

# Sentiment analysis with an MLP and vector representation

## Case Study: Sentiment Analysis

In this lab we use part of the 'Amazon\_Unlocked\_Mobile.csv' dataset published by Kaggle. The dataset contain the following information:

- Product Name
- Brand Name
- Price
- Rating
- Reviews
- Review Votes

We are mainly interested by the 'Reviews' (X) and by the 'Rating' (y)

The goal is to try to predict the 'Rating' after reading the 'Reviews'. I've prepared for you TRAIN and TEST set. The work to be done is as follows:

1. Feature extraction and baseline
  - read the dataset and understand it
  - put it in a format so that you can use `CountVectorizer` or `Tf-IDF` to extract the desired features
  - perform on the desired dates and preprocessing
  - use one of the classifiers you know to predict the polarity of different sentences
2. My first neural network
  - reuse the features already extracted
  - proposed a neural network built with Keras
3. Hyper-parameter fitting
  - for the base line: adjust `min_df`, `max_df`, `ngram`, `max_features` + model's hyper-parameter
  - for the neural network: adjust batch size, number of layers and number of neuron by layers, use `earlystop`
4. Word embedding
  - stage 1 build a network that uses Keras' embedding which is not language sensitive.

- stage 2 build a network that simultaneously uses Keras' embedding and the features extracted in the first weeks.
- stage 3 try to use an existing embedding (<https://github.com/facebookresearch/MUSE>)

**WARNING:** the dataset is voluminous, I can only encourage you to work first on a small part of it and only at the end, when the code is well debugged and that it is necessary to build the "final model", to use the whole dataset.

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## Read the dataset

Could you find below a proposal. You can complete them.

In [ ]:

```
import os

import numpy as np
import pandas as pd
import tensorflow as tf
import tensorflow_addons as tfa
from keras.layers import Dense, Embedding, Flatten, Input, TextVectorization
from sklearn.feature_extraction.text import CountVectorizer, TfidfVectorizer
from sklearn.metrics import f1_score
from sklearn.preprocessing import OneHotEncoder
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.layers import Dropout
from tensorflow.keras.models import Model, Sequential
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.preprocessing.text import Tokenizer, one_hot
from tensorflow_addons.metrics import F1Score
```

In [ ]:

```

TRAIN = pd.read_csv(
    "http://www.i3s.unice.fr/~riveill/dataset/Amazon_Unlocked_Mobile/train.csv.gz"
)
TEST = pd.read_csv(
    "http://www.i3s.unice.fr/~riveill/dataset/Amazon_Unlocked_Mobile/test.csv.gz"
)

TRAIN.head()

```

Out[ ]:

	Product Name	Brand Name	Price	Rating	Reviews	Review Votes
0	Samsung Galaxy Note 4 N910C Unlocked Cellphone...	Samsung	449.99	4	I love it!!! I absolutely love it!! 🍕👍	0.0
1	BLU Energy X Plus Smartphone - With 4000 mAh S...	BLU	139.00	5	I love the BLU phones! This is my second one t...	4.0
2	Apple iPhone 6 128GB Silver AT&T	Apple	599.95	5	Great phone	1.0
3	BLU Advance 4.0L Unlocked Smartphone -US GSM -...	BLU	51.99	4	Very happy with the performance. The apps work...	2.0
4	Huawei P8 Lite US Version- 5 Unlocked Android ...	Huawei	198.99	5	Easy to use great price	0.0

In [ ]:

```

# Construct X_train and y_train
X_train = TRAIN["Reviews"]
y_train = np.array(TRAIN["Rating"]).reshape(-1, 1)

X_test = TEST["Reviews"]
y_test = np.array(TEST["Rating"]).reshape(-1, 1)

nb_classes = len(np.unique(y_train))

ohe = OneHotEncoder(sparse=False, handle_unknown="ignore")
y_train_ohe = ohe.fit_transform(y_train)
y_test_ohe = ohe.fit_transform(y_test)

X_train.shape, y_train_ohe.shape, np.unique(y_train)

```

Out[ ]: ((5000,), (5000, 5), array([1, 2, 3, 4, 5]))

## Approach1 - BOW and MLP classifier

Using the course companion notebook, build a multi-layer perceptron using a BOW representation of the dataset and evaluate the model.

The dataset being unbalanced the metric will be the f1 score.

### *TODOSTUDENT*

- Build BOW representation of the train and test set
- Fix a value for vocab\_size = the maximum number of words to keep, based on word frequency. Only the most common vocab\_size-1 words will be kept.

```
In [ ]: # Your code
vocab_size = 20000
tokenizer = Tokenizer(num_words=vocab_size, char_level=False)
tokenizer.fit_on_texts(X_train)
X_train_ohe = tokenizer.texts_to_matrix(X_train, mode="tfidf")
X_test_ohe = tokenizer.texts_to_matrix(X_test, mode="tfidf")
```

### *TODOSTUDENT*

- Build an MLP and print the model (model.summary())

```
In [ ]: # build sequential model
model = Sequential()
model.add(Input(shape=(vocab_size,), name="input", dtype=tf.float32))
model.add(Dense(64, activation="relu", name="hidden"))
model.add(Dense(5, activation="softmax"))
model.build()
model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
hidden (Dense)	(None, 64)	1280064
dense (Dense)	(None, 5)	325

=====  
 Total params: 1,280,389  
 Trainable params: 1,280,389  
 Non-trainable params: 0

2022-02-02 22:29:59.079944: I tensorflow/stream\_executor/cuda/cuda\_gpu\_executor.cc:939] successful NUMA node read from SysFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero  
 2022-02-02 22:29:59.119856: W tensorflow/stream\_executor/platform/default/dso\_loader.cc:64] Could not load dynamic library 'libcudnn.so.8'; dlerror: libcudnn.so.8: cannot open shared object file: No such file or directory  
 2022-02-02 22:29:59.119880: W tensorflow/core/common\_runtime/gpu/gpu\_device.cc:1850] Cannot dlopen some GPU libraries. Please make sure the missing libraries mentioned above are installed properly if you would like to use GPU. Follow the guide at <https://www.tensorflow.org/install/gpu> for how to download and setup the required libraries for your platform.  
 Skipping registering GPU devices...  
 2022-02-02 22:29:59.120533: I tensorflow/core/platform/cpu\_feature\_guard.cc:151] This TensorFlow binary is optimized with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-critical operations: AVX2 FMA  
 To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.

### *TODOSTUDENT*

- Compile the network
- Fit the network using EarlyStopping
- Babysit your model
- Evaluate the network with f1 score

In [ ]: `X_train_ohe.shape`

Out[ ]: (5000, 20000)

In [ ]: `y_train_ohe.shape, y_test_ohe.shape`

Out[ ]: ((5000, 5), (1000, 5))

```
In [ ]: ## compile the model with f1 metrics
# define F1Score instance

f1_score_name = "f1_score"
f1 = F1Score(
    num_classes=len(np.unique(y_test)),
    name=f1_score_name,
    average="weighted",
)
# compile model
model.compile(
    optimizer="adam",
    loss="categorical_crossentropy",
    metrics=[f1, "accuracy"],
)

# define early stopping
early_stop = EarlyStopping(
    monitor="val_f1_score",
    patience=10,
    verbose=1,
    restore_best_weights=True,
    mode="max",
)

# fit model using early stopping
history = model.fit(
    x=X_train_ohe,
    y=y_train_ohe,
    validation_data=(X_test_ohe, y_test_ohe),
    # validation_split=.3,
    # batch_size=1,
    epochs=2000,
    verbose=1,
    callbacks=[early_stop],
    workers=6,
    use_multiprocessing=True,
)
```

```
2022-02-02 22:29:59.500494: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocation of 4000000000 exceeds 10% of free system memory.
```

```

Epoch 1/2000
157/157 [=====] - 2s 11ms/step - loss: 1.1492 - f1_score: 0.5581 - accuracy: 0.6274 - val_loss: 0.9113 - val_f1_score: 0.6291 - val_accuracy: 0.6910
Epoch 2/2000
157/157 [=====] - 1s 9ms/step - loss: 0.5338 - f1_score: 0.8091 - accuracy: 0.8262 - val_loss: 0.9460 - val_f1_score: 0.6371 - val_accuracy: 0.6780
Epoch 3/2000
157/157 [=====] - 1s 8ms/step - loss: 0.3167 - f1_score: 0.9006 - accuracy: 0.9052 - val_loss: 1.0495 - val_f1_score: 0.6390 - val_accuracy: 0.6700
Epoch 4/2000
157/157 [=====] - 1s 7ms/step - loss: 0.2150 - f1_score: 0.9379 - accuracy: 0.9398 - val_loss: 1.2120 - val_f1_score: 0.6411 - val_accuracy: 0.6680
Epoch 5/2000
157/157 [=====] - 1s 7ms/step - loss: 0.1648 - f1_score: 0.9512 - accuracy: 0.9524 - val_loss: 1.3394 - val_f1_score: 0.6449 - val_accuracy: 0.6690
Epoch 6/2000
157/157 [=====] - 1s 7ms/step - loss: 0.1370 - f1_score: 0.9593 - accuracy: 0.9602 - val_loss: 1.5184 - val_f1_score: 0.6354 - val_accuracy: 0.6630
Epoch 7/2000
157/157 [=====] - 1s 7ms/step - loss: 0.1175 - f1_score: 0.9657 - accuracy: 0.9664 - val_loss: 1.6241 - val_f1_score: 0.6284 - val_accuracy: 0.6410
Epoch 8/2000
157/157 [=====] - 1s 7ms/step - loss: 0.1056 - f1_score: 0.9680 - accuracy: 0.9686 - val_loss: 1.7804 - val_f1_score: 0.6263 - val_accuracy: 0.6470
Epoch 9/2000
157/157 [=====] - 1s 7ms/step - loss: 0.0963 - f1_score: 0.9694 - accuracy: 0.9700 - val_loss: 1.9529 - val_f1_score: 0.6206 - val_accuracy: 0.6430
Epoch 10/2000
157/157 [=====] - 1s 7ms/step - loss: 0.0885 - f1_score: 0.9715 - accuracy: 0.9720 - val_loss: 2.0608 - val_f1_score: 0.6182 - val_accuracy: 0.6410
Epoch 11/2000
157/157 [=====] - 1s 7ms/step - loss: 0.0836 - f1_score: 0.9732 - accuracy: 0.9736 - val_loss: 2.2013 - val_f1_score: 0.6242 - val_accuracy: 0.6510
Epoch 12/2000
157/157 [=====] - 1s 7ms/step - loss: 0.0788 - f1_score: 0.9733 - accuracy: 0.9738 - val_loss: 2.2726 - val_f1_score: 0.6230 - val_accuracy: 0.6410
Epoch 13/2000
157/157 [=====] - 1s 7ms/step - loss: 0.0747 - f1_score: 0.9765 - accuracy: 0.9768 - val_loss: 2.4134 - val_f1_score: 0.6233 - val_accuracy: 0.6430
Epoch 14/2000
157/157 [=====] - 1s 9ms/step - loss: 0.0709 - f1_score: 0.9756 - accuracy: 0.9760 - val_loss: 2.5198 - val_f1_score: 0.6164 - val_accuracy: 0.6360
Epoch 15/2000
154/157 [=====>.] - ETA: 0s - loss: 0.0673 - f1_score: 0.9771 - accuracy: 0.9775Restoring mode

```



```
l weights from the end of the best epoch: 5.
157/157 [=====] - 1s 9ms/step - loss: 0.0677 - f1_score: 0.9771 - accuracy: 0.9774 - val_loss: 2.6267 - val_f1_score: 0.6201 - val_accuracy: 0.6430
Epoch 00015: early stopping
```

```
In [ ]: import plotly.express as px

# Babysit the model - use you favourite plot
px.line(
    pd.DataFrame(
        {
            "val_loss": history.history["val_loss"],
            "loss": history.history["loss"],
            "val_f1_score": history.history["val_f1_score"],
            "f1_score": history.history["f1_score"],
            "val_accuracy": history.history["val_accuracy"],
            "accuracy": history.history["accuracy"],
        }
    )
)
```

```
In [ ]: # Evaluate the model with f1 metrics (Tensorflow f1 metrics or sklearn)
model.evaluate(X_test_ohe, y_test_ohe)
```

```
32/32 [=====] - 0s 3ms/step - loss: 1.3394 - f1_score: 0.6449 - accuracy: 0.6690
[1.3393656015396118, 0.6449266672134399, 0.6690000295639038]
```

```
Out[ ]:
```

## Approach2 - Keras word embedding and MLP classifier

Using the course companion notebook, build a multi-layer perceptron using an Embedding Keras layer and the same classifier as in approach 1. Evaluate the model.

### *TODOSTUDENTS*

- fix the max\_length of a review (max number of token in a review)
- use the same vocab\_size as previously
- fix the embedding dimension (embed\_dim variable)

In [ ]:

```
import nltk

X_train_tok = [nltk.word_tokenize(review) for review in X_train]
max_len = int(
    np.amax([len(review_tok) for review_tok in X_train_tok])
) # Sequence length to pad the outputs to
# In order to fix it, you have to know the distribution on length... see first lab
embed_dim = 300 # embedding dimension
```

### TODO STUDENTS

- Create a vectorizer\_layer with TextVectorization function
- Fit the vectorizer\_layer (adapt function)

In [ ]:

```
vectorize_layer = TextVectorization(
    max_tokens=vocab_size,
    output_sequence_length=max_len,
)
vectorize_layer.adapt(X_train)
vectorize_layer(X_test) # display vectorized test set
```

Out[ ]:

```
<tf.Tensor: shape=(1000, 1137), dtype=int64, numpy=
array([[ 2,  438,  12, ...,  0,  0,  0],
       [ 3,   29, 108, ...,  0,  0,  0],
       [ 3,   45,  15, ...,  0,  0,  0],
       ...,
       [ 16,   17, 113, ...,  0,  0,  0],
       [198, 1559, 10239, ...,  0,  0,  0],
       [ 82,    4,    9, ...,  0,  0,  0]])>
```

In [ ]:

```
vectorize_layer.get_vocabulary()
```

```
Out[ ]: [' ',  
         '[UNK]',  
         'the',  
         'i',  
         'it',  
         'and',  
         'phone',  
         'a',  
         'to',  
         'is',  
         'this',  
         'for',  
         'of',  
         'with',  
         'my',  
         'not',  
         'was',  
         'in',  
         'that',  
         'but',  
         'on',  
         'have',  
         'you',  
         'great',  
         'good',  
         'as',  
         'very',  
         'so',  
         'its',  
         'had',  
         'one',  
         'be',  
         'like',  
         'no',  
         'all',  
         'or',  
         'me',  
         'if',  
         'just',  
         'battery',  
         'use',  
         'screen',  
         'has',  
         'are',
```

'an',  
'would',  
'from',  
'only',  
'at',  
'when',  
'works',  
'can',  
'love',  
'will',  
'get',  
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'phones',  
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'do',  
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'does',  
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'fast',  
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'quality',  
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'doesnt',  
'then',  
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'came',  
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'best',  
'perfect',  
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'ive',  
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'att',  
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'3',  
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'able',  
'take',  
'since',  
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'ever',  
'old',  
'these',  
'call',  
'again',  
'last',  
'while',  
'purchased',  
'long',  
'app',  
'though',  
'cell',  
'give',  
'return',  
'expected',  
'galaxy',  
'find',  
'put',  
'pretty',  
'getting',  
'brand',  
'small',  
'wifi',  
'into',  
'awesome',  
'however',  
'right',  
'many',  
'condition',  
'calls',

'sure',  
'looking',  
'issue',  
'said',  
'ok',  
'who',  
'smart',  
'version',  
'every',  
'going',  
'sound',  
'touch',  
'people',  
'memory',  
'he',  
'something',  
'down',  
'smartphone',  
'wanted',  
'through',  
'data',  
'month',  
'look',  
'their',  
'enough',  
'arrived',  
'times',  
'made',  
'hard',  
'charging',  
'software',  
'pictures',  
'music',  
'seems',  
'4',  
'1',  
'tmobile',  
'excelente',  
'slow',  
'come',  
'should',  
'being',  
'us',  
'speaker',



'comes',  
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'stars',  
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'tried',  
'item',  
'wont',  
'took',  
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'sd',  
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'set',  
'turn',  
'plus',  
'light',  
'apple',  
'6',  
'thought',  
'thanks',  
'overall',  
'nothing',  
'nokia',  
'full',  
'low',  
'internet',  
'always',  
'those',  
'keyboard',  
'already',  
'bluetooth',  
'text',  
'sometimes',  
'found',  
'customer',  
'cheap',  
'worth',  
'weeks',  
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'send',  
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'review',  
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'loves',  
'lg',  
'display',  
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'absolutely',  
'takes',  
'sent',  
'second',  
'reviews',  
'hear',  
'cannot',

'clear',  
'satisfied',  
'read',  
'network',  
'exactly',  
'shipping',  
'once',  
'less',  
'couldnt',  
'why',  
'talk',  
'stopped',  
'reason',  
'original',  
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'cover',  
'carrier',  
'performance',  
'volume',  
'power',  
'order',  
'makes',  
'lte',  
'wouldnt',  
'user',  
'support',  
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'front',  
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'dropped',  
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'trying',  
'sony',  
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'simple',  
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'ill',  
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'experience',  
'el',  
'delivery',  
'charged',  
'y',  
'our',  
'home',  
'hand',  
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'easily',  
'change',  
'system',  
'needs',  
'longer',  
'his',  
'fix',  
'cellphone',  
'wrong',  
'value',  
'please',  
'nexus',  
'instead',  
'gift',  
'fit',  
'cost',  
'basic',  
'white',  
'moto',  
'expectations',  
'decided',  
'cool',  
'someone',  
'signal',  
'probably',  
'broke',  
'although',  
'3g',  
'side',

'muy',  
'lasts',  
'high',  
'half',  
'terrible',  
'person',  
'number',  
'might',  
'international',  
'games',  
'fact',  
'due',  
'connection',  
'access',  
'wireless',  
'unlock',  
'straight',  
'settings',  
'must',  
'micro',  
'messages',  
'etc',  
'contacts',  
'point',  
'minutes',  
'job',  
'factory',  
'expensive',  
'email',  
'7',  
'top',  
'protector',  
'pocket',  
'locked',  
'internal',  
'finally',  
'contact',  
'connect',  
'broken',  
'ago',  
'tell',  
'slot',  
'reset',  
'products',

'part',  
'open',  
'excellent',  
'delivered',  
'10',  
'waste',  
'turned',  
'maybe',  
'id',  
'headphones',  
'gps',  
'devices',  
'completely',  
's5',  
'real',  
'previous',  
'plastic',  
'fully',  
'especially',  
'30',  
'videos',  
'runs',  
'poor',  
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```
'provider',  
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'sealed',  
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'pop',  
'offer',  
'major',  
'lag',  
'knew',  
'keys',  
...]
```

```
In [ ]: vectorize_layer.get_config()
```

```
Out[ ]: {'name': 'text_vectorization',  
        'trainable': True,  
        'batch_input_shape': (None, None),  
        'dtype': 'string',  
        'max_tokens': 20000,  
        'standardize': 'lower_and_strip_punctuation',  
        'split': 'whitespace',  
        'ngrams': None,  
        'output_mode': 'int',  
        'output_sequence_length': 1137,  
        'pad_to_max_tokens': False,  
        'sparse': False,  
        'ragged': False,  
        'vocabulary': None,  
        'idf_weights': None}
```

### *TODOSTUDENT*

- Build an MLP and print the model (model.summary())

```
In [ ]: # Flatten after Embedding in order to reduce the dimension of tensors  
model = Sequential()  
model.add(Input(shape=(1,), dtype=tf.string))  
model.add(vectorize_layer)  
model.add(Embedding(input_dim=vocab_size, output_dim=64))  
model.add(Flatten())  
model.add(Dense(units=128, activation="relu"))  
model.add(Dropout(0.5))  
model.add(Dense(units=5, activation="sigmoid"))  
model.build()  
  
# get summary of the model  
model.summary()
```

Model: "sequential\_2"

Layer (type)	Output Shape	Param #
text_vectorization (TextVectorization)	(None, 1137)	0
embedding_1 (Embedding)	(None, 1137, 64)	1280000
flatten_1 (Flatten)	(None, 72768)	0
dense_3 (Dense)	(None, 128)	9314432
dropout_1 (Dropout)	(None, 128)	0
dense_4 (Dense)	(None, 5)	645
Total params: 10,595,077		
Trainable params: 10,595,077		
Non-trainable params: 0		

### *TODOSTUDENT*

- Compile the network
- Fit the network using EarlyStopping
- Babysit your model
- Evaluate the network with f1 score

```
In [ ]: vectorize_layer(X_train)
```

```
Out[ ]: <tf.Tensor: shape=(5000, 1137), dtype=int64, numpy=
array([[ 3, 52,  4, ...,  0,  0,  0],
       [ 3, 52,  2, ...,  0,  0,  0],
       [23,  6,  0, ...,  0,  0,  0],
       ...,
       [ 6, 50, 73, ...,  0,  0,  0],
       [23,  7,  0, ...,  0,  0,  0],
       [10,  9,  7, ...,  0,  0,  0]])>
```

```
In [ ]: # compile the model with metrics f1 score
model.compile(
    optimizer="adam",
    loss="categorical_crossentropy",
    metrics=[f1, "accuracy"],
)

# define early stopping
early_stop = EarlyStopping(
    monitor=f"val_{f1_score_name}",
    patience=10,
    verbose=3,
    restore_best_weights=True,
    mode="max",
)

# fit model using ealy stopping
history = model.fit(
    x=X_train,
    y=y_train_ohe,
    epochs=2000,
    validation_data=(X_test, y_test_ohe),
    callbacks=early_stop,
    use_multiprocessing=True,
    workers=6,
)
```

```
Epoch 1/2000
157/157 [=====] - 15s 92ms/step - loss: 1.3421 - f1_score: 0.6214 - accuracy: 0.5220 - val_loss: 1.1015 - val_f1_score: 0.4055 - val_accuracy: 0.5590
Epoch 2/2000
157/157 [=====] - 15s 94ms/step - loss: 1.0254 - f1_score: 0.5271 - accuracy: 0.6284 - val_loss: 0.9575 - val_f1_score: 0.5447 - val_accuracy: 0.6520
Epoch 3/2000
157/157 [=====] - 14s 92ms/step - loss: 0.8308 - f1_score: 0.6249 - accuracy: 0.7022 - val_loss: 0.9337 - val_f1_score: 0.5811 - val_accuracy: 0.6640
Epoch 4/2000
157/157 [=====] - 15s 98ms/step - loss: 0.6432 - f1_score: 0.7342 - accuracy: 0.7698 - val_loss: 0.9626 - val_f1_score: 0.6131 - val_accuracy: 0.6490
Epoch 5/2000
157/157 [=====] - 15s 96ms/step - loss: 0.4558 - f1_score: 0.8326 - accuracy: 0.8444 - val_loss: 1.0259 - val_f1_score: 0.6309 - val_accuracy: 0.6630
Epoch 6/2000
157/157 [=====] - 15s 95ms/step - loss: 0.3222 - f1_score: 0.8900 - accuracy: 0.8952 - val_loss: 1.1608 - val_f1_score: 0.6138 - val_accuracy: 0.6560
Epoch 7/2000
157/157 [=====] - 15s 97ms/step - loss: 0.2289 - f1_score: 0.9270 - accuracy: 0.9292 - val_loss: 1.2576 - val_f1_score: 0.6036 - val_accuracy: 0.6030
Epoch 8/2000
157/157 [=====] - 15s 95ms/step - loss: 0.1761 - f1_score: 0.9481 - accuracy: 0.9492 - val_loss: 1.4283 - val_f1_score: 0.6121 - val_accuracy: 0.6430
Epoch 9/2000
157/157 [=====] - 15s 95ms/step - loss: 0.1422 - f1_score: 0.9550 - accuracy: 0.9556 - val_loss: 1.5374 - val_f1_score: 0.6175 - val_accuracy: 0.6620
Epoch 10/2000
157/157 [=====] - 15s 95ms/step - loss: 0.1233 - f1_score: 0.9634 - accuracy: 0.9640 - val_loss: 1.5416 - val_f1_score: 0.6152 - val_accuracy: 0.6370
Epoch 11/2000
157/157 [=====] - 15s 93ms/step - loss: 0.1130 - f1_score: 0.9675 - accuracy: 0.9678 - val_loss: 1.6047 - val_f1_score: 0.6075 - val_accuracy: 0.6380
Epoch 12/2000
157/157 [=====] - 14s 92ms/step - loss: 0.0980 - f1_score: 0.9687 - accuracy: 0.9690 - val_loss: 1.7634 - val_f1_score: 0.6116 - val_accuracy: 0.6320
Epoch 13/2000
157/157 [=====] - 15s 93ms/step - loss: 0.0869 - f1_score: 0.9735 - accuracy: 0.9738 - val_loss: 1.6854 - val_f1_score: 0.6076 - val_accuracy: 0.6270
Epoch 14/2000
157/157 [=====] - 15s 93ms/step - loss: 0.0841 - f1_score: 0.9748 - accuracy: 0.9750 - val_loss: 1.9005 - val_f1_score: 0.6155 - val_accuracy: 0.6390
Epoch 15/2000
157/157 [=====] - ETA: 0s - loss: 0.0829 - f1_score: 0.9739 - accuracy: 0.9742Restoring mode
```

```
l weights from the end of the best epoch: 5.
157/157 [=====] - 15s 93ms/step - loss: 0.0829 - f1_score: 0.9739 - accuracy: 0.9742 - val_l
oss: 2.1375 - val_f1_score: 0.6138 - val_accuracy: 0.6570
Epoch 00015: early stopping
```

```
In [ ]: # Babysit the model
px.line(
    pd.DataFrame(
        {
            "val_loss": history.history["val_loss"],
            "loss": history.history["loss"],
            "val_f1_score": history.history["val_f1_score"],
            "f1_score": history.history["f1_score"],
            "val_accuracy": history.history["val_accuracy"],
            "accuracy": history.history["accuracy"],
        }
    )
)
```

```
In [ ]: # Evaluate the model
model.evaluate(X_test, y_test_ohe)
```

```
32/32 [=====] - 1s 16ms/step - loss: 1.0259 - f1_score: 0.6309 - accuracy: 0.6630
[1.025903344154358, 0.6308760643005371, 0.6629999876022339]
```

```
Out[ ]:
```

**The model seems to overfit: its results improve on the train set, but (at best) remain stable on the validation set.**

## Approach3 - Word embedding and MLP classifier

Using the course companion notebook, build a multi-layer perceptron using an existing embedding matrix (Word2Vec / Glove or FastText), or on an embedding matrix that you will have built using Gensim.

Use the same constant as a previous steps.

Evaluate the model.

```
In [ ]: import gensim
```

```

from gensim import models, utils

gensim_path = f"{gensim.__path__[0]}/test/test_data/"
corpus = "lee_background.cor"
corpus_path = gensim_path + corpus

class MyCorpus:
    """An iterator that yields sentences (lists of str)."""

    def __iter__(self):
        for line in open(corpus_path):
            # assume there's one document per line, tokens separated by whitespace
            yield utils.simple_preprocess(line)

```

```

In [ ]: sentences = MyCorpus()
        model = models.Word2Vec(sentences=sentences, vector_size=150)

```

```

In [ ]: # Same steps as Keras Embedding
        max_len = 10 # Sequence length to pad the outputs to.
        vectorizer = TextVectorization(max_tokens=vocab_size, output_sequence_length=max_len)
        vectorizer.adapt(X_train)
        X_train_vec = vectorizer(X_train)
        X_train_vec

```

```

Out[ ]: <tf.Tensor: shape=(5000, 10), dtype=int64, numpy=
        array([[ 3,  52,  4, ..., 4907,  0,  0],
               [ 3,  52,  2, ...,  14, 348, 30],
               [ 23,  6,  0, ...,  0,  0,  0],
               ...,
               [  6,  50, 73, ..., 182, 13, 100],
               [ 23,  7,  0, ...,  0,  0,  0],
               [ 10,  9,  7, ...,  4,  8, 2459]])>

```

```

In [ ]: # Build word dict
        voc = vectorizer.get_vocabulary()
        word_index = dict(zip(voc, range(len(voc))))

```

```

In [ ]: # Make a dict mapping words (strings) to their NumPy vector representation:

```

```
path_to_glove_file = "glove.6B/glove.6B.50d.txt"
embeddings_index = {}
with open(path_to_glove_file) as f:
    for line in f:
        word, coefs = line.split(maxsplit=1)
        coefs = np.fromstring(coefs, "f", sep=" ")
        embeddings_index[word] = coefs

print(f"Found {len(embeddings_index)} word vectors.")
```

Found 400000 word vectors.

In [ ]:

```
# Prepare embedding matrix

num_tokens = len(voc) + 2
embedding_dim = 50
hits = 0
misses = 0

# Prepare embedding matrix
embedding_matrix = np.zeros((num_tokens, embedding_dim))
for word, i in word_index.items():
    print(word, i)
    embedding_vector = embeddings_index.get(word)
    if embedding_vector is not None:
        # Words not found in embedding index will be all-zeros.
        # This includes the representation for "padding" and "OOV"
        embedding_matrix[i] = embedding_vector
        hits += 1
    else:
        misses += 1
print(f"Converted {hits} words ({misses} misses)")
```



0  
[UNK] 1  
the 2  
i 3  
it 4  
and 5  
phone 6  
a 7  
to 8  
is 9  
this 10  
for 11  
of 12  
with 13  
my 14  
not 15  
was 16  
in 17  
that 18  
but 19  
on 20  
have 21  
you 22  
great 23  
good 24  
as 25  
very 26  
so 27  
its 28  
had 29  
one 30  
be 31  
like 32  
no 33  
all 34  
or 35  
me 36  
if 37  
just 38  
battery 39  
use 40  
screen 41  
has 42  
are 43

an 44  
would 45  
from 46  
only 47  
at 48  
when 49  
works 50  
can 51  
love 52  
will 53  
get 54  
new 55  
they 56  
work 57  
up 58  
time 59  
really 60  
than 61  
phones 62  
dont 63  
price 64  
product 65  
out 66  
camera 67  
im 68  
am 69  
about 70  
do 71  
because 72  
well 73  
buy 74  
after 75  
sim 76  
bought 77  
card 78  
got 79  
even 80  
more 81  
what 82  
also 83  
other 84  
there 85  
which 86  
back 87

now 88  
your 89  
iphone 90  
does 91  
any 92  
some 93  
used 94  
nice 95  
excellent 96  
fast 97  
did 98  
better 99  
quality 100  
apps 101  
unlocked 102  
doesnt 103  
then 104  
much 105  
could 106  
case 107  
been 108  
problem 109  
came 110  
by 111  
best 112  
perfect 113  
using 114  
first 115  
android 116  
too 117  
working 118  
off 119  
2 120  
still 121  
want 122  
life 123  
need 124  
everything 125  
didnt 126  
cant 127  
go 128  
ive 129  
happy 130  
little 131

recommend 132  
them 133  
seller 134  
far 135  
easy 136  
day 137  
samsung 138  
money 139  
days 140  
we 141  
amazon 142  
charge 143  
purchase 144  
blu 145  
att 146  
over 147  
service 148  
how 149  
months 150  
device 151  
problems 152  
lot 153  
charger 154  
two 155  
watch 156  
received 157  
never 158  
without 159  
thing 160  
think 161  
box 162  
big 163  
before 164  
features 165  
3 166  
another 167  
5 168  
most 169  
know 170  
fine 171  
few 172  
amazing 173  
worked 174  
same 175

were 176  
way 177  
see 178  
she 179  
bad 180  
make 181  
issues 182  
size 183  
say 184  
looks 185  
able 186  
take 187  
since 188  
having 189  
ever 190  
old 191  
these 192  
call 193  
again 194  
last 195  
while 196  
purchased 197  
long 198  
app 199  
though 200  
cell 201  
give 202  
return 203  
expected 204  
galaxy 205  
find 206  
put 207  
pretty 208  
getting 209  
brand 210  
small 211  
wifi 212  
into 213  
awesome 214  
however 215  
right 216  
many 217  
condition 218  
calls 219

sure 220  
looking 221  
issue 222  
said 223  
ok 224  
who 225  
smart 226  
version 227  
every 228  
going 229  
sound 230  
touch 231  
people 232  
memory 233  
he 234  
something 235  
down 236  
smartphone 237  
wanted 238  
through 239  
data 240  
month 241  
look 242  
their 243  
enough 244  
arrived 245  
times 246  
made 247  
hard 248  
charging 249  
software 250  
pictures 251  
music 252  
seems 253  
4 254  
1 255  
tmobile 256  
excelente 257  
slow 258  
come 259  
should 260  
being 261  
us 262  
speaker 263

comes 264  
both 265  
went 266  
stars 267  
where 268  
week 269  
tried 270  
item 271  
wont 272  
took 273  
bit 274  
sd 275  
perfectly 276  
buying 277  
blackberry 278  
ordered 279  
definitely 280  
set 281  
turn 282  
plus 283  
light 284  
apple 285  
6 286  
thought 287  
thanks 288  
overall 289  
nothing 290  
nokia 291  
full 292  
low 293  
internet 294  
always 295  
those 296  
keyboard 297  
already 298  
bluetooth 299  
text 300  
sometimes 301  
found 302  
customer 303  
cheap 304  
worth 305  
weeks 306  
update 307

keep 308  
disappointed 309  
different 310  
deal 311  
100 312  
yet 313  
verizon 314  
store 315  
itself 316  
hours 317  
her 318  
isnt 319  
feel 320  
anything 321  
thank 322  
send 323  
couple 324  
thats 325  
may 326  
google 327  
model 328  
here 329  
company 330  
button 331  
year 332  
wasnt 333  
warranty 334  
pay 335  
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50even 10761  
5060 10762  
500prosthe 10763  
5000200 10764  
5000 10765  
4x 10766  
4way 10767  
4times 10768  
4stars 10769  
4severything 10770  
4ram 10771  
4pmmaybe 10772  
4mb 10773  
4lg 10774  
4ki 10775  
4hd 10776  
4glike 10777  
4g3 10778

4expandable 10779  
4dislikesno 10780  
499 10781  
495 10782  
48hrs 10783  
480 10784  
48 10785  
468917332 10786  
465 10787  
46 10788  
4500 10789  
450 10790  
44s 10791  
443 10792  
441 10793  
43 10794  
42mm 10795  
4272 10796  
421 10797  
411 10798  
40l 10799  
40and 10800  
40300 10801  
4000map 10802  
3xx 10803  
3pmand 10804  
3month 10805  
3led 10806  
3gwifi 10807  
3ghspa 10808  
3dish 10809  
3days 10810  
399 10811  
38mm 10812  
375 10813  
366gbs 10814  
35mm 10815  
3500mah 10816  
3500 10817  
350 10818  
34s 10819  
349 10820  
345k 10821  
34 10822

32gbi 10823  
329 10824  
320g 10825  
312 10826  
30sec1min 10827  
30screen 10828  
30month 10829  
30mins 10830  
30fps 10831  
30camera 10832  
30amonth 10833  
30957 10834  
3045 10835  
301 10836  
300pros 10837  
3000mah 10838  
30000 10839  
2when 10840  
2sim 10841  
2now 10842  
2nd5th 10843  
2mths 10844  
2minutes 10845  
2installed 10846  
2getting 10847  
2day 10848  
299rs 10849  
29960 10850  
29957 10851  
292 10852  
2856 10853  
279and 10854  
279 10855  
27 10856  
2666 10857  
26091 10858  
2600 10859  
25mins 10860  
256gno 10861  
2535 10862  
252gb 10863  
25260 10864  
2500 10865  
24hrs 10866

24h 10867  
24999 10868  
249 10869  
240 10870  
239gb 10871  
235 10872  
234 10873  
23000 10874  
22hrs 10875  
228 10876  
2250 10877  
222 10878  
2200mah 10879  
21mbps 10880  
219 10881  
216155165050 10882  
21500 10883  
2116yesterday 10884  
20x 10885  
20touchless 10886  
20con 10887  
20also 10888  
2080 10889  
20595 10890  
2050 10891  
2030 10892  
2017 10893  
2016the 10894  
2015touchpad 10895  
2015revised 10896  
2015first 10897  
2013one 10898  
2010 10899  
200stop 10900  
200smooth 10901  
200gb 10902  
2008ish 10903  
2007 10904  
2005 10905  
200400 10906  
2000si 10907  
2000mah 10908  
1★ 10909  
1x 10910



lwe 10911  
ltime 10912  
lthe 10913  
lstar 10914  
lplease 10915  
lmy 10916  
lmonth 10917  
li 10918  
1980s 10919  
1970 10920  
196 10921  
1920 10922  
19000higher 10923  
189 10924  
187 10925  
180 10926  
17002100aws 10927  
16th 10928  
16m 10929  
16gbs 10930  
163 10931  
16000 10932  
15th 10933  
15minute 10934  
158 10935  
150mb4g 10936  
150200 10937  
15000 10938  
1500 10939  
14th 10940  
1495 10941  
148gbphone 10942  
142 10943  
1415this 10944  
13th 10945  
13015 10946  
130 10947  
12month 10948  
12hrs 10949  
12900 10950  
129 10951  
12899 10952  
1280 10953  
12500 10954

123 10955  
12072015 10956  
1200 10957  
11yeqr 10958  
11th 10959  
11days 10960  
114 10961  
11339437047263422 10962  
1130 10963  
111516after 10964  
11142016one 10965  
1111 10966  
11 10967  
10th 10968  
10mins 10969  
10if 10970  
10i 10971  
10gb 10972  
10days 10973  
1090day 10974  
108dbm 10975  
1082015 10976  
1080x1920 10977  
1080p 10978  
106 10979  
105dbm 10980  
1032680 10981  
103 10982  
1024ghz 10983  
10232009well 10984  
1020i 10985  
102015 10986  
1012 10987  
100i 10988  
100hours 10989  
10000 10990  
1000 10991  
0stars 10992  
08 10993  
06 10994  
05gb 10995  
05 10996  
031ah 10997  
03 10998

```
010 10999
002amp 11000
0000this 11001
Converted 7586 words (3416 misses)
```

In [ ]:

```
# Define embedding layers

embedding_layer = Embedding(
    num_tokens,
    embedding_dim,
    embeddings_initializer=tf.keras.initializers.Constant(embedding_matrix),
    trainable=False,
)
```

In [ ]:

```
# define the model
input_ = Input(shape=(max_len,), dtype=tf.int32)
x = embedding_layer(input_)
x = Flatten()(x)
output_ = Dense(5, activation="sigmoid")(x)
model = Model(input_, output_)
# summarize the model
model.summary()
```

Model: "model"

Layer (type)	Output Shape	Param #
=====		
input_3 (InputLayer)	[(None, 10)]	0
embedding_2 (Embedding)	(None, 10, 50)	550200
flatten_2 (Flatten)	(None, 500)	0
dense_5 (Dense)	(None, 5)	2505
=====		
Total params: 552,705		
Trainable params: 2,505		
Non-trainable params: 550,200		

In [ ]:

```
# compile the model
model.compile(
    optimizer="adam",
    loss="categorical_crossentropy",
    metrics=[f1, "accuracy"],
)

# define early stopping
early_stop = EarlyStopping(
    monitor=f"val_{f1_score_name}",
    patience=100,
    verbose=2,
    mode="max",
    restore_best_weights=True,
)

# fit model using ealy stopping
history = model.fit(
    x=vectorizer(X_train),
    y=y_train_ohe,
    validation_data=(vectorizer(X_test), y_test_ohe),
    epochs=2000,
    callbacks=early_stop,
)
```

Epoch 1/2000  
157/157 [=====] - 1s 2ms/step - loss: 1.3633 - f1\_score: 0.4682 - accuracy: 0.5100 - val\_loss: 1.2228 - val\_f1\_score: 0.4791 - val\_accuracy: 0.5680

Epoch 2/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.1875 - f1\_score: 0.4861 - accuracy: 0.5644 - val\_loss: 1.1650 - val\_f1\_score: 0.4867 - val\_accuracy: 0.5780

Epoch 3/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1245 - f1\_score: 0.5007 - accuracy: 0.5798 - val\_loss: 1.1537 - val\_f1\_score: 0.4971 - val\_accuracy: 0.5800

Epoch 4/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.0877 - f1\_score: 0.5210 - accuracy: 0.5924 - val\_loss: 1.1395 - val\_f1\_score: 0.4949 - val\_accuracy: 0.5920

Epoch 5/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.0636 - f1\_score: 0.5274 - accuracy: 0.6004 - val\_loss: 1.1223 - val\_f1\_score: 0.5032 - val\_accuracy: 0.5760

Epoch 6/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.0413 - f1\_score: 0.5396 - accuracy: 0.6072 - val\_loss: 1.1239 - val\_f1\_score: 0.5090 - val\_accuracy: 0.5900

Epoch 7/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.0261 - f1\_score: 0.5529 - accuracy: 0.6176 - val\_loss: 1.1315 - val\_f1\_score: 0.5289 - val\_accuracy: 0.5700

Epoch 8/2000  
157/157 [=====] - 0s 1ms/step - loss: 1.0144 - f1\_score: 0.5539 - accuracy: 0.6158 - val\_loss: 1.1255 - val\_f1\_score: 0.5157 - val\_accuracy: 0.5730

Epoch 9/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.0037 - f1\_score: 0.5623 - accuracy: 0.6222 - val\_loss: 1.1248 - val\_f1\_score: 0.4987 - val\_accuracy: 0.5810

Epoch 10/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9951 - f1\_score: 0.5681 - accuracy: 0.6242 - val\_loss: 1.1255 - val\_f1\_score: 0.5033 - val\_accuracy: 0.5800

Epoch 11/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9863 - f1\_score: 0.5646 - accuracy: 0.6224 - val\_loss: 1.1235 - val\_f1\_score: 0.5184 - val\_accuracy: 0.5780

Epoch 12/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9784 - f1\_score: 0.5724 - accuracy: 0.6284 - val\_loss: 1.1327 - val\_f1\_score: 0.5188 - val\_accuracy: 0.5900

Epoch 13/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9720 - f1\_score: 0.5756 - accuracy: 0.6286 - val\_loss: 1.1292 - val\_f1\_score: 0.5166 - val\_accuracy: 0.5870

Epoch 14/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9673 - f1\_score: 0.5810 - accuracy: 0.6342 - val\_loss: 1.1437 - val\_f1\_score: 0.5360 - val\_accuracy: 0.5700

Epoch 15/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9625 - f1\_score: 0.5844 - accuracy: 0.6352 - val\_loss:

```
s: 1.1335 - val_f1_score: 0.5339 - val_accuracy: 0.5810
Epoch 16/2000
157/157 [=====] - 0s 2ms/step - loss: 0.9561 - f1_score: 0.5896 - accuracy: 0.6370 - val_loss: 1.1323 - val_f1_score: 0.5234 - val_accuracy: 0.5860
Epoch 17/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9550 - f1_score: 0.5854 - accuracy: 0.6356 - val_loss: 1.1416 - val_f1_score: 0.5347 - val_accuracy: 0.5820
Epoch 18/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9510 - f1_score: 0.5987 - accuracy: 0.6420 - val_loss: 1.1435 - val_f1_score: 0.5108 - val_accuracy: 0.5920
Epoch 19/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9478 - f1_score: 0.5917 - accuracy: 0.6398 - val_loss: 1.1405 - val_f1_score: 0.5279 - val_accuracy: 0.5750
Epoch 20/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9431 - f1_score: 0.6012 - accuracy: 0.6456 - val_loss: 1.1455 - val_f1_score: 0.5292 - val_accuracy: 0.5840
Epoch 21/2000
157/157 [=====] - 0s 2ms/step - loss: 0.9425 - f1_score: 0.5979 - accuracy: 0.6418 - val_loss: 1.1499 - val_f1_score: 0.5229 - val_accuracy: 0.5880
Epoch 22/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9374 - f1_score: 0.5987 - accuracy: 0.6434 - val_loss: 1.1456 - val_f1_score: 0.5260 - val_accuracy: 0.5770
Epoch 23/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9351 - f1_score: 0.6050 - accuracy: 0.6466 - val_loss: 1.1494 - val_f1_score: 0.5322 - val_accuracy: 0.5810
Epoch 24/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9336 - f1_score: 0.6017 - accuracy: 0.6446 - val_loss: 1.1526 - val_f1_score: 0.5277 - val_accuracy: 0.5860
Epoch 25/2000
157/157 [=====] - 0s 2ms/step - loss: 0.9302 - f1_score: 0.6024 - accuracy: 0.6444 - val_loss: 1.1521 - val_f1_score: 0.5295 - val_accuracy: 0.5730
Epoch 26/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9272 - f1_score: 0.6046 - accuracy: 0.6454 - val_loss: 1.1678 - val_f1_score: 0.5275 - val_accuracy: 0.5860
Epoch 27/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9256 - f1_score: 0.6054 - accuracy: 0.6468 - val_loss: 1.1593 - val_f1_score: 0.5327 - val_accuracy: 0.5820
Epoch 28/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9237 - f1_score: 0.6089 - accuracy: 0.6490 - val_loss: 1.1597 - val_f1_score: 0.5281 - val_accuracy: 0.5850
Epoch 29/2000
157/157 [=====] - 0s 1ms/step - loss: 0.9218 - f1_score: 0.6087 - accuracy: 0.6488 - val_loss: 1.1762 - val_f1_score: 0.5214 - val_accuracy: 0.5890
Epoch 30/2000
```

157/157 [=====] - 0s 2ms/step - loss: 0.9201 - f1\_score: 0.6126 - accuracy: 0.6506 - val\_loss: 1.1693 - val\_f1\_score: 0.5225 - val\_accuracy: 0.5810  
Epoch 31/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9183 - f1\_score: 0.6069 - accuracy: 0.6464 - val\_loss: 1.1681 - val\_f1\_score: 0.5291 - val\_accuracy: 0.5800  
Epoch 32/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.9179 - f1\_score: 0.6116 - accuracy: 0.6514 - val\_loss: 1.1690 - val\_f1\_score: 0.5360 - val\_accuracy: 0.5880  
Epoch 33/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9157 - f1\_score: 0.6155 - accuracy: 0.6530 - val\_loss: 1.1699 - val\_f1\_score: 0.5318 - val\_accuracy: 0.5870  
Epoch 34/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9157 - f1\_score: 0.6177 - accuracy: 0.6548 - val\_loss: 1.1816 - val\_f1\_score: 0.5259 - val\_accuracy: 0.5840  
Epoch 35/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9135 - f1\_score: 0.6141 - accuracy: 0.6520 - val\_loss: 1.1824 - val\_f1\_score: 0.5180 - val\_accuracy: 0.5880  
Epoch 36/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9141 - f1\_score: 0.6161 - accuracy: 0.6536 - val\_loss: 1.1906 - val\_f1\_score: 0.5239 - val\_accuracy: 0.5890  
Epoch 37/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9119 - f1\_score: 0.6112 - accuracy: 0.6494 - val\_loss: 1.1804 - val\_f1\_score: 0.5321 - val\_accuracy: 0.5890  
Epoch 38/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9097 - f1\_score: 0.6134 - accuracy: 0.6494 - val\_loss: 1.1913 - val\_f1\_score: 0.5368 - val\_accuracy: 0.5950  
Epoch 39/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.9099 - f1\_score: 0.6169 - accuracy: 0.6542 - val\_loss: 1.1922 - val\_f1\_score: 0.5295 - val\_accuracy: 0.5840  
Epoch 40/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9088 - f1\_score: 0.6152 - accuracy: 0.6524 - val\_loss: 1.1872 - val\_f1\_score: 0.5293 - val\_accuracy: 0.5710  
Epoch 41/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9059 - f1\_score: 0.6149 - accuracy: 0.6518 - val\_loss: 1.1843 - val\_f1\_score: 0.5371 - val\_accuracy: 0.5840  
Epoch 42/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9066 - f1\_score: 0.6182 - accuracy: 0.6542 - val\_loss: 1.1879 - val\_f1\_score: 0.5287 - val\_accuracy: 0.5780  
Epoch 43/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9064 - f1\_score: 0.6145 - accuracy: 0.6520 - val\_loss: 1.1883 - val\_f1\_score: 0.5300 - val\_accuracy: 0.5710  
Epoch 44/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9041 - f1\_score: 0.6146 - accuracy: 0.6502 - val\_loss: 1.2006 - val\_f1\_score: 0.5408 - val\_accuracy: 0.5660

Epoch 45/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9069 - f1\_score: 0.6162 - accuracy: 0.6534 - val\_loss: 1.1941 - val\_f1\_score: 0.5365 - val\_accuracy: 0.5830

Epoch 46/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.9035 - f1\_score: 0.6200 - accuracy: 0.6546 - val\_loss: 1.1945 - val\_f1\_score: 0.5332 - val\_accuracy: 0.5810

Epoch 47/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9031 - f1\_score: 0.6147 - accuracy: 0.6516 - val\_loss: 1.2039 - val\_f1\_score: 0.5340 - val\_accuracy: 0.5680

Epoch 48/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9003 - f1\_score: 0.6227 - accuracy: 0.6568 - val\_loss: 1.2027 - val\_f1\_score: 0.5280 - val\_accuracy: 0.5920

Epoch 49/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9027 - f1\_score: 0.6200 - accuracy: 0.6550 - val\_loss: 1.2010 - val\_f1\_score: 0.5303 - val\_accuracy: 0.5800

Epoch 50/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9001 - f1\_score: 0.6189 - accuracy: 0.6540 - val\_loss: 1.1998 - val\_f1\_score: 0.5360 - val\_accuracy: 0.5780

Epoch 51/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.9006 - f1\_score: 0.6184 - accuracy: 0.6516 - val\_loss: 1.2086 - val\_f1\_score: 0.5286 - val\_accuracy: 0.5920

Epoch 52/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8988 - f1\_score: 0.6183 - accuracy: 0.6532 - val\_loss: 1.2012 - val\_f1\_score: 0.5299 - val\_accuracy: 0.5730

Epoch 53/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8980 - f1\_score: 0.6174 - accuracy: 0.6532 - val\_loss: 1.2073 - val\_f1\_score: 0.5358 - val\_accuracy: 0.5840

Epoch 54/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8998 - f1\_score: 0.6192 - accuracy: 0.6544 - val\_loss: 1.2064 - val\_f1\_score: 0.5333 - val\_accuracy: 0.5700

Epoch 55/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8972 - f1\_score: 0.6284 - accuracy: 0.6616 - val\_loss: 1.2077 - val\_f1\_score: 0.5297 - val\_accuracy: 0.5830

Epoch 56/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8965 - f1\_score: 0.6210 - accuracy: 0.6554 - val\_loss: 1.2184 - val\_f1\_score: 0.5296 - val\_accuracy: 0.5820

Epoch 57/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8965 - f1\_score: 0.6203 - accuracy: 0.6552 - val\_loss: 1.2101 - val\_f1\_score: 0.5354 - val\_accuracy: 0.5710

Epoch 58/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8944 - f1\_score: 0.6205 - accuracy: 0.6560 - val\_loss: 1.2145 - val\_f1\_score: 0.5443 - val\_accuracy: 0.5690

Epoch 59/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8956 - f1\_score: 0.6228 - accuracy: 0.6564 - val\_loss:



```
s: 1.2207 - val_f1_score: 0.5246 - val_accuracy: 0.5770
Epoch 60/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8969 - f1_score: 0.6164 - accuracy: 0.6528 - val_loss: 1.2141 - val_f1_score: 0.5331 - val_accuracy: 0.5700
Epoch 61/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8951 - f1_score: 0.6221 - accuracy: 0.6538 - val_loss: 1.2203 - val_f1_score: 0.5269 - val_accuracy: 0.5790
Epoch 62/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8954 - f1_score: 0.6214 - accuracy: 0.6558 - val_loss: 1.2165 - val_f1_score: 0.5313 - val_accuracy: 0.5790
Epoch 63/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8933 - f1_score: 0.6253 - accuracy: 0.6604 - val_loss: 1.2166 - val_f1_score: 0.5343 - val_accuracy: 0.5840
Epoch 64/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8931 - f1_score: 0.6236 - accuracy: 0.6572 - val_loss: 1.2365 - val_f1_score: 0.5424 - val_accuracy: 0.5590
Epoch 65/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8947 - f1_score: 0.6279 - accuracy: 0.6592 - val_loss: 1.2153 - val_f1_score: 0.5338 - val_accuracy: 0.5760
Epoch 66/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8926 - f1_score: 0.6218 - accuracy: 0.6568 - val_loss: 1.2207 - val_f1_score: 0.5311 - val_accuracy: 0.5750
Epoch 67/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8917 - f1_score: 0.6272 - accuracy: 0.6598 - val_loss: 1.2195 - val_f1_score: 0.5332 - val_accuracy: 0.5810
Epoch 68/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8933 - f1_score: 0.6222 - accuracy: 0.6558 - val_loss: 1.2235 - val_f1_score: 0.5438 - val_accuracy: 0.5730
Epoch 69/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8916 - f1_score: 0.6252 - accuracy: 0.6582 - val_loss: 1.2231 - val_f1_score: 0.5346 - val_accuracy: 0.5660
Epoch 70/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8909 - f1_score: 0.6292 - accuracy: 0.6610 - val_loss: 1.2240 - val_f1_score: 0.5317 - val_accuracy: 0.5760
Epoch 71/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8913 - f1_score: 0.6276 - accuracy: 0.6604 - val_loss: 1.2322 - val_f1_score: 0.5482 - val_accuracy: 0.5820
Epoch 72/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8905 - f1_score: 0.6256 - accuracy: 0.6570 - val_loss: 1.2325 - val_f1_score: 0.5269 - val_accuracy: 0.5770
Epoch 73/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8908 - f1_score: 0.6215 - accuracy: 0.6552 - val_loss: 1.2259 - val_f1_score: 0.5313 - val_accuracy: 0.5720
Epoch 74/2000
```

157/157 [=====] - 0s 1ms/step - loss: 0.8885 - f1\_score: 0.6295 - accuracy: 0.6602 - val\_loss: 1.2287 - val\_f1\_score: 0.5337 - val\_accuracy: 0.5800  
Epoch 75/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8903 - f1\_score: 0.6259 - accuracy: 0.6578 - val\_loss: 1.2311 - val\_f1\_score: 0.5429 - val\_accuracy: 0.5760  
Epoch 76/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8893 - f1\_score: 0.6242 - accuracy: 0.6566 - val\_loss: 1.2323 - val\_f1\_score: 0.5228 - val\_accuracy: 0.5760  
Epoch 77/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8893 - f1\_score: 0.6272 - accuracy: 0.6590 - val\_loss: 1.2343 - val\_f1\_score: 0.5259 - val\_accuracy: 0.5780  
Epoch 78/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8881 - f1\_score: 0.6250 - accuracy: 0.6580 - val\_loss: 1.2325 - val\_f1\_score: 0.5274 - val\_accuracy: 0.5660  
Epoch 79/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8913 - f1\_score: 0.6250 - accuracy: 0.6566 - val\_loss: 1.2320 - val\_f1\_score: 0.5291 - val\_accuracy: 0.5710  
Epoch 80/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8887 - f1\_score: 0.6328 - accuracy: 0.6630 - val\_loss: 1.2314 - val\_f1\_score: 0.5339 - val\_accuracy: 0.5740  
Epoch 81/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8893 - f1\_score: 0.6284 - accuracy: 0.6600 - val\_loss: 1.2347 - val\_f1\_score: 0.5399 - val\_accuracy: 0.5660  
Epoch 82/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8866 - f1\_score: 0.6268 - accuracy: 0.6590 - val\_loss: 1.2440 - val\_f1\_score: 0.5238 - val\_accuracy: 0.5670  
Epoch 83/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8883 - f1\_score: 0.6263 - accuracy: 0.6610 - val\_loss: 1.2483 - val\_f1\_score: 0.5378 - val\_accuracy: 0.5620  
Epoch 84/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8867 - f1\_score: 0.6308 - accuracy: 0.6616 - val\_loss: 1.2455 - val\_f1\_score: 0.5243 - val\_accuracy: 0.5780  
Epoch 85/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8880 - f1\_score: 0.6312 - accuracy: 0.6622 - val\_loss: 1.2411 - val\_f1\_score: 0.5313 - val\_accuracy: 0.5710  
Epoch 86/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8855 - f1\_score: 0.6293 - accuracy: 0.6600 - val\_loss: 1.2406 - val\_f1\_score: 0.5264 - val\_accuracy: 0.5680  
Epoch 87/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8868 - f1\_score: 0.6303 - accuracy: 0.6624 - val\_loss: 1.2384 - val\_f1\_score: 0.5347 - val\_accuracy: 0.5660  
Epoch 88/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8849 - f1\_score: 0.6321 - accuracy: 0.6624 - val\_loss: 1.2387 - val\_f1\_score: 0.5338 - val\_accuracy: 0.5720

Epoch 89/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8863 - f1\_score: 0.6285 - accuracy: 0.6598 - val\_loss: 1.2427 - val\_f1\_score: 0.5346 - val\_accuracy: 0.5660  
Epoch 90/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8873 - f1\_score: 0.6244 - accuracy: 0.6566 - val\_loss: 1.2485 - val\_f1\_score: 0.5244 - val\_accuracy: 0.5640  
Epoch 91/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8857 - f1\_score: 0.6304 - accuracy: 0.6612 - val\_loss: 1.2414 - val\_f1\_score: 0.5271 - val\_accuracy: 0.5690  
Epoch 92/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8849 - f1\_score: 0.6237 - accuracy: 0.6568 - val\_loss: 1.2436 - val\_f1\_score: 0.5391 - val\_accuracy: 0.5740  
Epoch 93/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8850 - f1\_score: 0.6298 - accuracy: 0.6600 - val\_loss: 1.2490 - val\_f1\_score: 0.5268 - val\_accuracy: 0.5690  
Epoch 94/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8861 - f1\_score: 0.6252 - accuracy: 0.6580 - val\_loss: 1.2474 - val\_f1\_score: 0.5357 - val\_accuracy: 0.5710  
Epoch 95/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8831 - f1\_score: 0.6302 - accuracy: 0.6630 - val\_loss: 1.2440 - val\_f1\_score: 0.5368 - val\_accuracy: 0.5650  
Epoch 96/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8838 - f1\_score: 0.6297 - accuracy: 0.6606 - val\_loss: 1.2448 - val\_f1\_score: 0.5281 - val\_accuracy: 0.5660  
Epoch 97/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8838 - f1\_score: 0.6274 - accuracy: 0.6578 - val\_loss: 1.2483 - val\_f1\_score: 0.5394 - val\_accuracy: 0.5710  
Epoch 98/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8838 - f1\_score: 0.6309 - accuracy: 0.6620 - val\_loss: 1.2488 - val\_f1\_score: 0.5239 - val\_accuracy: 0.5700  
Epoch 99/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8831 - f1\_score: 0.6315 - accuracy: 0.6620 - val\_loss: 1.2483 - val\_f1\_score: 0.5213 - val\_accuracy: 0.5650  
Epoch 100/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8833 - f1\_score: 0.6303 - accuracy: 0.6604 - val\_loss: 1.2506 - val\_f1\_score: 0.5283 - val\_accuracy: 0.5700  
Epoch 101/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8821 - f1\_score: 0.6278 - accuracy: 0.6584 - val\_loss: 1.2497 - val\_f1\_score: 0.5305 - val\_accuracy: 0.5640  
Epoch 102/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8844 - f1\_score: 0.6335 - accuracy: 0.6634 - val\_loss: 1.2499 - val\_f1\_score: 0.5273 - val\_accuracy: 0.5680  
Epoch 103/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8839 - f1\_score: 0.6279 - accuracy: 0.6594 - val\_loss:

```
s: 1.2493 - val_f1_score: 0.5336 - val_accuracy: 0.5760
Epoch 104/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8845 - f1_score: 0.6304 - accuracy: 0.6614 - val_loss: 1.2520 - val_f1_score: 0.5309 - val_accuracy: 0.5710
Epoch 105/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8859 - f1_score: 0.6265 - accuracy: 0.6580 - val_loss: 1.2581 - val_f1_score: 0.5227 - val_accuracy: 0.5800
Epoch 106/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8849 - f1_score: 0.6271 - accuracy: 0.6588 - val_loss: 1.2523 - val_f1_score: 0.5294 - val_accuracy: 0.5690
Epoch 107/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8827 - f1_score: 0.6313 - accuracy: 0.6620 - val_loss: 1.2510 - val_f1_score: 0.5348 - val_accuracy: 0.5640
Epoch 108/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8822 - f1_score: 0.6303 - accuracy: 0.6612 - val_loss: 1.2575 - val_f1_score: 0.5376 - val_accuracy: 0.5660
Epoch 109/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8818 - f1_score: 0.6320 - accuracy: 0.6624 - val_loss: 1.2578 - val_f1_score: 0.5270 - val_accuracy: 0.5600
Epoch 110/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8817 - f1_score: 0.6313 - accuracy: 0.6614 - val_loss: 1.2538 - val_f1_score: 0.5294 - val_accuracy: 0.5660
Epoch 111/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8819 - f1_score: 0.6299 - accuracy: 0.6608 - val_loss: 1.2578 - val_f1_score: 0.5357 - val_accuracy: 0.5660
Epoch 112/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8826 - f1_score: 0.6301 - accuracy: 0.6608 - val_loss: 1.2563 - val_f1_score: 0.5259 - val_accuracy: 0.5640
Epoch 113/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8808 - f1_score: 0.6306 - accuracy: 0.6622 - val_loss: 1.2584 - val_f1_score: 0.5417 - val_accuracy: 0.5790
Epoch 114/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8820 - f1_score: 0.6307 - accuracy: 0.6610 - val_loss: 1.2580 - val_f1_score: 0.5262 - val_accuracy: 0.5650
Epoch 115/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8823 - f1_score: 0.6287 - accuracy: 0.6598 - val_loss: 1.2581 - val_f1_score: 0.5402 - val_accuracy: 0.5700
Epoch 116/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8796 - f1_score: 0.6285 - accuracy: 0.6598 - val_loss: 1.2597 - val_f1_score: 0.5307 - val_accuracy: 0.5690
Epoch 117/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8820 - f1_score: 0.6351 - accuracy: 0.6634 - val_loss: 1.2583 - val_f1_score: 0.5355 - val_accuracy: 0.5630
Epoch 118/2000
```

157/157 [=====] - 0s 1ms/step - loss: 0.8852 - f1\_score: 0.6335 - accuracy: 0.6628 - val\_loss: 1.2686 - val\_f1\_score: 0.5384 - val\_accuracy: 0.5550  
Epoch 119/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8812 - f1\_score: 0.6349 - accuracy: 0.6628 - val\_loss: 1.2664 - val\_f1\_score: 0.5289 - val\_accuracy: 0.5710  
Epoch 120/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8816 - f1\_score: 0.6285 - accuracy: 0.6594 - val\_loss: 1.2643 - val\_f1\_score: 0.5319 - val\_accuracy: 0.5650  
Epoch 121/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8808 - f1\_score: 0.6296 - accuracy: 0.6600 - val\_loss: 1.2609 - val\_f1\_score: 0.5376 - val\_accuracy: 0.5640  
Epoch 122/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8801 - f1\_score: 0.6319 - accuracy: 0.6624 - val\_loss: 1.2608 - val\_f1\_score: 0.5322 - val\_accuracy: 0.5690  
Epoch 123/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8794 - f1\_score: 0.6324 - accuracy: 0.6626 - val\_loss: 1.2633 - val\_f1\_score: 0.5318 - val\_accuracy: 0.5660  
Epoch 124/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8788 - f1\_score: 0.6272 - accuracy: 0.6586 - val\_loss: 1.2626 - val\_f1\_score: 0.5374 - val\_accuracy: 0.5640  
Epoch 125/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8785 - f1\_score: 0.6330 - accuracy: 0.6618 - val\_loss: 1.2612 - val\_f1\_score: 0.5331 - val\_accuracy: 0.5680  
Epoch 126/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8798 - f1\_score: 0.6365 - accuracy: 0.6652 - val\_loss: 1.2694 - val\_f1\_score: 0.5172 - val\_accuracy: 0.5680  
Epoch 127/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8831 - f1\_score: 0.6273 - accuracy: 0.6580 - val\_loss: 1.2682 - val\_f1\_score: 0.5162 - val\_accuracy: 0.5650  
Epoch 128/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8797 - f1\_score: 0.6279 - accuracy: 0.6596 - val\_loss: 1.2632 - val\_f1\_score: 0.5439 - val\_accuracy: 0.5710  
Epoch 129/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8792 - f1\_score: 0.6307 - accuracy: 0.6614 - val\_loss: 1.2613 - val\_f1\_score: 0.5323 - val\_accuracy: 0.5720  
Epoch 130/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8811 - f1\_score: 0.6337 - accuracy: 0.6630 - val\_loss: 1.2697 - val\_f1\_score: 0.5282 - val\_accuracy: 0.5780  
Epoch 131/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8802 - f1\_score: 0.6287 - accuracy: 0.6596 - val\_loss: 1.2660 - val\_f1\_score: 0.5347 - val\_accuracy: 0.5600  
Epoch 132/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8794 - f1\_score: 0.6295 - accuracy: 0.6602 - val\_loss: 1.2732 - val\_f1\_score: 0.5331 - val\_accuracy: 0.5580

Epoch 133/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8787 - f1\_score: 0.6364 - accuracy: 0.6654 - val\_loss: 1.2691 - val\_f1\_score: 0.5222 - val\_accuracy: 0.5610  
Epoch 134/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8800 - f1\_score: 0.6333 - accuracy: 0.6624 - val\_loss: 1.2710 - val\_f1\_score: 0.5359 - val\_accuracy: 0.5670  
Epoch 135/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8805 - f1\_score: 0.6344 - accuracy: 0.6640 - val\_loss: 1.2683 - val\_f1\_score: 0.5333 - val\_accuracy: 0.5590  
Epoch 136/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8790 - f1\_score: 0.6382 - accuracy: 0.6672 - val\_loss: 1.2667 - val\_f1\_score: 0.5233 - val\_accuracy: 0.5580  
Epoch 137/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8786 - f1\_score: 0.6327 - accuracy: 0.6620 - val\_loss: 1.2709 - val\_f1\_score: 0.5259 - val\_accuracy: 0.5730  
Epoch 138/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8785 - f1\_score: 0.6309 - accuracy: 0.6624 - val\_loss: 1.2824 - val\_f1\_score: 0.5348 - val\_accuracy: 0.5600  
Epoch 139/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8801 - f1\_score: 0.6333 - accuracy: 0.6616 - val\_loss: 1.2720 - val\_f1\_score: 0.5279 - val\_accuracy: 0.5660  
Epoch 140/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8794 - f1\_score: 0.6288 - accuracy: 0.6596 - val\_loss: 1.2775 - val\_f1\_score: 0.5294 - val\_accuracy: 0.5580  
Epoch 141/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8781 - f1\_score: 0.6308 - accuracy: 0.6604 - val\_loss: 1.2679 - val\_f1\_score: 0.5236 - val\_accuracy: 0.5620  
Epoch 142/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8780 - f1\_score: 0.6327 - accuracy: 0.6622 - val\_loss: 1.2763 - val\_f1\_score: 0.5308 - val\_accuracy: 0.5760  
Epoch 143/2000  
157/157 [=====] - 0s 2ms/step - loss: 0.8796 - f1\_score: 0.6306 - accuracy: 0.6610 - val\_loss: 1.2718 - val\_f1\_score: 0.5357 - val\_accuracy: 0.5630  
Epoch 144/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8801 - f1\_score: 0.6288 - accuracy: 0.6576 - val\_loss: 1.2714 - val\_f1\_score: 0.5321 - val\_accuracy: 0.5680  
Epoch 145/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8772 - f1\_score: 0.6348 - accuracy: 0.6640 - val\_loss: 1.2765 - val\_f1\_score: 0.5216 - val\_accuracy: 0.5720  
Epoch 146/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8801 - f1\_score: 0.6286 - accuracy: 0.6590 - val\_loss: 1.2755 - val\_f1\_score: 0.5209 - val\_accuracy: 0.5610  
Epoch 147/2000  
157/157 [=====] - 0s 1ms/step - loss: 0.8781 - f1\_score: 0.6293 - accuracy: 0.6602 - val\_loss:

```
s: 1.2774 - val_f1_score: 0.5353 - val_accuracy: 0.5620
Epoch 148/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8770 - f1_score: 0.6362 - accuracy: 0.6648 - val_loss: 1.2757 - val_f1_score: 0.5191 - val_accuracy: 0.5580
Epoch 149/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8796 - f1_score: 0.6303 - accuracy: 0.6604 - val_loss: 1.2725 - val_f1_score: 0.5376 - val_accuracy: 0.5690
Epoch 150/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8776 - f1_score: 0.6321 - accuracy: 0.6608 - val_loss: 1.2746 - val_f1_score: 0.5357 - val_accuracy: 0.5670
Epoch 151/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8751 - f1_score: 0.6356 - accuracy: 0.6656 - val_loss: 1.2760 - val_f1_score: 0.5264 - val_accuracy: 0.5640
Epoch 152/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8785 - f1_score: 0.6317 - accuracy: 0.6622 - val_loss: 1.2750 - val_f1_score: 0.5277 - val_accuracy: 0.5560
Epoch 153/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8781 - f1_score: 0.6348 - accuracy: 0.6622 - val_loss: 1.2732 - val_f1_score: 0.5308 - val_accuracy: 0.5640
Epoch 154/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8791 - f1_score: 0.6303 - accuracy: 0.6594 - val_loss: 1.2765 - val_f1_score: 0.5366 - val_accuracy: 0.5590
Epoch 155/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8753 - f1_score: 0.6329 - accuracy: 0.6624 - val_loss: 1.2751 - val_f1_score: 0.5210 - val_accuracy: 0.5640
Epoch 156/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8781 - f1_score: 0.6331 - accuracy: 0.6638 - val_loss: 1.2792 - val_f1_score: 0.5360 - val_accuracy: 0.5580
Epoch 157/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8774 - f1_score: 0.6337 - accuracy: 0.6622 - val_loss: 1.2759 - val_f1_score: 0.5264 - val_accuracy: 0.5650
Epoch 158/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8768 - f1_score: 0.6363 - accuracy: 0.6658 - val_loss: 1.2826 - val_f1_score: 0.5390 - val_accuracy: 0.5590
Epoch 159/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8781 - f1_score: 0.6361 - accuracy: 0.6632 - val_loss: 1.2808 - val_f1_score: 0.5178 - val_accuracy: 0.5610
Epoch 160/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8784 - f1_score: 0.6325 - accuracy: 0.6628 - val_loss: 1.2743 - val_f1_score: 0.5293 - val_accuracy: 0.5680
Epoch 161/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8772 - f1_score: 0.6367 - accuracy: 0.6654 - val_loss: 1.2816 - val_f1_score: 0.5199 - val_accuracy: 0.5570
Epoch 162/2000
```

```

157/157 [=====] - 0s 1ms/step - loss: 0.8767 - f1_score: 0.6339 - accuracy: 0.6650 - val_loss: 1.2764 - val_f1_score: 0.5267 - val_accuracy: 0.5660
Epoch 163/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8762 - f1_score: 0.6326 - accuracy: 0.6612 - val_loss: 1.2789 - val_f1_score: 0.5215 - val_accuracy: 0.5610
Epoch 164/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8750 - f1_score: 0.6313 - accuracy: 0.6614 - val_loss: 1.2777 - val_f1_score: 0.5297 - val_accuracy: 0.5730
Epoch 165/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8760 - f1_score: 0.6332 - accuracy: 0.6622 - val_loss: 1.2797 - val_f1_score: 0.5308 - val_accuracy: 0.5760
Epoch 166/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8756 - f1_score: 0.6287 - accuracy: 0.6590 - val_loss: 1.2814 - val_f1_score: 0.5342 - val_accuracy: 0.5580
Epoch 167/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8778 - f1_score: 0.6364 - accuracy: 0.6648 - val_loss: 1.2813 - val_f1_score: 0.5316 - val_accuracy: 0.5580
Epoch 168/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8773 - f1_score: 0.6332 - accuracy: 0.6622 - val_loss: 1.2810 - val_f1_score: 0.5202 - val_accuracy: 0.5720
Epoch 169/2000
157/157 [=====] - 0s 2ms/step - loss: 0.8771 - f1_score: 0.6315 - accuracy: 0.6618 - val_loss: 1.2779 - val_f1_score: 0.5274 - val_accuracy: 0.5650
Epoch 170/2000
157/157 [=====] - 0s 1ms/step - loss: 0.8753 - f1_score: 0.6302 - accuracy: 0.6608 - val_loss: 1.2833 - val_f1_score: 0.5340 - val_accuracy: 0.5550
Epoch 171/2000
130/157 [=====>.....] - ETA: 0s - loss: 0.8760 - f1_score: 0.6448 - accuracy: 0.6733Restoring model weights from the end of the best epoch: 71.
157/157 [=====] - 0s 1ms/step - loss: 0.8763 - f1_score: 0.6411 - accuracy: 0.6696 - val_loss: 1.2803 - val_f1_score: 0.5354 - val_accuracy: 0.5650
Epoch 00171: early stopping

```

In [ ]:

```

# Babysit the model
px.line(
    pd.DataFrame(
        {
            "loss": history.history["loss"],
            "val_loss": history.history["val_loss"],
            "f1_score": history.history["f1_score"],
            "val_f1_score": history.history["val_f1_score"],
            "accuracy": history.history["accuracy"],
            "val_accuracy": history.history["val_accuracy"],

```



```

    }
)
)

```

```

In [ ]: # Evaluate the model
        model.evaluate(vectorizer(X_test), y_test_ohe)

```

```

Out[ ]: 32/32 [=====] - 0s 887us/step - loss: 1.2322 - f1_score: 0.5482 - accuracy: 0.5820
        [1.2321563959121704, 0.5482052564620972, 0.5820000171661377]

```

## Approach3 (bis) - Word embedding and MLP classifier

Using the course companion notebook, build a multi-layer perceptron using an existing embedding matrix (Word2Vec / Glove or FastText), or on an embedding matrix that you will have built using Gensim.

Use the same constant as a previous steps.

Evaluate the model.

```

In [ ]: # Build gensim model
import gensim
from gensim.test.utils import datapath
from gensim import utils
import gensim.models

gensim_path = f"{gensim.__path__[0]}/test/test_data/"
corpus = "lee_background.cor"
corpus_path = gensim_path + corpus

class MyCorpus:
    """An iterator that yields sentences (lists of str)."""

    def __iter__(self):
        for line in open(corpus_path):
            # assume there's one document per line, tokens separated by whitespace
            yield utils.simple_preprocess(line)

```

```
sentences = MyCorpus()
model = gensim.models.Word2Vec(sentences=sentences, vector_size=150)
```

```
In [ ]: # Export gensim model
import tempfile

with tempfile.NamedTemporaryFile(prefix="gensim-model-", delete=False) as tmp:
    temporary_filepath = tmp.name
    print(temporary_filepath)
    model.save(temporary_filepath)
    #
    # The model is now safely stored in the filepath.
    # You can copy it to other machines, share it with others, etc.
    #
    # To load a saved model:
    #
    new_model = gensim.models.Word2Vec.load(temporary_filepath)
```

/tmp/gensim-model-ylf38uv3

```
In [ ]: # Load gensim model
new_model = gensim.models.Word2Vec.load(temporary_filepath)
```

```
In [ ]: # Prepare embedding matrix
num_tokens = len(voc) + 2
embedding_dim = 150
hits = 0
misses = 0

# Prepare embedding matrix
embedding_matrix = np.zeros((num_tokens, embedding_dim))
for word, i in word_index.items():
    try:
        model.wv[word]
        # Words not found in embedding index will be all-zeros.
        # This includes the representation for "padding" and "OOV"
        embedding_matrix[i] = model.wv[word]
        hits += 1
    except :
```

```

        misses += 1
    print("Converted %d words (%d misses)" % (hits, misses))

```

Converted 1083 words (9919 misses)

In [ ]:

```

# Define embedding layers
embedding_layer = Embedding(
    num_tokens,
    embedding_dim,
    embeddings_initializer=tf.keras.initializers.Constant(embedding_matrix),
    trainable=False,
)

```

In [ ]:

```

# define the model
input_ = Input(shape=(max_len,), dtype=tf.int32)
x = embedding_layer(input_)
x = Flatten()(x)
output_ = Dense(5, activation='sigmoid')(x)
model = Model(input_, output_)
# summarize the model
model.summary()

```

Model: "model\_1"

Layer (type)	Output Shape	Param #
=====		
input_4 (InputLayer)	[(None, 10)]	0
embedding_3 (Embedding)	(None, 10, 150)	1650600
flatten_3 (Flatten)	(None, 1500)	0
dense_6 (Dense)	(None, 5)	7505
=====		
Total params: 1,658,105		
Trainable params: 7,505		
Non-trainable params: 1,650,600		

In [ ]:

```

# compile the model

```

```
model.compile(
    optimizer="adam",
    loss="categorical_crossentropy",
    metrics=["accuracy", f1],
)

# define early stopping
early_stop = EarlyStopping(
    monitor="val_f1_score",
    patience=100,
    verbose=1,
    restore_best_weights=True,
    mode="max",
)

# fit model using ealy stopping
history = model.fit(
    x=vectorizer(X_train),
    y=y_train_ohe,
    epochs=2000,
    verbose=1,
    validation_data=(vectorizer(X_test), y_test_ohe),
    callbacks=[early_stop],
    workers=6,
    use_multiprocessing=True,
)
```

Epoch 1/2000  
157/157 [=====] - 1s 3ms/step - loss: 1.2221 - accuracy: 0.5424 - f1\_score: 0.4302 - val\_loss: 1.2033 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4037

Epoch 2/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2244 - accuracy: 0.5384 - f1\_score: 0.4154 - val\_loss: 1.2292 - val\_accuracy: 0.5480 - val\_f1\_score: 0.4507

Epoch 3/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2230 - accuracy: 0.5392 - f1\_score: 0.4156 - val\_loss: 1.2014 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4093

Epoch 4/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2275 - accuracy: 0.5380 - f1\_score: 0.4153 - val\_loss: 1.2129 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4173

Epoch 5/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2241 - accuracy: 0.5426 - f1\_score: 0.4197 - val\_loss: 1.1941 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4442

Epoch 6/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2220 - accuracy: 0.5352 - f1\_score: 0.4146 - val\_loss: 1.2081 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4462

Epoch 7/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2218 - accuracy: 0.5428 - f1\_score: 0.4177 - val\_loss: 1.2064 - val\_accuracy: 0.5470 - val\_f1\_score: 0.4464

Epoch 8/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2211 - accuracy: 0.5434 - f1\_score: 0.4180 - val\_loss: 1.1962 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4266

Epoch 9/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2222 - accuracy: 0.5386 - f1\_score: 0.4165 - val\_loss: 1.2020 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4236

Epoch 10/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2229 - accuracy: 0.5414 - f1\_score: 0.4231 - val\_loss: 1.1977 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4119

Epoch 11/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2198 - accuracy: 0.5406 - f1\_score: 0.4156 - val\_loss: 1.1999 - val\_accuracy: 0.5490 - val\_f1\_score: 0.4185

Epoch 12/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2202 - accuracy: 0.5412 - f1\_score: 0.4227 - val\_loss: 1.2030 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4324

Epoch 13/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2229 - accuracy: 0.5378 - f1\_score: 0.4148 - val\_loss: 1.2209 - val\_accuracy: 0.5190 - val\_f1\_score: 0.4435

Epoch 14/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2211 - accuracy: 0.5396 - f1\_score: 0.4172 - val\_loss: 1.2056 - val\_accuracy: 0.5560 - val\_f1\_score: 0.3998

Epoch 15/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2190 - accuracy: 0.5416 - f1\_score: 0.4217 - val\_loss:

s: 1.1972 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4149  
Epoch 16/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2253 - accuracy: 0.5370 - f1\_score: 0.4131 - val\_loss: 1.2121 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4566  
Epoch 17/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2196 - accuracy: 0.5394 - f1\_score: 0.4154 - val\_loss: 1.1990 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4262  
Epoch 18/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2235 - accuracy: 0.5344 - f1\_score: 0.4158 - val\_loss: 1.1968 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4003  
Epoch 19/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2246 - accuracy: 0.5404 - f1\_score: 0.4154 - val\_loss: 1.2012 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4408  
Epoch 20/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2253 - accuracy: 0.5368 - f1\_score: 0.4191 - val\_loss: 1.1976 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4166  
Epoch 21/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2217 - accuracy: 0.5404 - f1\_score: 0.4194 - val\_loss: 1.2095 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4310  
Epoch 22/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2177 - accuracy: 0.5418 - f1\_score: 0.4212 - val\_loss: 1.2059 - val\_accuracy: 0.5450 - val\_f1\_score: 0.4482  
Epoch 23/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2247 - accuracy: 0.5406 - f1\_score: 0.4162 - val\_loss: 1.1987 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4339  
Epoch 24/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2210 - accuracy: 0.5414 - f1\_score: 0.4190 - val\_loss: 1.1994 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4221  
Epoch 25/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2223 - accuracy: 0.5406 - f1\_score: 0.4197 - val\_loss: 1.1912 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4139  
Epoch 26/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2207 - accuracy: 0.5416 - f1\_score: 0.4182 - val\_loss: 1.1981 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4475  
Epoch 27/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2166 - accuracy: 0.5388 - f1\_score: 0.4156 - val\_loss: 1.2142 - val\_accuracy: 0.5510 - val\_f1\_score: 0.4343  
Epoch 28/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2230 - accuracy: 0.5416 - f1\_score: 0.4206 - val\_loss: 1.2094 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4275  
Epoch 29/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2184 - accuracy: 0.5398 - f1\_score: 0.4188 - val\_loss: 1.2039 - val\_accuracy: 0.5510 - val\_f1\_score: 0.4354  
Epoch 30/2000

```
157/157 [=====] - 0s 2ms/step - loss: 1.2229 - accuracy: 0.5390 - f1_score: 0.4173 - val_loss: 1.2041 - val_accuracy: 0.5600 - val_f1_score: 0.4205
Epoch 31/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2205 - accuracy: 0.5384 - f1_score: 0.4150 - val_loss: 1.2164 - val_accuracy: 0.5580 - val_f1_score: 0.4392
Epoch 32/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2220 - accuracy: 0.5416 - f1_score: 0.4195 - val_loss: 1.1969 - val_accuracy: 0.5550 - val_f1_score: 0.4351
Epoch 33/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2198 - accuracy: 0.5400 - f1_score: 0.4194 - val_loss: 1.1975 - val_accuracy: 0.5590 - val_f1_score: 0.4494
Epoch 34/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2200 - accuracy: 0.5406 - f1_score: 0.4186 - val_loss: 1.1963 - val_accuracy: 0.5560 - val_f1_score: 0.4410
Epoch 35/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2158 - accuracy: 0.5440 - f1_score: 0.4191 - val_loss: 1.1960 - val_accuracy: 0.5570 - val_f1_score: 0.4199
Epoch 36/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2202 - accuracy: 0.5412 - f1_score: 0.4226 - val_loss: 1.2056 - val_accuracy: 0.5560 - val_f1_score: 0.3973
Epoch 37/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2199 - accuracy: 0.5396 - f1_score: 0.4203 - val_loss: 1.2109 - val_accuracy: 0.5560 - val_f1_score: 0.4240
Epoch 38/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2218 - accuracy: 0.5418 - f1_score: 0.4196 - val_loss: 1.2080 - val_accuracy: 0.5600 - val_f1_score: 0.4466
Epoch 39/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2185 - accuracy: 0.5440 - f1_score: 0.4242 - val_loss: 1.2014 - val_accuracy: 0.5570 - val_f1_score: 0.4605
Epoch 40/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2225 - accuracy: 0.5366 - f1_score: 0.4181 - val_loss: 1.1906 - val_accuracy: 0.5610 - val_f1_score: 0.4214
Epoch 41/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2165 - accuracy: 0.5406 - f1_score: 0.4140 - val_loss: 1.1995 - val_accuracy: 0.5530 - val_f1_score: 0.4263
Epoch 42/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2179 - accuracy: 0.5396 - f1_score: 0.4140 - val_loss: 1.2195 - val_accuracy: 0.5410 - val_f1_score: 0.4496
Epoch 43/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2202 - accuracy: 0.5406 - f1_score: 0.4204 - val_loss: 1.2098 - val_accuracy: 0.5560 - val_f1_score: 0.3976
Epoch 44/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2199 - accuracy: 0.5394 - f1_score: 0.4191 - val_loss: 1.1968 - val_accuracy: 0.5520 - val_f1_score: 0.4158
```

Epoch 45/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2192 - accuracy: 0.5412 - f1\_score: 0.4193 - val\_loss: 1.1908 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4265  
Epoch 46/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2176 - accuracy: 0.5402 - f1\_score: 0.4196 - val\_loss: 1.1996 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4194  
Epoch 47/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2157 - accuracy: 0.5412 - f1\_score: 0.4208 - val\_loss: 1.1952 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4124  
Epoch 48/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2186 - accuracy: 0.5404 - f1\_score: 0.4216 - val\_loss: 1.2189 - val\_accuracy: 0.5560 - val\_f1\_score: 0.3973  
Epoch 49/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2192 - accuracy: 0.5414 - f1\_score: 0.4168 - val\_loss: 1.1938 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4399  
Epoch 50/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2189 - accuracy: 0.5450 - f1\_score: 0.4282 - val\_loss: 1.2028 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4358  
Epoch 51/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2208 - accuracy: 0.5352 - f1\_score: 0.4169 - val\_loss: 1.1906 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4332  
Epoch 52/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2183 - accuracy: 0.5384 - f1\_score: 0.4156 - val\_loss: 1.1952 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4199  
Epoch 53/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2182 - accuracy: 0.5430 - f1\_score: 0.4226 - val\_loss: 1.2004 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4277  
Epoch 54/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2150 - accuracy: 0.5448 - f1\_score: 0.4202 - val\_loss: 1.1971 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4421  
Epoch 55/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2216 - accuracy: 0.5392 - f1\_score: 0.4236 - val\_loss: 1.1954 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4325  
Epoch 56/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2189 - accuracy: 0.5408 - f1\_score: 0.4225 - val\_loss: 1.1995 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4403  
Epoch 57/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2202 - accuracy: 0.5406 - f1\_score: 0.4203 - val\_loss: 1.1998 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4390  
Epoch 58/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2174 - accuracy: 0.5420 - f1\_score: 0.4241 - val\_loss: 1.1951 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4588  
Epoch 59/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2208 - accuracy: 0.5424 - f1\_score: 0.4213 - val\_loss:



s: 1.1989 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4149  
Epoch 60/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2175 - accuracy: 0.5438 - f1\_score: 0.4194 - val\_loss: 1.2127 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4305  
Epoch 61/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2127 - accuracy: 0.5452 - f1\_score: 0.4221 - val\_loss: 1.2056 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4205  
Epoch 62/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2165 - accuracy: 0.5418 - f1\_score: 0.4226 - val\_loss: 1.1996 - val\_accuracy: 0.5520 - val\_f1\_score: 0.4263  
Epoch 63/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2140 - accuracy: 0.5414 - f1\_score: 0.4182 - val\_loss: 1.1954 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4445  
Epoch 64/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2182 - accuracy: 0.5418 - f1\_score: 0.4239 - val\_loss: 1.2287 - val\_accuracy: 0.5280 - val\_f1\_score: 0.4472  
Epoch 65/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2162 - accuracy: 0.5378 - f1\_score: 0.4204 - val\_loss: 1.1987 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4281  
Epoch 66/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2145 - accuracy: 0.5424 - f1\_score: 0.4182 - val\_loss: 1.2092 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4492  
Epoch 67/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2204 - accuracy: 0.5418 - f1\_score: 0.4215 - val\_loss: 1.1958 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4132  
Epoch 68/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2166 - accuracy: 0.5400 - f1\_score: 0.4233 - val\_loss: 1.2254 - val\_accuracy: 0.5270 - val\_f1\_score: 0.4491  
Epoch 69/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2199 - accuracy: 0.5380 - f1\_score: 0.4218 - val\_loss: 1.1970 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4108  
Epoch 70/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2176 - accuracy: 0.5450 - f1\_score: 0.4258 - val\_loss: 1.1923 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4561  
Epoch 71/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2168 - accuracy: 0.5396 - f1\_score: 0.4226 - val\_loss: 1.1924 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4474  
Epoch 72/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2190 - accuracy: 0.5416 - f1\_score: 0.4217 - val\_loss: 1.1970 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4288  
Epoch 73/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2178 - accuracy: 0.5390 - f1\_score: 0.4175 - val\_loss: 1.2050 - val\_accuracy: 0.5490 - val\_f1\_score: 0.4494  
Epoch 74/2000

157/157 [=====] - 0s 2ms/step - loss: 1.2224 - accuracy: 0.5398 - f1\_score: 0.4212 - val\_loss: 1.1907 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4213  
Epoch 75/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2154 - accuracy: 0.5386 - f1\_score: 0.4162 - val\_loss: 1.1960 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4442  
Epoch 76/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2153 - accuracy: 0.5398 - f1\_score: 0.4185 - val\_loss: 1.2016 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4248  
Epoch 77/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2179 - accuracy: 0.5402 - f1\_score: 0.4185 - val\_loss: 1.1958 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4330  
Epoch 78/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2112 - accuracy: 0.5450 - f1\_score: 0.4221 - val\_loss: 1.2060 - val\_accuracy: 0.5510 - val\_f1\_score: 0.4336  
Epoch 79/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2168 - accuracy: 0.5408 - f1\_score: 0.4166 - val\_loss: 1.2001 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4631  
Epoch 80/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2137 - accuracy: 0.5420 - f1\_score: 0.4200 - val\_loss: 1.1966 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4278  
Epoch 81/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2155 - accuracy: 0.5432 - f1\_score: 0.4183 - val\_loss: 1.1972 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4432  
Epoch 82/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2114 - accuracy: 0.5414 - f1\_score: 0.4198 - val\_loss: 1.2068 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4125  
Epoch 83/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2153 - accuracy: 0.5434 - f1\_score: 0.4231 - val\_loss: 1.1946 - val\_accuracy: 0.5540 - val\_f1\_score: 0.3975  
Epoch 84/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.2147 - accuracy: 0.5402 - f1\_score: 0.4218 - val\_loss: 1.2045 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4167  
Epoch 85/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2153 - accuracy: 0.5418 - f1\_score: 0.4168 - val\_loss: 1.2056 - val\_accuracy: 0.5500 - val\_f1\_score: 0.4181  
Epoch 86/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.2135 - accuracy: 0.5444 - f1\_score: 0.4235 - val\_loss: 1.1958 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4541  
Epoch 87/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.2139 - accuracy: 0.5440 - f1\_score: 0.4207 - val\_loss: 1.2023 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4211  
Epoch 88/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2153 - accuracy: 0.5406 - f1\_score: 0.4226 - val\_loss: 1.1921 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4213

Epoch 89/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.2153 - accuracy: 0.5418 - f1\_score: 0.4240 - val\_loss: 1.1953 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4144

Epoch 90/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2119 - accuracy: 0.5452 - f1\_score: 0.4286 - val\_loss: 1.2070 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4473

Epoch 91/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2190 - accuracy: 0.5436 - f1\_score: 0.4239 - val\_loss: 1.1948 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4036

Epoch 92/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2149 - accuracy: 0.5432 - f1\_score: 0.4227 - val\_loss: 1.1989 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4398

Epoch 93/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2132 - accuracy: 0.5436 - f1\_score: 0.4203 - val\_loss: 1.1883 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4220

Epoch 94/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2179 - accuracy: 0.5398 - f1\_score: 0.4226 - val\_loss: 1.2244 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4208

Epoch 95/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2122 - accuracy: 0.5398 - f1\_score: 0.4182 - val\_loss: 1.1944 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4231

Epoch 96/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.2151 - accuracy: 0.5426 - f1\_score: 0.4243 - val\_loss: 1.1937 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4184

Epoch 97/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2140 - accuracy: 0.5480 - f1\_score: 0.4307 - val\_loss: 1.1949 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4264

Epoch 98/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2136 - accuracy: 0.5402 - f1\_score: 0.4231 - val\_loss: 1.1977 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4280

Epoch 99/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2128 - accuracy: 0.5418 - f1\_score: 0.4191 - val\_loss: 1.1971 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4443

Epoch 100/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2148 - accuracy: 0.5412 - f1\_score: 0.4176 - val\_loss: 1.2179 - val\_accuracy: 0.5470 - val\_f1\_score: 0.4331

Epoch 101/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2111 - accuracy: 0.5468 - f1\_score: 0.4312 - val\_loss: 1.2018 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4496

Epoch 102/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2113 - accuracy: 0.5434 - f1\_score: 0.4231 - val\_loss: 1.2001 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4375

Epoch 103/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2128 - accuracy: 0.5454 - f1\_score: 0.4284 - val\_loss:

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s: 1.1890 - val_accuracy: 0.5550 - val_f1_score: 0.4226
Epoch 104/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2165 - accuracy: 0.5406 - f1_score: 0.4236 - val_loss: 1.1941 - val_accuracy: 0.5650 - val_f1_score: 0.4529
Epoch 105/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2144 - accuracy: 0.5444 - f1_score: 0.4199 - val_loss: 1.1908 - val_accuracy: 0.5550 - val_f1_score: 0.4210
Epoch 106/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2108 - accuracy: 0.5458 - f1_score: 0.4209 - val_loss: 1.1951 - val_accuracy: 0.5570 - val_f1_score: 0.4065
Epoch 107/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2090 - accuracy: 0.5444 - f1_score: 0.4208 - val_loss: 1.1932 - val_accuracy: 0.5580 - val_f1_score: 0.4490
Epoch 108/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2145 - accuracy: 0.5450 - f1_score: 0.4256 - val_loss: 1.1857 - val_accuracy: 0.5650 - val_f1_score: 0.4353
Epoch 109/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2131 - accuracy: 0.5434 - f1_score: 0.4270 - val_loss: 1.2045 - val_accuracy: 0.5550 - val_f1_score: 0.4011
Epoch 110/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2113 - accuracy: 0.5424 - f1_score: 0.4199 - val_loss: 1.1866 - val_accuracy: 0.5620 - val_f1_score: 0.4242
Epoch 111/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2068 - accuracy: 0.5490 - f1_score: 0.4306 - val_loss: 1.1902 - val_accuracy: 0.5580 - val_f1_score: 0.4086
Epoch 112/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2105 - accuracy: 0.5456 - f1_score: 0.4260 - val_loss: 1.1864 - val_accuracy: 0.5600 - val_f1_score: 0.4228
Epoch 113/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2142 - accuracy: 0.5446 - f1_score: 0.4299 - val_loss: 1.1930 - val_accuracy: 0.5570 - val_f1_score: 0.4301
Epoch 114/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2131 - accuracy: 0.5412 - f1_score: 0.4217 - val_loss: 1.1849 - val_accuracy: 0.5580 - val_f1_score: 0.4117
Epoch 115/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2091 - accuracy: 0.5450 - f1_score: 0.4239 - val_loss: 1.1909 - val_accuracy: 0.5580 - val_f1_score: 0.4066
Epoch 116/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2100 - accuracy: 0.5434 - f1_score: 0.4244 - val_loss: 1.1895 - val_accuracy: 0.5610 - val_f1_score: 0.4191
Epoch 117/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2160 - accuracy: 0.5386 - f1_score: 0.4194 - val_loss: 1.1939 - val_accuracy: 0.5590 - val_f1_score: 0.4261
Epoch 118/2000
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157/157 [=====] - 0s 2ms/step - loss: 1.2087 - accuracy: 0.5450 - f1\_score: 0.4209 - val\_loss: 1.1946 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4593  
Epoch 119/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2137 - accuracy: 0.5416 - f1\_score: 0.4228 - val\_loss: 1.1881 - val\_accuracy: 0.5640 - val\_f1\_score: 0.4538  
Epoch 120/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2122 - accuracy: 0.5430 - f1\_score: 0.4241 - val\_loss: 1.1908 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4307  
Epoch 121/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2119 - accuracy: 0.5414 - f1\_score: 0.4179 - val\_loss: 1.1985 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4214  
Epoch 122/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2088 - accuracy: 0.5434 - f1\_score: 0.4215 - val\_loss: 1.1941 - val\_accuracy: 0.5700 - val\_f1\_score: 0.4423  
Epoch 123/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2112 - accuracy: 0.5426 - f1\_score: 0.4176 - val\_loss: 1.1927 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4248  
Epoch 124/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2119 - accuracy: 0.5430 - f1\_score: 0.4210 - val\_loss: 1.1831 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4365  
Epoch 125/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2085 - accuracy: 0.5442 - f1\_score: 0.4199 - val\_loss: 1.2006 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4646  
Epoch 126/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2096 - accuracy: 0.5444 - f1\_score: 0.4234 - val\_loss: 1.1924 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4506  
Epoch 127/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2126 - accuracy: 0.5466 - f1\_score: 0.4287 - val\_loss: 1.1921 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4386  
Epoch 128/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2089 - accuracy: 0.5436 - f1\_score: 0.4218 - val\_loss: 1.1963 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4277  
Epoch 129/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2069 - accuracy: 0.5436 - f1\_score: 0.4214 - val\_loss: 1.2184 - val\_accuracy: 0.5480 - val\_f1\_score: 0.4536  
Epoch 130/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2184 - accuracy: 0.5358 - f1\_score: 0.4266 - val\_loss: 1.1876 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4187  
Epoch 131/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2045 - accuracy: 0.5418 - f1\_score: 0.4191 - val\_loss: 1.1959 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4517  
Epoch 132/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2131 - accuracy: 0.5418 - f1\_score: 0.4205 - val\_loss: 1.1923 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4629

Epoch 133/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2139 - accuracy: 0.5460 - f1\_score: 0.4295 - val\_loss: 1.2012 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4427  
Epoch 134/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2125 - accuracy: 0.5470 - f1\_score: 0.4312 - val\_loss: 1.1881 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4382  
Epoch 135/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2137 - accuracy: 0.5448 - f1\_score: 0.4307 - val\_loss: 1.1898 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4454  
Epoch 136/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2112 - accuracy: 0.5434 - f1\_score: 0.4228 - val\_loss: 1.1861 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4174  
Epoch 137/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2095 - accuracy: 0.5424 - f1\_score: 0.4212 - val\_loss: 1.1951 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4330  
Epoch 138/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2084 - accuracy: 0.5484 - f1\_score: 0.4292 - val\_loss: 1.1959 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4102  
Epoch 139/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2080 - accuracy: 0.5462 - f1\_score: 0.4229 - val\_loss: 1.2022 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4633  
Epoch 140/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2079 - accuracy: 0.5426 - f1\_score: 0.4244 - val\_loss: 1.1936 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4138  
Epoch 141/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2107 - accuracy: 0.5436 - f1\_score: 0.4225 - val\_loss: 1.1952 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4350  
Epoch 142/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2060 - accuracy: 0.5462 - f1\_score: 0.4256 - val\_loss: 1.1854 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4493  
Epoch 143/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2093 - accuracy: 0.5438 - f1\_score: 0.4257 - val\_loss: 1.2045 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4563  
Epoch 144/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2116 - accuracy: 0.5448 - f1\_score: 0.4281 - val\_loss: 1.1954 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4469  
Epoch 145/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2085 - accuracy: 0.5426 - f1\_score: 0.4274 - val\_loss: 1.1872 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4113  
Epoch 146/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2103 - accuracy: 0.5420 - f1\_score: 0.4200 - val\_loss: 1.1919 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4287  
Epoch 147/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2109 - accuracy: 0.5440 - f1\_score: 0.4237 - val\_loss:

s: 1.1907 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4583  
Epoch 148/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2099 - accuracy: 0.5404 - f1\_score: 0.4237 - val\_loss: 1.1973 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4281  
Epoch 149/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2068 - accuracy: 0.5478 - f1\_score: 0.4265 - val\_loss: 1.1902 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4467  
Epoch 150/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2091 - accuracy: 0.5476 - f1\_score: 0.4293 - val\_loss: 1.1871 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4591  
Epoch 151/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2066 - accuracy: 0.5450 - f1\_score: 0.4267 - val\_loss: 1.1938 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4540  
Epoch 152/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2066 - accuracy: 0.5484 - f1\_score: 0.4257 - val\_loss: 1.1898 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4555  
Epoch 153/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2093 - accuracy: 0.5430 - f1\_score: 0.4257 - val\_loss: 1.1916 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4209  
Epoch 154/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2078 - accuracy: 0.5458 - f1\_score: 0.4293 - val\_loss: 1.2105 - val\_accuracy: 0.5370 - val\_f1\_score: 0.4532  
Epoch 155/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2113 - accuracy: 0.5416 - f1\_score: 0.4196 - val\_loss: 1.2247 - val\_accuracy: 0.5400 - val\_f1\_score: 0.4558  
Epoch 156/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2104 - accuracy: 0.5362 - f1\_score: 0.4180 - val\_loss: 1.1860 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4242  
Epoch 157/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2091 - accuracy: 0.5422 - f1\_score: 0.4233 - val\_loss: 1.1962 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4053  
Epoch 158/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2066 - accuracy: 0.5432 - f1\_score: 0.4231 - val\_loss: 1.2073 - val\_accuracy: 0.5520 - val\_f1\_score: 0.4133  
Epoch 159/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2077 - accuracy: 0.5432 - f1\_score: 0.4205 - val\_loss: 1.2039 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4768  
Epoch 160/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2055 - accuracy: 0.5430 - f1\_score: 0.4215 - val\_loss: 1.1936 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4572  
Epoch 161/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2147 - accuracy: 0.5390 - f1\_score: 0.4168 - val\_loss: 1.1936 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4541  
Epoch 162/2000

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157/157 [=====] - 0s 2ms/step - loss: 1.2095 - accuracy: 0.5434 - f1_score: 0.4239 - val_loss: 1.1944 - val_accuracy: 0.5640 - val_f1_score: 0.4391
Epoch 163/2000
157/157 [=====] - 0s 3ms/step - loss: 1.2046 - accuracy: 0.5434 - f1_score: 0.4237 - val_loss: 1.1918 - val_accuracy: 0.5600 - val_f1_score: 0.4367
Epoch 164/2000
157/157 [=====] - 0s 3ms/step - loss: 1.2054 - accuracy: 0.5458 - f1_score: 0.4232 - val_loss: 1.1934 - val_accuracy: 0.5520 - val_f1_score: 0.4077
Epoch 165/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2109 - accuracy: 0.5396 - f1_score: 0.4243 - val_loss: 1.1904 - val_accuracy: 0.5620 - val_f1_score: 0.4395
Epoch 166/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2069 - accuracy: 0.5434 - f1_score: 0.4220 - val_loss: 1.1953 - val_accuracy: 0.5710 - val_f1_score: 0.4681
Epoch 167/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2089 - accuracy: 0.5452 - f1_score: 0.4254 - val_loss: 1.1937 - val_accuracy: 0.5620 - val_f1_score: 0.4529
Epoch 168/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2050 - accuracy: 0.5496 - f1_score: 0.4294 - val_loss: 1.1950 - val_accuracy: 0.5580 - val_f1_score: 0.4481
Epoch 169/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2065 - accuracy: 0.5474 - f1_score: 0.4275 - val_loss: 1.1990 - val_accuracy: 0.5590 - val_f1_score: 0.4486
Epoch 170/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2090 - accuracy: 0.5438 - f1_score: 0.4283 - val_loss: 1.1952 - val_accuracy: 0.5610 - val_f1_score: 0.4349
Epoch 171/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2068 - accuracy: 0.5444 - f1_score: 0.4252 - val_loss: 1.1895 - val_accuracy: 0.5610 - val_f1_score: 0.4464
Epoch 172/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2068 - accuracy: 0.5458 - f1_score: 0.4295 - val_loss: 1.1903 - val_accuracy: 0.5540 - val_f1_score: 0.4226
Epoch 173/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2041 - accuracy: 0.5464 - f1_score: 0.4271 - val_loss: 1.1896 - val_accuracy: 0.5610 - val_f1_score: 0.4361
Epoch 174/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2033 - accuracy: 0.5416 - f1_score: 0.4234 - val_loss: 1.1961 - val_accuracy: 0.5600 - val_f1_score: 0.4112
Epoch 175/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2052 - accuracy: 0.5440 - f1_score: 0.4247 - val_loss: 1.1828 - val_accuracy: 0.5690 - val_f1_score: 0.4437
Epoch 176/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2075 - accuracy: 0.5420 - f1_score: 0.4226 - val_loss: 1.1819 - val_accuracy: 0.5600 - val_f1_score: 0.4369
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Epoch 177/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2050 - accuracy: 0.5482 - f1\_score: 0.4324 - val\_loss: 1.1929 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4487  
Epoch 178/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2074 - accuracy: 0.5434 - f1\_score: 0.4268 - val\_loss: 1.2072 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4586  
Epoch 179/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2028 - accuracy: 0.5464 - f1\_score: 0.4228 - val\_loss: 1.1945 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4477  
Epoch 180/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2089 - accuracy: 0.5424 - f1\_score: 0.4277 - val\_loss: 1.1968 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4265  
Epoch 181/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2036 - accuracy: 0.5488 - f1\_score: 0.4285 - val\_loss: 1.1994 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4128  
Epoch 182/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2046 - accuracy: 0.5458 - f1\_score: 0.4268 - val\_loss: 1.1853 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4128  
Epoch 183/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2044 - accuracy: 0.5422 - f1\_score: 0.4225 - val\_loss: 1.2022 - val\_accuracy: 0.5530 - val\_f1\_score: 0.4446  
Epoch 184/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2075 - accuracy: 0.5422 - f1\_score: 0.4275 - val\_loss: 1.1918 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4391  
Epoch 185/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2052 - accuracy: 0.5466 - f1\_score: 0.4275 - val\_loss: 1.1821 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4260  
Epoch 186/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2085 - accuracy: 0.5462 - f1\_score: 0.4270 - val\_loss: 1.1902 - val\_accuracy: 0.5710 - val\_f1\_score: 0.4581  
Epoch 187/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2040 - accuracy: 0.5462 - f1\_score: 0.4265 - val\_loss: 1.1977 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4229  
Epoch 188/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2086 - accuracy: 0.5418 - f1\_score: 0.4231 - val\_loss: 1.1915 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4043  
Epoch 189/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2029 - accuracy: 0.5462 - f1\_score: 0.4282 - val\_loss: 1.2152 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4641  
Epoch 190/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2034 - accuracy: 0.5464 - f1\_score: 0.4297 - val\_loss: 1.1966 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4212  
Epoch 191/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2063 - accuracy: 0.5436 - f1\_score: 0.4302 - val\_loss

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s: 1.2083 - val_accuracy: 0.5570 - val_f1_score: 0.4102
Epoch 192/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2054 - accuracy: 0.5478 - f1_score: 0.4286 - val_loss: 1.1954 - val_accuracy: 0.5590 - val_f1_score: 0.4123
Epoch 193/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2030 - accuracy: 0.5456 - f1_score: 0.4258 - val_loss: 1.1834 - val_accuracy: 0.5600 - val_f1_score: 0.4167
Epoch 194/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2086 - accuracy: 0.5420 - f1_score: 0.4253 - val_loss: 1.1909 - val_accuracy: 0.5570 - val_f1_score: 0.4346
Epoch 195/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2071 - accuracy: 0.5438 - f1_score: 0.4248 - val_loss: 1.1904 - val_accuracy: 0.5570 - val_f1_score: 0.4366
Epoch 196/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2091 - accuracy: 0.5428 - f1_score: 0.4250 - val_loss: 1.1961 - val_accuracy: 0.5600 - val_f1_score: 0.4511
Epoch 197/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2068 - accuracy: 0.5470 - f1_score: 0.4282 - val_loss: 1.1954 - val_accuracy: 0.5560 - val_f1_score: 0.4221
Epoch 198/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2024 - accuracy: 0.5464 - f1_score: 0.4250 - val_loss: 1.1946 - val_accuracy: 0.5570 - val_f1_score: 0.4551
Epoch 199/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2010 - accuracy: 0.5446 - f1_score: 0.4251 - val_loss: 1.1898 - val_accuracy: 0.5540 - val_f1_score: 0.4200
Epoch 200/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2036 - accuracy: 0.5478 - f1_score: 0.4272 - val_loss: 1.1879 - val_accuracy: 0.5650 - val_f1_score: 0.4302
Epoch 201/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2042 - accuracy: 0.5490 - f1_score: 0.4305 - val_loss: 1.1981 - val_accuracy: 0.5530 - val_f1_score: 0.4346
Epoch 202/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2044 - accuracy: 0.5440 - f1_score: 0.4254 - val_loss: 1.1824 - val_accuracy: 0.5600 - val_f1_score: 0.4200
Epoch 203/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2000 - accuracy: 0.5446 - f1_score: 0.4254 - val_loss: 1.1955 - val_accuracy: 0.5540 - val_f1_score: 0.4277
Epoch 204/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2008 - accuracy: 0.5428 - f1_score: 0.4256 - val_loss: 1.2090 - val_accuracy: 0.5620 - val_f1_score: 0.4207
Epoch 205/2000
157/157 [=====] - 0s 2ms/step - loss: 1.2045 - accuracy: 0.5472 - f1_score: 0.4316 - val_loss: 1.2091 - val_accuracy: 0.5440 - val_f1_score: 0.4612
Epoch 206/2000
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157/157 [=====] - 0s 2ms/step - loss: 1.2073 - accuracy: 0.5418 - f1\_score: 0.4242 - val\_loss: 1.1843 - val\_accuracy: 0.5640 - val\_f1\_score: 0.4400  
Epoch 207/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2023 - accuracy: 0.5452 - f1\_score: 0.4257 - val\_loss: 1.1898 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4198  
Epoch 208/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2029 - accuracy: 0.5460 - f1\_score: 0.4305 - val\_loss: 1.2091 - val\_accuracy: 0.5470 - val\_f1\_score: 0.4800  
Epoch 209/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2019 - accuracy: 0.5504 - f1\_score: 0.4338 - val\_loss: 1.1971 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4084  
Epoch 210/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2051 - accuracy: 0.5460 - f1\_score: 0.4299 - val\_loss: 1.1876 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4471  
Epoch 211/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1993 - accuracy: 0.5476 - f1\_score: 0.4295 - val\_loss: 1.2048 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4262  
Epoch 212/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2055 - accuracy: 0.5430 - f1\_score: 0.4248 - val\_loss: 1.1991 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4495  
Epoch 213/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2009 - accuracy: 0.5474 - f1\_score: 0.4338 - val\_loss: 1.2030 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4479  
Epoch 214/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2041 - accuracy: 0.5448 - f1\_score: 0.4275 - val\_loss: 1.1982 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4408  
Epoch 215/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2019 - accuracy: 0.5486 - f1\_score: 0.4322 - val\_loss: 1.1955 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4103  
Epoch 216/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2024 - accuracy: 0.5442 - f1\_score: 0.4270 - val\_loss: 1.2065 - val\_accuracy: 0.5710 - val\_f1\_score: 0.4518  
Epoch 217/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2060 - accuracy: 0.5430 - f1\_score: 0.4240 - val\_loss: 1.1915 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4384  
Epoch 218/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2023 - accuracy: 0.5506 - f1\_score: 0.4351 - val\_loss: 1.1782 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4305  
Epoch 219/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2026 - accuracy: 0.5466 - f1\_score: 0.4290 - val\_loss: 1.1888 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4505  
Epoch 220/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2012 - accuracy: 0.5468 - f1\_score: 0.4305 - val\_loss: 1.1949 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4377

Epoch 221/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2033 - accuracy: 0.5486 - f1\_score: 0.4344 - val\_loss: 1.1852 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4560  
Epoch 222/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1992 - accuracy: 0.5486 - f1\_score: 0.4311 - val\_loss: 1.1907 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4292  
Epoch 223/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2016 - accuracy: 0.5482 - f1\_score: 0.4336 - val\_loss: 1.1971 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4260  
Epoch 224/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2003 - accuracy: 0.5486 - f1\_score: 0.4336 - val\_loss: 1.1951 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4327  
Epoch 225/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2017 - accuracy: 0.5496 - f1\_score: 0.4304 - val\_loss: 1.2109 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4425  
Epoch 226/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2032 - accuracy: 0.5468 - f1\_score: 0.4305 - val\_loss: 1.1833 - val\_accuracy: 0.5670 - val\_f1\_score: 0.4350  
Epoch 227/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2005 - accuracy: 0.5448 - f1\_score: 0.4247 - val\_loss: 1.1876 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4350  
Epoch 228/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1999 - accuracy: 0.5500 - f1\_score: 0.4347 - val\_loss: 1.1803 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4259  
Epoch 229/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2015 - accuracy: 0.5446 - f1\_score: 0.4279 - val\_loss: 1.2077 - val\_accuracy: 0.5550 - val\_f1\_score: 0.4013  
Epoch 230/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2022 - accuracy: 0.5478 - f1\_score: 0.4298 - val\_loss: 1.1825 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4189  
Epoch 231/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2019 - accuracy: 0.5474 - f1\_score: 0.4340 - val\_loss: 1.1984 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4241  
Epoch 232/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2034 - accuracy: 0.5446 - f1\_score: 0.4291 - val\_loss: 1.1937 - val\_accuracy: 0.5640 - val\_f1\_score: 0.4695  
Epoch 233/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2040 - accuracy: 0.5458 - f1\_score: 0.4323 - val\_loss: 1.1901 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4208  
Epoch 234/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2018 - accuracy: 0.5466 - f1\_score: 0.4252 - val\_loss: 1.1777 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4253  
Epoch 235/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1984 - accuracy: 0.5502 - f1\_score: 0.4315 - val\_loss:

s: 1.2019 - val\_accuracy: 0.5450 - val\_f1\_score: 0.4471  
Epoch 236/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1988 - accuracy: 0.5492 - f1\_score: 0.4315 - val\_loss: 1.1972 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4556  
Epoch 237/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2003 - accuracy: 0.5454 - f1\_score: 0.4316 - val\_loss: 1.1974 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4531  
Epoch 238/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1999 - accuracy: 0.5426 - f1\_score: 0.4190 - val\_loss: 1.2072 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4691  
Epoch 239/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2038 - accuracy: 0.5420 - f1\_score: 0.4256 - val\_loss: 1.1986 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4606  
Epoch 240/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2013 - accuracy: 0.5450 - f1\_score: 0.4289 - val\_loss: 1.1851 - val\_accuracy: 0.5700 - val\_f1\_score: 0.4580  
Epoch 241/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2018 - accuracy: 0.5484 - f1\_score: 0.4317 - val\_loss: 1.1788 - val\_accuracy: 0.5680 - val\_f1\_score: 0.4533  
Epoch 242/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2043 - accuracy: 0.5478 - f1\_score: 0.4320 - val\_loss: 1.1833 - val\_accuracy: 0.5640 - val\_f1\_score: 0.4508  
Epoch 243/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2022 - accuracy: 0.5416 - f1\_score: 0.4210 - val\_loss: 1.2141 - val\_accuracy: 0.5500 - val\_f1\_score: 0.4612  
Epoch 244/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2002 - accuracy: 0.5480 - f1\_score: 0.4328 - val\_loss: 1.2013 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4639  
Epoch 245/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2034 - accuracy: 0.5448 - f1\_score: 0.4297 - val\_loss: 1.2072 - val\_accuracy: 0.5410 - val\_f1\_score: 0.4543  
Epoch 246/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2006 - accuracy: 0.5474 - f1\_score: 0.4290 - val\_loss: 1.1934 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4480  
Epoch 247/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1967 - accuracy: 0.5456 - f1\_score: 0.4299 - val\_loss: 1.1797 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4362  
Epoch 248/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1985 - accuracy: 0.5458 - f1\_score: 0.4281 - val\_loss: 1.2156 - val\_accuracy: 0.5350 - val\_f1\_score: 0.4574  
Epoch 249/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1989 - accuracy: 0.5516 - f1\_score: 0.4395 - val\_loss: 1.1978 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4463  
Epoch 250/2000

157/157 [=====] - 0s 2ms/step - loss: 1.1982 - accuracy: 0.5518 - f1\_score: 0.4378 - val\_loss: 1.1881 - val\_accuracy: 0.5560 - val\_f1\_score: 0.4248  
Epoch 251/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1986 - accuracy: 0.5478 - f1\_score: 0.4285 - val\_loss: 1.1980 - val\_accuracy: 0.5680 - val\_f1\_score: 0.4511  
Epoch 252/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1993 - accuracy: 0.5462 - f1\_score: 0.4255 - val\_loss: 1.1844 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4301  
Epoch 253/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1997 - accuracy: 0.5460 - f1\_score: 0.4311 - val\_loss: 1.1864 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4347  
Epoch 254/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1975 - accuracy: 0.5436 - f1\_score: 0.4263 - val\_loss: 1.1866 - val\_accuracy: 0.5700 - val\_f1\_score: 0.4512  
Epoch 255/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1968 - accuracy: 0.5486 - f1\_score: 0.4297 - val\_loss: 1.1850 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4172  
Epoch 256/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2022 - accuracy: 0.5426 - f1\_score: 0.4289 - val\_loss: 1.2104 - val\_accuracy: 0.5450 - val\_f1\_score: 0.4497  
Epoch 257/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2028 - accuracy: 0.5464 - f1\_score: 0.4275 - val\_loss: 1.1870 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4407  
Epoch 258/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1962 - accuracy: 0.5498 - f1\_score: 0.4266 - val\_loss: 1.2101 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4590  
Epoch 259/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1995 - accuracy: 0.5420 - f1\_score: 0.4289 - val\_loss: 1.1898 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4330  
Epoch 260/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2032 - accuracy: 0.5482 - f1\_score: 0.4301 - val\_loss: 1.1822 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4513  
Epoch 261/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1969 - accuracy: 0.5498 - f1\_score: 0.4332 - val\_loss: 1.2010 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4023  
Epoch 262/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2000 - accuracy: 0.5488 - f1\_score: 0.4304 - val\_loss: 1.1826 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4402  
Epoch 263/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1984 - accuracy: 0.5418 - f1\_score: 0.4239 - val\_loss: 1.1876 - val\_accuracy: 0.5700 - val\_f1\_score: 0.4547  
Epoch 264/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2001 - accuracy: 0.5464 - f1\_score: 0.4286 - val\_loss: 1.1890 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4444

Epoch 265/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1958 - accuracy: 0.5484 - f1\_score: 0.4306 - val\_loss: 1.2009 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4530  
Epoch 266/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1975 - accuracy: 0.5472 - f1\_score: 0.4262 - val\_loss: 1.1799 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4485  
Epoch 267/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1956 - accuracy: 0.5494 - f1\_score: 0.4321 - val\_loss: 1.1895 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4121  
Epoch 268/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1973 - accuracy: 0.5482 - f1\_score: 0.4283 - val\_loss: 1.2037 - val\_accuracy: 0.5540 - val\_f1\_score: 0.4253  
Epoch 269/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2023 - accuracy: 0.5454 - f1\_score: 0.4298 - val\_loss: 1.1958 - val\_accuracy: 0.5570 - val\_f1\_score: 0.4461  
Epoch 270/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1968 - accuracy: 0.5462 - f1\_score: 0.4325 - val\_loss: 1.1912 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4446  
Epoch 271/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1987 - accuracy: 0.5446 - f1\_score: 0.4274 - val\_loss: 1.1929 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4317  
Epoch 272/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1952 - accuracy: 0.5474 - f1\_score: 0.4261 - val\_loss: 1.1880 - val\_accuracy: 0.5620 - val\_f1\_score: 0.4655  
Epoch 273/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.1945 - accuracy: 0.5468 - f1\_score: 0.4283 - val\_loss: 1.2093 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4629  
Epoch 274/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.1982 - accuracy: 0.5406 - f1\_score: 0.4250 - val\_loss: 1.1875 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4161  
Epoch 275/2000  
157/157 [=====] - 0s 3ms/step - loss: 1.1983 - accuracy: 0.5472 - f1\_score: 0.4292 - val\_loss: 1.1815 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4176  
Epoch 276/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1978 - accuracy: 0.5488 - f1\_score: 0.4323 - val\_loss: 1.1926 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4689  
Epoch 277/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1972 - accuracy: 0.5486 - f1\_score: 0.4353 - val\_loss: 1.1793 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4345  
Epoch 278/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1976 - accuracy: 0.5450 - f1\_score: 0.4266 - val\_loss: 1.1825 - val\_accuracy: 0.5630 - val\_f1\_score: 0.4379  
Epoch 279/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1990 - accuracy: 0.5462 - f1\_score: 0.4327 - val\_loss

s: 1.1826 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4131  
Epoch 280/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2004 - accuracy: 0.5474 - f1\_score: 0.4298 - val\_loss: 1.1912 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4609  
Epoch 281/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1971 - accuracy: 0.5468 - f1\_score: 0.4271 - val\_loss: 1.1792 - val\_accuracy: 0.5690 - val\_f1\_score: 0.4490  
Epoch 282/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1956 - accuracy: 0.5500 - f1\_score: 0.4357 - val\_loss: 1.2029 - val\_accuracy: 0.5450 - val\_f1\_score: 0.4537  
Epoch 283/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1980 - accuracy: 0.5448 - f1\_score: 0.4267 - val\_loss: 1.1866 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4309  
Epoch 284/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1972 - accuracy: 0.5472 - f1\_score: 0.4270 - val\_loss: 1.1931 - val\_accuracy: 0.5710 - val\_f1\_score: 0.4621  
Epoch 285/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1981 - accuracy: 0.5486 - f1\_score: 0.4307 - val\_loss: 1.1866 - val\_accuracy: 0.5650 - val\_f1\_score: 0.4522  
Epoch 286/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1948 - accuracy: 0.5484 - f1\_score: 0.4289 - val\_loss: 1.1898 - val\_accuracy: 0.5600 - val\_f1\_score: 0.4099  
Epoch 287/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1969 - accuracy: 0.5496 - f1\_score: 0.4348 - val\_loss: 1.1866 - val\_accuracy: 0.5640 - val\_f1\_score: 0.4482  
Epoch 288/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1967 - accuracy: 0.5456 - f1\_score: 0.4272 - val\_loss: 1.1979 - val\_accuracy: 0.5590 - val\_f1\_score: 0.4638  
Epoch 289/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1947 - accuracy: 0.5490 - f1\_score: 0.4323 - val\_loss: 1.1940 - val\_accuracy: 0.5710 - val\_f1\_score: 0.4473  
Epoch 290/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1971 - accuracy: 0.5438 - f1\_score: 0.4243 - val\_loss: 1.1857 - val\_accuracy: 0.5670 - val\_f1\_score: 0.4509  
Epoch 291/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1986 - accuracy: 0.5496 - f1\_score: 0.4327 - val\_loss: 1.1801 - val\_accuracy: 0.5670 - val\_f1\_score: 0.4491  
Epoch 292/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.1937 - accuracy: 0.5492 - f1\_score: 0.4352 - val\_loss: 1.2103 - val\_accuracy: 0.5580 - val\_f1\_score: 0.4020  
Epoch 293/2000  
157/157 [=====] - 0s 2ms/step - loss: 1.2000 - accuracy: 0.5458 - f1\_score: 0.4332 - val\_loss: 1.1961 - val\_accuracy: 0.5660 - val\_f1\_score: 0.4404  
Epoch 294/2000



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157/157 [=====] - 0s 2ms/step - loss: 1.1949 - accuracy: 0.5522 - f1_score: 0.4368 - val_loss: 1.1841 - val_accuracy: 0.5650 - val_f1_score: 0.4260
Epoch 295/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1970 - accuracy: 0.5486 - f1_score: 0.4335 - val_loss: 1.1805 - val_accuracy: 0.5620 - val_f1_score: 0.4196
Epoch 296/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1975 - accuracy: 0.5474 - f1_score: 0.4299 - val_loss: 1.1862 - val_accuracy: 0.5650 - val_f1_score: 0.4536
Epoch 297/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1922 - accuracy: 0.5532 - f1_score: 0.4388 - val_loss: 1.2039 - val_accuracy: 0.5630 - val_f1_score: 0.4467
Epoch 298/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1961 - accuracy: 0.5478 - f1_score: 0.4291 - val_loss: 1.1847 - val_accuracy: 0.5570 - val_f1_score: 0.4058
Epoch 299/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1980 - accuracy: 0.5492 - f1_score: 0.4355 - val_loss: 1.1884 - val_accuracy: 0.5580 - val_f1_score: 0.4679
Epoch 300/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1972 - accuracy: 0.5474 - f1_score: 0.4318 - val_loss: 1.1923 - val_accuracy: 0.5610 - val_f1_score: 0.4563
Epoch 301/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1974 - accuracy: 0.5488 - f1_score: 0.4338 - val_loss: 1.1844 - val_accuracy: 0.5640 - val_f1_score: 0.4595
Epoch 302/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1987 - accuracy: 0.5452 - f1_score: 0.4335 - val_loss: 1.1855 - val_accuracy: 0.5590 - val_f1_score: 0.4215
Epoch 303/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1947 - accuracy: 0.5492 - f1_score: 0.4312 - val_loss: 1.1804 - val_accuracy: 0.5580 - val_f1_score: 0.4283
Epoch 304/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1966 - accuracy: 0.5480 - f1_score: 0.4332 - val_loss: 1.1962 - val_accuracy: 0.5610 - val_f1_score: 0.4191
Epoch 305/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1975 - accuracy: 0.5506 - f1_score: 0.4353 - val_loss: 1.1888 - val_accuracy: 0.5560 - val_f1_score: 0.4175
Epoch 306/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1930 - accuracy: 0.5512 - f1_score: 0.4347 - val_loss: 1.1890 - val_accuracy: 0.5590 - val_f1_score: 0.4539
Epoch 307/2000
157/157 [=====] - 0s 2ms/step - loss: 1.1931 - accuracy: 0.5500 - f1_score: 0.4310 - val_loss: 1.1864 - val_accuracy: 0.5630 - val_f1_score: 0.4384
Epoch 308/2000
155/157 [=====>.] - ETA: 0s - loss: 1.1986 - accuracy: 0.5516 - f1_score: 0.4385Restoring model weights from the end of the best epoch: 208.
```

157/157 [=====] - 0s 2ms/step - loss: 1.1984 - accuracy: 0.5518 - f1\_score: 0.4385 - val\_loss: 1.1839 - val\_accuracy: 0.5610 - val\_f1\_score: 0.4309  
Epoch 00308: early stopping

In [ ]:

```
# Babysit the model
px.line(
    pd.DataFrame(
        {
            "val_loss": history.history["val_loss"],
            "loss": history.history["loss"],
            "val_f1_score": history.history["val_f1_score"],
            "f1_score": history.history["f1_score"],
            "val_accuracy": history.history["val_accuracy"],
            "accuracy": history.history["accuracy"],
        }
    )
)
```

In [ ]:

```
# evaluate the model
model.evaluate(vectorizer(X_test), y_test_ohe, verbose=1)
```

32/32 [=====] - 0s 1ms/step - loss: 1.2091 - accuracy: 0.5470 - f1\_score: 0.4800  
[1.209080457687378, 0.546999990940094, 0.47998419404029846]

Out[ ]: