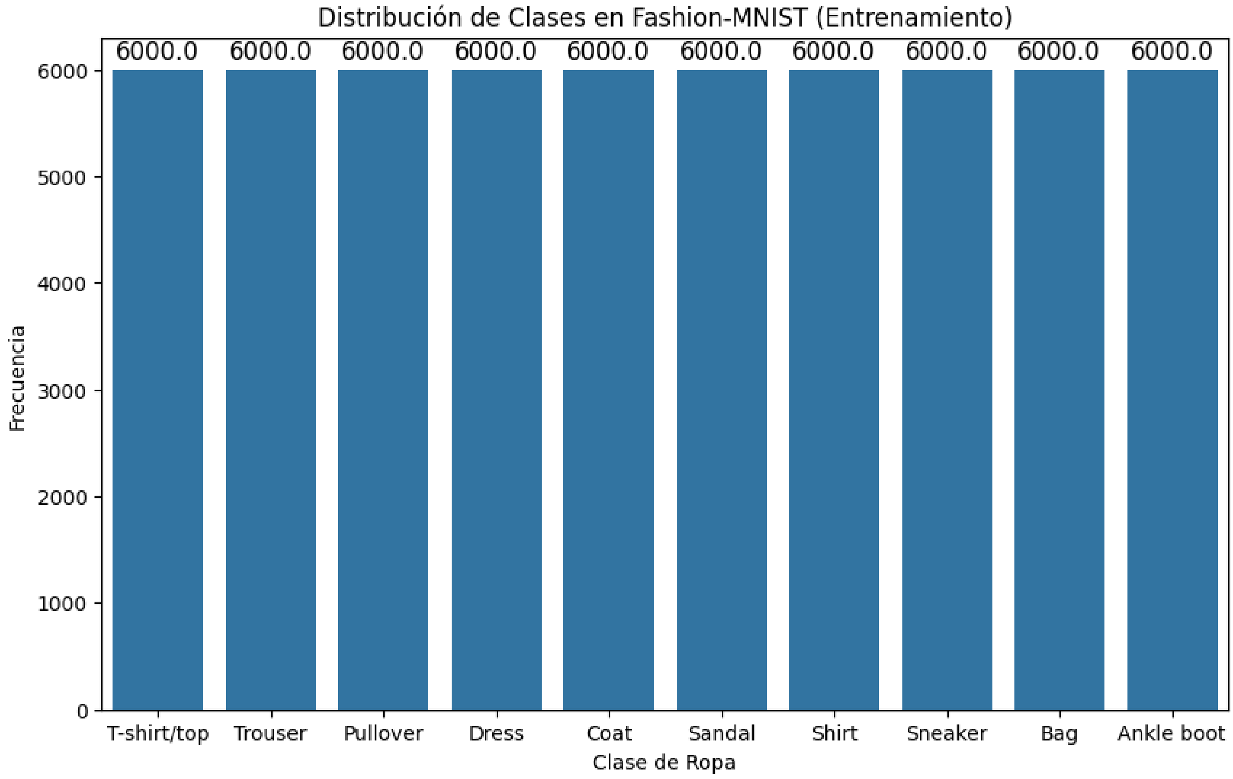
```
──────┤
│ flatten (Flatten)                  │ (None, 128)              │
0 │
├────────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dense (Dense)                      │ (None, 128)              │
16,512 │
├────────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dropout (Dropout)                  │ (None, 128)              │
0 │
├────────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dense_1 (Dense)                    │ (None, 10)               │
1,290 │
└────────────────────────────────────┴──────────────────────────┴──────────
──────┘

 Total params: 110,476 (431.55 KB)

 Trainable params: 110,474 (431.54 KB)

 Non-trainable params: 0 (0.00 B)

 Optimizer params: 2 (12.00 B)

Transformer Model □
```

Visualizar la Distribución de Clases

```python
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from tensorflow.keras.datasets import imdb, fashion_mnist

# Reload the datasets to get original labels
(X_train_imdb, y_train_imdb), (X_test_imdb, y_test_imdb) =
imdb.load_data(num_words=10000)
(X_train_fashion, y_train_fashion), (X_test_fashion, y_test_fashion) =
fashion_mnist.load_data()

# Visualización del desbalance de clases en IMDB
plt.figure(figsize=(10, 6))

# Contar las clases de IMDB
ax = sns.countplot(x=y_train_imdb)  # y_train_imdb are the original
IMDB labels (0 or 1)
plt.title("Distribución de Clases en IMDB (Entrenamiento)")
plt.xlabel("Sentimiento")
plt.ylabel("Frecuencia")
plt.xticks([0, 1], ['Negativo', 'Positivo'])

# Añadir los valores encima de las barras
for p in ax.patches:
    ax.annotate(f'{p.get_height()}',
                (p.get_x() + p.get_width() / 2., p.get_height()),
                ha='center', va='center',
                fontsize=12, color='black',
                xytext=(0, 9), textcoords='offset points')

plt.show()

# Visualización del desbalance de clases en Fashion-MNIST
plt.figure(figsize=(10, 6))

# Contar las clases de Fashion-MNIST (etiquetas de 0 a 9)
ax = sns.countplot(x=y_train_fashion)  # y_train_fashion are the
original Fashion-MNIST labels
plt.title("Distribución de Clases en Fashion-MNIST (Entrenamiento)")
plt.xlabel("Clase de Ropa")
plt.ylabel("Frecuencia")
plt.xticks(np.arange(10), ['T-shirt/top', 'Trouser', 'Pullover',
'Dress', 'Coat', 'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot'])

# Añadir los valores encima de las barras
for p in ax.patches:
    ax.annotate(f'{p.get_height()}',
                (p.get_x() + p.get_width() / 2., p.get_height()),
                ha='center', va='center',
                fontsize=12, color='black',
                xytext=(0, 9), textcoords='offset points')

plt.show()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/imdb.npz
17464789/17464789 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/train-labels-idx1-ubyte.gz
29515/29515 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/train-images-idx3-ubyte.gz
26421880/26421880 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/t10k-labels-idx1-ubyte.gz
5148/5148 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/t10k-images-idx3-ubyte.gz
4422102/4422102 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```





Reducción de la Arquitectura del Modelo y Fusión

```
from tensorflow.keras.layers import Input, Concatenate, Dense,
Flatten, Dropout, BatchNormalization, MaxPooling2D, Conv2D
from tensorflow.keras.layers import GlobalAveragePooling1D,
MultiHeadAttention, LayerNormalization, Embedding
from tensorflow.keras.models import Model

# Parámetros
MAX_LEN = 250
EMBED_DIM = 128
NUM_HEADS = 4
FF_DIM = 128
NUM_ENCODER_BLOCKS = 2
NUM_DECODER_BLOCKS = 2
DROPOUT_RATE = 0.3  # Aumentamos el dropout para evitar sobreajuste
VOCAB_SIZE = 10000
NUM_CLASSES_CNN = 10  # Número de clases en Fashion-MNIST

# Definir las entradas
image_input = Input(shape=(28, 28, 1), name="image_input")  #
Dimensiones de las imágenes
text_input = Input(shape=(MAX_LEN,), name="text_input")  # Longitud de
las secuencias de texto

# --- CNN (Imágenes de Fashion-MNIST) ---
cnn_x = Conv2D(32, (3, 3), activation='relu')(image_input)
cnn_x = BatchNormalization()(cnn_x)
cnn_x = MaxPooling2D((2, 2))(cnn_x)

cnn_x = Conv2D(64, (3, 3), activation='relu')(cnn_x)
cnn_x = BatchNormalization()(cnn_x)
cnn_x = MaxPooling2D((2, 2))(cnn_x)

cnn_x = Conv2D(128, (3, 3), activation='relu')(cnn_x)
cnn_x = BatchNormalization()(cnn_x)
cnn_x = MaxPooling2D((2, 2))(cnn_x)

cnn_x = Flatten()(cnn_x)
cnn_x = Dense(128, activation='relu')(cnn_x)
cnn_output_features = Dropout(DROPOUT_RATE)(cnn_x)  # Dropout para
regularizar

# --- Transformer (Texto IMDB) ---
embedding_layer = Embedding(input_dim=VOCAB_SIZE,
output_dim=EMBED_DIM, input_length=MAX_LEN, mask_zero=True)
x_enc = embedding_layer(text_input)
x_dec = embedding_layer(text_input)  # Decoder input es también la
secuencia de texto

def transformer_encoder(inputs):
    attention = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(inputs, inputs)
    attention = Dropout(DROPOUT_RATE)(attention)
    out1 = LayerNormalization(epsilon=1e-6)(inputs + attention)
    ff = Dense(FF_DIM, activation="relu")(out1)
    ff = Dense(EMBED_DIM)(ff)
    ff = Dropout(DROPOUT_RATE)(ff)
    return LayerNormalization(epsilon=1e-6)(out1 + ff)

def transformer_decoder(inputs, encoder_output):
    attention1 = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(inputs, inputs)
    attention1 = Dropout(DROPOUT_RATE)(attention1)
    out1 = LayerNormalization(epsilon=1e-6)(inputs + attention1)
    attention2 = MultiHeadAttention(num_heads=NUM_HEADS,
key_dim=EMBED_DIM)(out1, encoder_output)
    attention2 = Dropout(DROPOUT_RATE)(attention2)
    out2 = LayerNormalization(epsilon=1e-6)(out1 + attention2)
    ff = Dense(FF_DIM, activation="relu")(out2)
    ff = Dense(EMBED_DIM)(ff)
    ff = Dropout(DROPOUT_RATE)(ff)
    return LayerNormalization(epsilon=1e-6)(out2 + ff)

# Apply encoder and decoder blocks
x_enc_rebuilt = x_enc
for _ in range(NUM_ENCODER_BLOCKS):
    x_enc_rebuilt = transformer_encoder(x_enc_rebuilt)

x_dec_rebuilt = x_dec
for _ in range(NUM_DECODER_BLOCKS):
    x_dec_rebuilt = transformer_decoder(x_dec_rebuilt, x_enc_rebuilt)

transformer_output_features = GlobalAveragePooling1D()(x_dec_rebuilt)
transformer_output_features = Dropout(DROPOUT_RATE)
(transformer_output_features)

# --- Fusión de los Modelos ---
merged = Concatenate()([cnn_output_features,
transformer_output_features])

# --- Capa Final de Clasificación ---
final_output = Dense(1, activation='sigmoid', name="final_output")
(merged)

# --- Crear el modelo fusionado ---
final_model = Model(inputs=[image_input, text_input],
outputs=final_output)

# --- Compilar el modelo final ---
final_model.compile(optimizer='adam', loss='binary_crossentropy',
metrics=['accuracy'])
```

```python
# --- Resumen del modelo fusionado ---
final_model.summary()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/
embedding.py:90: UserWarning: Argument `input_length` is deprecated.
Just remove it.
  warnings.warn(

Model: "functional_23"

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━━━━━┓
┃ Layer (type)         ┃ Output Shape       ┃     Param # ┃ Connected to
┃
┡━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━
━━━━━┩
│ text_input           │ (None, 250)        │           0 │ -
│
│ (InputLayer)         │                    │             │
│
├──────────────────────┼────────────────────┼─────────────┼───────────────
─────┤
│ embedding            │ (None, 250, 128)   │   1,280,000 │ text_input[0]
[0], │
│ (Embedding)          │                    │             │ text_input[0]
[0]  │
├──────────────────────┼────────────────────┼─────────────┼───────────────
─────┤
│ not_equal            │ (None, 250)        │           0 │ text_input[0]
[0]  │
│ (NotEqual)           │                    │             │
│
├──────────────────────┼────────────────────┼─────────────┼───────────────
─────┤
│ multi_head_attenti…  │ (None, 250, 128)   │     263,808 │ embedding[0]
[0],  │
│ (MultiHeadAttentio…  │                    │             │ embedding[0]
[0],  │
│                      │                    │             │ not_equal[0]
[0],  │
│                      │                    │             │ not_equal[0]
[0]   │
├──────────────────────┼────────────────────┼─────────────┼───────────────
─────┤
│ dropout_2 (Dropout)  │ (None, 250, 128)   │           0 │
multi_head_atten… │
├──────────────────────┼────────────────────┼─────────────┼───────────────
─────┤
│ add (Add)            │ (None, 250, 128)   │           0 │ embedding[0]
```

```
[0],  │
│                     │                    │            │ dropout_2[0]
[0]   │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ layer_normalization │ (None, 250, 128)   │        256 │ add[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dense_1 (Dense)     │ (None, 250, 128)   │     16,512 │
layer_normalizat… │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dense_2 (Dense)     │ (None, 250, 128)   │     16,512 │ dense_1[0][0]
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dropout_3 (Dropout) │ (None, 250, 128)   │          0 │ dense_2[0][0]
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ add_1 (Add)         │ (None, 250, 128)   │          0 │
layer_normalizat… │
│                     │                    │            │ dropout_3[0]
[0]   │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_1[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ multi_head_attenti… │ (None, 250, 128)   │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                    │            │
layer_normalizat… │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dropout_5 (Dropout) │ (None, 250, 128)   │          0 │
multi_head_atten… │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ add_2 (Add)         │ (None, 250, 128)   │          0 │
layer_normalizat… │
│                     │                    │            │ dropout_5[0]
[0]   │
```

```
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_2[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ not_equal_1         │ (None, 250)       │          0 │ text_input[0]
[0]  │
│ (NotEqual)          │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ dense_3 (Dense)     │ (None, 250, 128)  │     16,512 │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │ embedding[1]
[0],  │
│ (MultiHeadAttentio… │                   │            │ embedding[1]
[0],  │
│                     │                   │            │
not_equal_1[0][0… │
│                     │                   │            │
not_equal_1[0][0] │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ dense_4 (Dense)     │ (None, 250, 128)  │     16,512 │ dense_3[0][0]
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ dropout_8 (Dropout) │ (None, 250, 128)  │          0 │
multi_head_atten… │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ dropout_6 (Dropout) │ (None, 250, 128)  │          0 │ dense_4[0][0]
│
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ add_4 (Add)         │ (None, 250, 128)  │          0 │ embedding[1]
[0],  │
│                     │                   │            │ dropout_8[0]
[0]   │
├─────────────────────┼───────────────────┼────────────┼───────────────
─────┤
│ add_3 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_6[0]
```

```
[0]      │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_4[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_3[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ multi_head_attenti… │ (None, 250, 128)   │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                    │            │
layer_normalizat… │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dropout_10          │ (None, 250, 128)   │          0 │
multi_head_atten… │
│ (Dropout)           │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ add_5 (Add)         │ (None, 250, 128)   │          0 │
layer_normalizat… │
│                     │                    │            │ dropout_10[0]
[0]    │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ layer_normalizatio… │ (None, 250, 128)   │        256 │ add_5[0][0]
│
│ (LayerNormalizatio… │                    │            │
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dense_5 (Dense)     │ (None, 250, 128)   │     16,512 │
layer_normalizat… │
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dense_6 (Dense)     │ (None, 250, 128)   │     16,512 │ dense_5[0][0]
│
├─────────────────────┼────────────────────┼────────────┼──────────────
──────┤
│ dropout_11          │ (None, 250, 128)   │          0 │ dense_6[0][0]
│
```

```
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_6 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_11[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_6[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                   │            │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_13          │ (None, 250, 128)  │          0 │
multi_head_atten… │
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ image_input         │ (None, 28, 28, 1) │          0 │ -
│
│ (InputLayer)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_7 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_13[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2d (Conv2D)     │ (None, 26, 26,    │        320 │
image_input[0][0] │
│                     │ 32)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_7[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ batch_normalization │ (None, 26, 26,    │        128 │ conv2d[0][0]
│
│ (BatchNormalizatio… │ 32)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ multi_head_attenti… │ (None, 250, 128)  │    263,808 │
layer_normalizat… │
│ (MultiHeadAttentio… │                   │            │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ max_pooling2d       │ (None, 13, 13,    │          0 │
batch_normalizat… │
│ (MaxPooling2D)      │ 32)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_15          │ (None, 250, 128)  │          0 │
multi_head_atten… │
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2d_1 (Conv2D)   │ (None, 11, 11,    │     18,496 │
max_pooling2d[0]… │
│                     │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_8 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_15[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ batch_normalizatio… │ (None, 11, 11,    │        256 │ conv2d_1[0]
[0]    │
│ (BatchNormalizatio… │ 64)               │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_8[0][0]
│
│ (LayerNormalizatio… │                   │            │
│
```

```
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ max_pooling2d_1     │ (None, 5, 5, 64)  │          0 │
batch_normalizat… │
│ (MaxPooling2D)      │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dense_7 (Dense)     │ (None, 250, 128)  │     16,512 │
layer_normalizat… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ conv2d_2 (Conv2D)   │ (None, 3, 3, 128) │     73,856 │
max_pooling2d_1[… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dense_8 (Dense)     │ (None, 250, 128)  │     16,512 │ dense_7[0][0]
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ batch_normalizatio… │ (None, 3, 3, 128) │        512 │ conv2d_2[0]
[0]    │
│ (BatchNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ dropout_16          │ (None, 250, 128)  │          0 │ dense_8[0][0]
│
│ (Dropout)           │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ max_pooling2d_2     │ (None, 1, 1, 128) │          0 │
batch_normalizat… │
│ (MaxPooling2D)      │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ add_9 (Add)         │ (None, 250, 128)  │          0 │
layer_normalizat… │
│                     │                   │            │ dropout_16[0]
[0]  │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ flatten (Flatten)   │ (None, 128)       │          0 │
max_pooling2d_2[… │
├─────────────────────┼───────────────────┼────────────┼──────────────
─────┤
│ layer_normalizatio… │ (None, 250, 128)  │        256 │ add_9[0][0]
```

```
│
│ (LayerNormalizatio… │                     │             │
│
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ dense (Dense)        │ (None, 128)        │      16,512 │ flatten[0][0]
│
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ global_average_poo… │ (None, 128)        │           0 │
layer_normalizat… │
│ (GlobalAveragePool… │                    │             │
│
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ dropout (Dropout)    │ (None, 128)        │           0 │ dense[0][0]
│
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ dropout_17           │ (None, 128)        │           0 │
global_average_p… │
│ (Dropout)            │                    │             │
│
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ concatenate          │ (None, 256)        │           0 │ dropout[0]
[0],     │
│ (Concatenate)        │                    │             │ dropout_17[0]
[0]  │
├──────────────────────┼────────────────────┼─────────────┼──────────────
─────┤
│ final_output         │ (None, 1)          │         257 │
concatenate[0][0] │
│ (Dense)              │                    │             │
│
└──────────────────────┴────────────────────┴─────────────┴──────────────
─────┘

 Total params: 3,107,841 (11.86 MB)

 Trainable params: 3,107,393 (11.85 MB)

 Non-trainable params: 448 (1.75 KB)
```

Fase 16: Entrenamiento del Modelo

```
import tensorflow as tf
from tensorflow.keras import layers, Model
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten,
Dense, Embedding, MultiHeadAttention
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.datasets import fashion_mnist, imdb
from tensorflow.keras.utils import to_categorical
import os

# Cargar Fashion-MNIST (imágenes) y IMDB (texto)
(X_train_img, y_train_img), (X_test_img, y_test_img) =
fashion_mnist.load_data()
(X_train_text, y_train_text), (X_test_text, y_test_text) =
imdb.load_data(num_words=10000)

# Ensure both datasets have the same number of samples for training
and testing
# Reduce training data to 25000 samples
X_train_img = X_train_img[:25000]
y_train_img = y_train_img[:25000]
X_train_text = X_train_text[:25000]
y_train_text = y_train_text[:25000]

# Reduce test data to 10000 samples (matching the original Fashion-
MNIST test set size)
X_test_img = X_test_img[:10000]
y_test_img = y_test_img[:10000]
X_test_text = X_test_text[:10000]
y_test_text = y_test_text[:10000]


# Verificación del tamaño de los datos
print(f'X_train_img shape: {X_train_img.shape}')
print(f'X_train_text shape: {len(X_train_text)}')
print(f'y_train_img shape: {y_train_img.shape}')
print(f'y_train_text shape: {len(y_train_text)}')
print(f'X_test_img shape: {X_test_img.shape}')
print(f'X_test_text shape: {len(X_test_text)}')
print(f'y_test_img shape: {y_test_img.shape}')
print(f'y_test_text shape: {len(y_test_text)}')


# Normalización de imágenes
X_train_img = X_train_img.astype('float32') / 255.0
X_test_img = X_test_img.astype('float32') / 255.0
X_train_img = X_train_img.reshape(-1, 28, 28, 1)
X_test_img = X_test_img.reshape(-1, 28, 28, 1)

# Preprocesamiento de texto (pad_sequences)
```

```
MAX_LEN = 250
X_train_text = pad_sequences(X_train_text, maxlen=MAX_LEN,
padding='post', truncating='post')
X_test_text = pad_sequences(X_test_text, maxlen=MAX_LEN,
padding='post', truncating='post')

# Convertir etiquetas de imagen a formato one-hot
y_train_img = to_categorical(y_train_img, 10)
y_test_img = to_categorical(y_test_img, 10)

# Convertir etiquetas de texto a formato one-hot
y_train_text = to_categorical(y_train_text, 2)  # IMDB tiene 2 clases:
positiva o negativa
y_test_text = to_categorical(y_test_text, 2)

# Definir el modelo CNN para imágenes
cnn_input = layers.Input(shape=(28, 28, 1))
x_img = Conv2D(32, (3, 3), activation='relu')(cnn_input)
x_img = MaxPooling2D((2, 2))(x_img)
x_img = Conv2D(64, (3, 3), activation='relu')(x_img)
x_img = MaxPooling2D((2, 2))(x_img)
x_img = Conv2D(128, (3, 3), activation='relu')(x_img)
x_img = MaxPooling2D((2, 2))(x_img)
x_img = Flatten()(x_img)

# Definir el modelo Transformer para texto
text_input = layers.Input(shape=(MAX_LEN,))
embedding_text = Embedding(input_dim=10000, output_dim=128)
(text_input)
attention = MultiHeadAttention(num_heads=4, key_dim=128)
(embedding_text, embedding_text)
x_text = Flatten()(attention)

# Fusionar ambas representaciones (imagen y texto)
merged = layers.concatenate([x_img, x_text])

# Clasificación final
x = Dense(128, activation='relu')(merged)
x = Dense(10, activation='softmax')(x)  # 10 classes for Fashion-MNIST

# Create the final model
fusion_model = Model(inputs=[cnn_input, text_input], outputs=x)

# Compilación del modelo
fusion_model.compile(optimizer=Adam(learning_rate=0.001),
                     loss='categorical_crossentropy',
                     metrics=['accuracy'])

# Rutas para guardar el modelo
checkpoint_dir = '/content/drive/MyDrive/fusion'
```

```
os.makedirs(checkpoint_dir, exist_ok=True)
checkpoint_callback = ModelCheckpoint(os.path.join(checkpoint_dir,
'fusion_model.h5'),
                                      save_best_only=True,
                                      monitor='val_loss',
                                      mode='min',
                                      verbose=1)

early_stopping_callback = EarlyStopping(monitor='val_loss',
patience=3, restore_best_weights=True, verbose=1)

# Entrenamiento del modelo fusionado
history = fusion_model.fit(
    [X_train_img, X_train_text], y_train_img,  # Entrenamiento con
imágenes y texto
    epochs=30, batch_size=64,
    validation_data=([X_test_img, X_test_text], y_test_img),
    callbacks=[checkpoint_callback, early_stopping_callback]
)

# Evaluación
loss, accuracy = fusion_model.evaluate([X_test_img, X_test_text],
y_test_img, verbose=1)
print(f'Final accuracy: {accuracy*100:.2f}%')
```

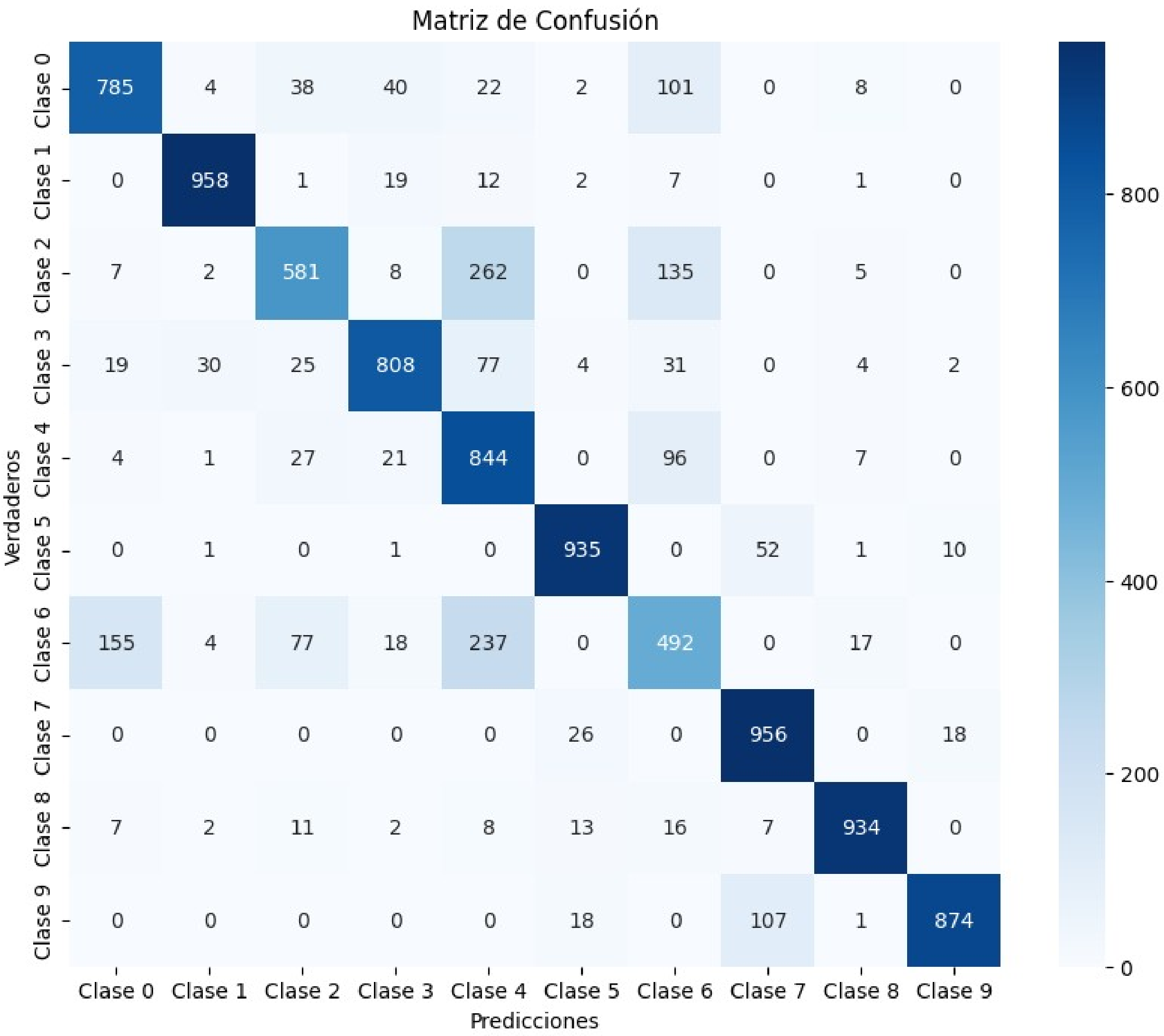
```
X_train_img shape: (25000, 28, 28)
X_train_text shape: 25000
y_train_img shape: (25000,)
y_train_text shape: 25000
X_test_img shape: (10000, 28, 28)
X_test_text shape: 10000
y_test_img shape: (10000,)
y_test_text shape: 10000
Epoch 1/30
391/391 ━━━━━━━━━━━━━━━━━━━━ 0s 31ms/step - accuracy: 0.5237 - loss:
1.2251
Epoch 1: val_loss improved from inf to 0.75170, saving model to
/content/drive/MyDrive/fusion/fusion_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 391/391 ━━━━━━━━━━━━━━━━━━━━ 23s 40ms/step - accuracy: 0.5241 - loss:
1.2242 - val_accuracy: 0.7132 - val_loss: 0.7517
Epoch 2/30
389/391 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step - accuracy: 0.7694 - loss:
0.6062
```

```
Epoch 2: val_loss improved from 0.75170 to 0.53581, saving model to
/content/drive/MyDrive/fusion/fusion_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 391/391 ━━━━━━━━━━━━━━━━━━━━ 11s 27ms/step - accuracy: 0.7695 - loss:
0.6060 - val_accuracy: 0.8032 - val_loss: 0.5358
Epoch 3/30
389/391 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.8143 - loss:
0.5074
Epoch 3: val_loss improved from 0.53581 to 0.50501, saving model to
/content/drive/MyDrive/fusion/fusion_model.h5

WARNING:absl:You are saving your model as an HDF5 file via
`model.save()` or `keras.saving.save_model(model)`. This file format
is considered legacy. We recommend using instead the native Keras
format, e.g. `model.save('my_model.keras')` or
`keras.saving.save_model(model, 'my_model.keras')`.

 391/391 ━━━━━━━━━━━━━━━━━━━━ 22s 31ms/step - accuracy: 0.8144 - loss:
0.5074 - val_accuracy: 0.8167 - val_loss: 0.5050
Epoch 4/30
390/391 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.8355 - loss:
0.4547
Epoch 4: val_loss did not improve from 0.50501
391/391 ━━━━━━━━━━━━━━━━━━━━ 11s 27ms/step - accuracy: 0.8355 - loss:
0.4547 - val_accuracy: 0.8153 - val_loss: 0.5163
Epoch 5/30
389/391 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.8747 - loss:
0.3508
Epoch 5: val_loss did not improve from 0.50501
391/391 ━━━━━━━━━━━━━━━━━━━━ 22s 31ms/step - accuracy: 0.8747 - loss:
0.3509 - val_accuracy: 0.7975 - val_loss: 0.5912
Epoch 6/30
389/391 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.9233 - loss:
0.2234
Epoch 6: val_loss did not improve from 0.50501
391/391 ━━━━━━━━━━━━━━━━━━━━ 12s 30ms/step - accuracy: 0.9232 - loss:
0.2235 - val_accuracy: 0.8005 - val_loss: 0.7052
Epoch 6: early stopping
Restoring model weights from the end of the best epoch: 3.
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 5ms/step - accuracy: 0.8152 - loss:
0.5099
Final accuracy: 81.67%
```

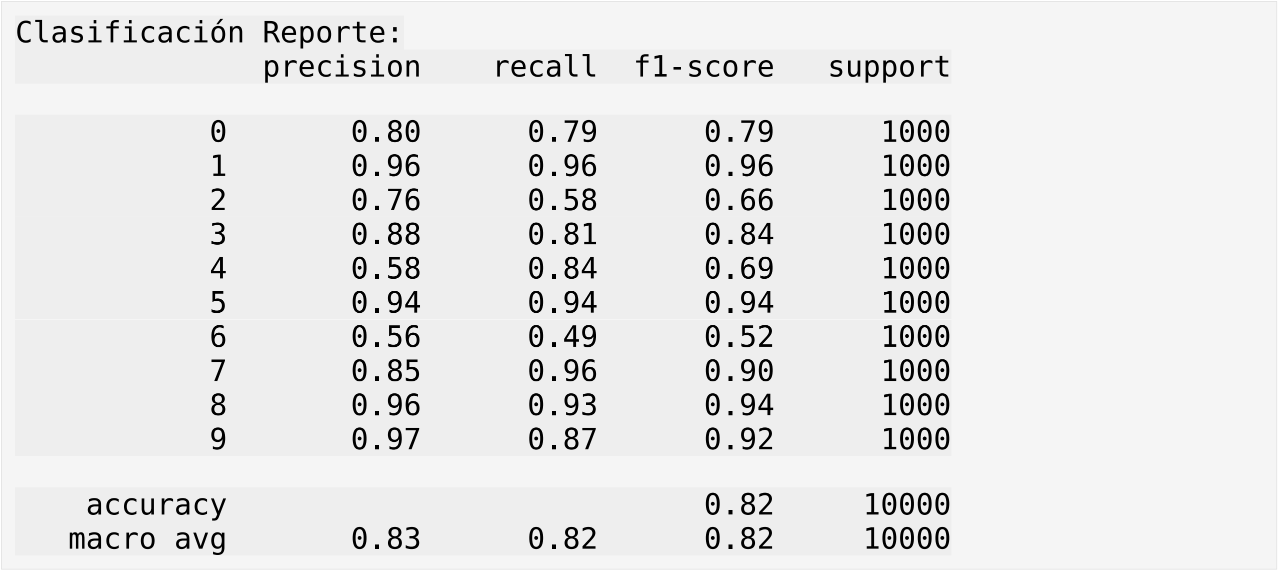
Fase 17: Evaluación del Modelo y Matriz de Confusión

```
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix, classification_report,
roc_curve, auc
import numpy as np

# Predicciones sobre el conjunto de prueba
y_pred = fusion_model.predict([X_test_img, X_test_text])

# Convertir las predicciones a etiquetas (la predicción más probable)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true_classes = np.argmax(y_test_img, axis=1)

# 1. Matriz de Confusión
cm = confusion_matrix(y_true_classes, y_pred_classes)

plt.figure(figsize=(10, 8))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
xticklabels=[f'Clase {i}' for i in range(10)], yticklabels=[f'Clase
{i}' for i in range(10)])
plt.title('Matriz de Confusión')
plt.xlabel('Predicciones')
plt.ylabel('Verdaderos')
plt.show()

# 2. Reporte de clasificación (precisión, recall, F1-score)
print("Clasificación Reporte:")
print(classification_report(y_true_classes, y_pred_classes))
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 6ms/step
```



	Clase 0	Clase 1	Clase 2	Clase 3	Clase 4	Clase 5	Clase 6	Clase 7	Clase 8	Clase 9
Clase 0	785	4	38	40	22	2	101	0	8	0
Clase 1	0	958	1	19	12	2	7	0	1	0
Clase 2	7	2	581	8	262	0	135	0	5	0
Clase 3	19	30	25	808	77	4	31	0	4	2
Clase 4	4	1	27	21	844	0	96	0	7	0
Clase 5	0	1	0	1	0	935	0	52	1	10
Clase 6	155	4	77	18	237	0	492	0	17	0
Clase 7	0	0	0	0	0	26	0	956	0	18
Clase 8	7	2	11	2	8	13	16	7	934	0
Clase 9	0	0	0	0	0	18	0	107	1	874



```
Clasificación Reporte:
              precision    recall  f1-score   support

           0       0.80      0.79      0.79      1000
           1       0.96      0.96      0.96      1000
           2       0.76      0.58      0.66      1000
           3       0.88      0.81      0.84      1000
           4       0.58      0.84      0.69      1000
           5       0.94      0.94      0.94      1000
           6       0.56      0.49      0.52      1000
           7       0.85      0.96      0.90      1000
           8       0.96      0.93      0.94      1000
           9       0.97      0.87      0.92      1000

    accuracy                           0.82     10000
   macro avg       0.83      0.82      0.82     10000
```

```
weighted avg       0.83      0.82      0.82     10000
```

Fase 18: Gradio para el modelo de análisis de sentimiento (Transformer)

```
pip install gradio
```

```
Requirement already satisfied: gradio in
/usr/local/lib/python3.11/dist-packages (5.31.0)
Requirement already satisfied: aiofiles<25.0,>=22.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (24.1.0)
Requirement already satisfied: anyio<5.0,>=3.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (4.9.0)
Requirement already satisfied: fastapi<1.0,>=0.115.2 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.116.0)
Requirement already satisfied: ffmpy in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.6.0)
Requirement already satisfied: gradio-client==1.10.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (1.10.1)
Requirement already satisfied: groovy~=0.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.1.2)
Requirement already satisfied: httpx>=0.24.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.28.1)
Requirement already satisfied: huggingface-hub>=0.28.1 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.33.2)
Requirement already satisfied: jinja2<4.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.1.6)
Requirement already satisfied: markupsafe<4.0,>=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.0.2)
Requirement already satisfied: numpy<3.0,>=1.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.0.2)
Requirement already satisfied: orjson~=3.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (3.10.18)
Requirement already satisfied: packaging in
/usr/local/lib/python3.11/dist-packages (from gradio) (24.2)
Requirement already satisfied: pandas<3.0,>=1.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.2.2)
Requirement already satisfied: pillow<12.0,>=8.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (11.2.1)
Requirement already satisfied: pydantic<2.12,>=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.11.7)
Requirement already satisfied: pydub in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.25.1)
Requirement already satisfied: python-multipart>=0.0.18 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.0.20)
Requirement already satisfied: pyyaml<7.0,>=5.0 in
```

```
/usr/local/lib/python3.11/dist-packages (from gradio) (6.0.2)
Requirement already satisfied: ruff>=0.9.3 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.12.2)
Requirement already satisfied: safehttpx<0.2.0,>=0.1.6 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.1.6)
Requirement already satisfied: semantic-version~=2.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (2.10.0)
Requirement already satisfied: starlette<1.0,>=0.40.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.46.2)
Requirement already satisfied: tomlkit<0.14.0,>=0.12.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.13.3)
Requirement already satisfied: typer<1.0,>=0.12 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.16.0)
Requirement already satisfied: typing-extensions~=4.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (4.14.1)
Requirement already satisfied: uvicorn>=0.14.0 in
/usr/local/lib/python3.11/dist-packages (from gradio) (0.35.0)
Requirement already satisfied: fsspec in
/usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.1-
>gradio) (2025.3.2)
Requirement already satisfied: websockets<16.0,>=10.0 in
/usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.1-
>gradio) (15.0.1)
Requirement already satisfied: idna>=2.8 in
/usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio)
(3.10)
Requirement already satisfied: sniffio>=1.1 in
/usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio)
(1.3.1)
Requirement already satisfied: certifi in
/usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio)
(2025.7.9)
Requirement already satisfied: httpcore==1.* in
/usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio)
(1.0.9)
Requirement already satisfied: h11>=0.16 in
/usr/local/lib/python3.11/dist-packages (from httpcore==1.*-
>httpx>=0.24.1->gradio) (0.16.0)
Requirement already satisfied: filelock in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (3.18.0)
Requirement already satisfied: requests in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (2.32.3)
Requirement already satisfied: tqdm>=4.42.1 in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (4.67.1)
Requirement already satisfied: hf-xet<2.0.0,>=1.1.2 in
/usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1-
>gradio) (1.1.5)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in
/usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0-
>gradio) (2025.2)
Requirement already satisfied: annotated-types>=0.6.0 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.2 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (2.33.2)
Requirement already satisfied: typing-inspection>=0.4.0 in
/usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0-
>gradio) (0.4.1)
Requirement already satisfied: click>=8.0.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (8.2.1)
Requirement already satisfied: shellingham>=1.3.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (1.5.4)
Requirement already satisfied: rich>=10.11.0 in
/usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12-
>gradio) (13.9.4)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.8.2-
>pandas<3.0,>=1.0->gradio) (1.17.0)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.11/dist-packages (from rich>=10.11.0-
>typer<1.0,>=0.12->gradio) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/usr/local/lib/python3.11/dist-packages (from rich>=10.11.0-
>typer<1.0,>=0.12->gradio) (2.19.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.11/dist-packages (from requests->huggingface-
hub>=0.28.1->gradio) (3.4.2)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests->huggingface-
hub>=0.28.1->gradio) (2.4.0)
Requirement already satisfied: mdurl~=0.1 in
/usr/local/lib/python3.11/dist-packages (from markdown-it-py>=2.2.0-
>rich>=10.11.0->typer<1.0,>=0.12->gradio) (0.1.2)
```

```python
import gradio as gr
import numpy as np
from tensorflow.keras.preprocessing import image
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.models import load_model
from tensorflow.keras.preprocessing.text import Tokenizer
import tensorflow as tf

# Cargar el modelo previamente guardado
model = load_model('/content/drive/MyDrive/fusion/fusion_model.h5')

# Inicializar el tokenizador para el texto
tokenizer = Tokenizer(num_words=10000)  # Limitar a las 10,000
palabras más comunes

# Mapear las clases a nombres de categorías (esto se debe ajustar
según tu problema)
class_names = {
    0: "T-shirt/top",
    1: "Trouser",
    2: "Pullover",
    3: "Dress",
    4: "Coat",
    5: "Sandal",
    6: "Shirt",
    7: "Sneaker",
    8: "Bag",
    9: "Ankle boot"
}

# Preprocesar la imagen para la entrada al modelo
def preprocess_image(img):
    img = img.convert("L")  # Convertir la imagen a escala de grises
    img = img.resize((28, 28))  # Redimensionar la imagen a 28x28
    img = np.array(img)
    img = img.astype('float32') / 255.0  # Normalizar
    img = np.expand_dims(img, axis=-1)  # Asegurarse de que tenga la
forma correcta
    return np.expand_dims(img, axis=0)  # Añadir la dimensión de batch

# Preprocesar el texto
def preprocess_text(text):
    MAX_LEN = 250
    # Ajustamos el tokenizador al texto de entrada
    tokenizer.fit_on_texts([text])  # Entrenar el tokenizador solo con
el texto ingresado
    text_seq = tokenizer.texts_to_sequences([text])  # Convertir el
texto en secuencia de enteros
    text_seq = pad_sequences(text_seq, maxlen=MAX_LEN, padding='post',
truncating='post')
    return text_seq

# Función para la predicción
```

```python
def predict(image, text):
    try:
        # Preprocesar imagen y texto
        processed_image = preprocess_image(image)
        processed_text = preprocess_text(text)

        # Hacer la predicción
        predictions = model.predict([processed_image, processed_text])

        # Devolver la clase predicha y su probabilidad
        predicted_class = np.argmax(predictions, axis=1)  # Clase con
la mayor probabilidad
        predicted_prob = np.max(predictions)  # Probabilidad de la
clase predicha

        # Determinar el nombre de la categoría a partir de la clase
predicha
        category_name = class_names.get(predicted_class[0],
"Desconocido")

        # Determinar si la reseña es positiva o negativa
        if predicted_prob >= 0.5:  # Puedes ajustar este umbral
            review_sentiment = "Positiva"
        else:
            review_sentiment = "Negativa"

        # Retornar la clase predicha (nombre) y el sentimiento
        return category_name, review_sentiment
    except Exception as e:
        return f"Error: {str(e)}", ""

# Crear la interfaz de Gradio
iface = gr.Interface(fn=predict,
                     inputs=[gr.Image(type="pil"), gr.Textbox()],
                     outputs=["text", "text"],
                     live=True,
                     description="Introduce una imagen y un texto para
predecir la clase y el sentimiento de la reseña.")

# Iniciar la interfaz
iface.launch()
```

```
WARNING:absl:Compiled the loaded model, but the compiled metrics have
yet to be built. `model.compile_metrics` will be empty until you train
or evaluate the model.
```

```
It looks like you are running Gradio on a hosted a Jupyter notebook.
For the Gradio app to work, sharing must be enabled. Automatically
setting `share=True` (you can turn this off by setting `share=False`
in `launch()` explicitly).
```

```
Colab notebook detected. To show errors in colab notebook, set
debug=True in launch()
* Running on public URL: https://c9a0f942bce2a94ec7.gradio.live

This share link expires in 1 week. For free permanent hosting and GPU
upgrades, run `gradio deploy` from the terminal in the working
directory to deploy to Hugging Face Spaces
(https://huggingface.co/spaces)

<IPython.core.display.HTML object>
```