generateAmazonDataset

April 19, 2023

[ ]:
```
def remove_prefix(text, prefix):
    if text.startswith(prefix):
        return text[len(prefix):]
    return text
```

[ ]:
```
import os
import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import matplotlib.pyplot as plt
```

```
2023-04-19 18:48:05.498513: I tensorflow/core/platform/cpu_feature_guard.cc:193]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  AVX2 AVX_VNNI FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
2023-04-19 18:48:05.552992: I tensorflow/core/util/port.cc:104] oneDNN custom
operations are on. You may see slightly different numerical results due to
floating-point round-off errors from different computation orders. To turn them
off, set the environment variable `TF_ENABLE_ONEDNN_OPTS=0`.
2023-04-19 18:48:05.826900: W
tensorflow/compiler/xla/stream_executor/platform/default/dso_loader.cc:64] Could
not load dynamic library 'libnvinfer.so.7'; dlerror: libnvinfer.so.7: cannot
open shared object file: No such file or directory; LD_LIBRARY_PATH:
:/home/victorxesus.barreiro/anaconda3/envs/deepgpu4/lib/
2023-04-19 18:48:05.826932: W
tensorflow/compiler/xla/stream_executor/platform/default/dso_loader.cc:64] Could
not load dynamic library 'libnvinfer_plugin.so.7'; dlerror:
libnvinfer_plugin.so.7: cannot open shared object file: No such file or
directory; LD_LIBRARY_PATH:
:/home/victorxesus.barreiro/anaconda3/envs/deepgpu4/lib/
2023-04-19 18:48:05.826934: W
tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Cannot
dlopen some TensorRT libraries. If you would like to use Nvidia GPU with
TensorRT, please make sure the missing libraries mentioned above are installed
properly.
```

[ ]:
```
#reads a file. Each line has the format: label text
#Returns a list with the text and a list with the labels
def readData(fname):

    with open(fname, 'r', encoding="utf-8") as f:
        fileData = f.read()

    lines = fileData.split("\n")
    textData = list()
    textLabel = list()
    lineLength = np.zeros(len(lines))

    for i, aLine in enumerate(lines):
        if not aLine:
            break
        label = aLine.split(" ")[0]
        lineLength[i] = len(aLine.split(" "))
        if(label == "__label__1"):
            textLabel.append(0)
            textData.append(remove_prefix(aLine, "__label__1 "))

        elif(label == "__label__2"):
            textLabel.append(1)
            textData.append(remove_prefix(aLine, "__label__2 "))

        else:
            print("\nError in readData: ", i, aLine)
            exit()

    f.close()
    return textData, textLabel, int(np.average(lineLength)+2*np.std(lineLength))
```

[ ]:
```
from tensorflow.keras import layers

def transformData(x_train, y_train, x_test, y_test, maxFeatures, seqLength):
    #transforms text input to int input based on the vocabulary
    #max_tokens = maxFeatures is the size of the vocabulary
    #output_sequence_length =  seqLength is the maximum length of the␣
 ↪transformed text. Adds 0 is text length is shorter
    precLayer = layers.experimental.preprocessing.TextVectorization(max_tokens␣
 ↪= maxFeatures,
    standardize =  'lower_and_strip_punctuation', split = 'whitespace',␣
 ↪output_mode = 'int',
    output_sequence_length =  seqLength)
    precLayer.adapt(x_train)
    #print(precLayer.get_vocabulary())
    x_train_int = precLayer(x_train)
```

```
    y_train = tf.convert_to_tensor(y_train)
    #print(x_train_int)
    #print(y_train)
    x_test_int= precLayer(x_test)
    y_test = tf.convert_to_tensor(y_test)
    #print(x_test_int)
    #print(y_test)

    return x_train_int, y_train, x_test_int, y_test
```

[ ]:
```
import sys
```

[ ]:
```
x_train, y_train, seqLength = readData("amazon/train_small.txt")
x_test, y_test, tmp = readData("amazon/test_small.txt")

del tmp

print(sys.getsizeof(x_train))
print(sys.getsizeof(y_train))
print(sys.getsizeof(x_test))
print(sys.getsizeof(y_test))


#maxFeatures is a hyperparameter
maxFeatures = 5500

x_train_int, y_train, x_test_int, y_test = transformData(x_train, y_train,␣
 ↪x_test, y_test, maxFeatures, seqLength)

print("O obxecto")
print(sys.getsizeof(transformData))

del x_train
del x_test
del transformData
```

```
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```

```
2023-04-19 18:48:06.403634: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.405835: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
```

```
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.405901: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.406092: I tensorflow/core/platform/cpu_feature_guard.cc:193]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  AVX2 AVX_VNNI FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
2023-04-19 18:48:06.406461: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.406515: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.406551: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.699228: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.699305: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.699348: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_gpu_executor.cc:981]
successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2023-04-19 18:48:06.699392: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1613] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 20000 MB memory:  -> device:
0, name: NVIDIA GeForce RTX 4090, pci bus id: 0000:01:00.0, compute capability:
8.9

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```

[ ]:
```
from keras.layers import Input,Conv2D, MaxPooling2D, Flatten, Dense, Dropout
from keras import Input, Model
from keras.utils import plot_model
```

```
from tensorflow.keras.callbacks import ModelCheckpoint

import matplotlib.pyplot as plt
import numpy as np
import time

# Directory where the checkpoints will be saved.
dir = "models/"

def visualize_fit(history):
    """Visualize the fit of a model.

    Args:
        history (list): list of metrics along the epochs.
    """
    history_dict = history.history
    print(history_dict.keys())
    history_dict.keys()

    loss_values = history_dict['loss']
    val_loss_values = history_dict['val_loss']

    epochs = range(1, len(loss_values) + 1)

    plt.figure(figsize=(10,5))
    plt.subplot(1, 2, 1)
    plt.plot(epochs, loss_values, 'b-o', label='Training loss')
    plt.plot(epochs, val_loss_values, 'r-o', label='Validation loss')

    plt.title('Training and validation loss')
    plt.xlabel('Epochs')
    plt.ylabel('Loss')
    plt.legend()

    plt.subplot(1, 2, 2)
    acc = history_dict['accuracy']
    val_acc = history_dict['val_accuracy']

    plt.plot(epochs, acc, 'b-o', label='Training Accuracy')
    plt.plot(epochs, val_acc, 'r-o', label='Validation Accuracy')
    plt.title('Training and validation Accuracy')
    plt.xlabel('Epochs')
    plt.ylabel('MAE')
    plt.ylim([0, 1])
    plt.legend()

    plt.tight_layout()
```

```
    plt.show()
```

[ ]:
```
def fitModel(model, x_train, y_train, ds_val, num_epochs=20,␣
↪monitor='val_accuracy', model_name='best_model.h5', callbacks=[],␣
↪batch_size=32):
    """Function to train a model. It saves the best model in a file. It also␣
↪prints the evolution of the training process.


    Args:
        model (Model): The model to be trained.
        ds_train (_type_): The training dataset.
        ds_val (_type_): The validation dataset.
        num_epochs (int, optional): Defaults to 20.
        monitor (str, optional): Metric to monitor and save the best model.␣
↪Defaults to 'val_mean_absolute_error'.
        model_name (str, optional): Name of the file where the best model will␣
↪be saved. Defaults to 'best_model.h5'.
        callbacks (list, optional): List of callbacks to be used during␣
↪training. Defaults to [].

    Returns:
        final_metrics (list): List with the final metrics of the model
    """
    checkpoint = ModelCheckpoint(dir + model_name, save_best_only=True,␣
↪save_weights_only=False, monitor=monitor, mode='auto', verbose=1)
    history = model.fit(x_train, y_train, verbose = 1, epochs=num_epochs,␣
↪callbacks=callbacks+[checkpoint], validation_data=ds_val,␣
↪batch_size=batch_size)
    visualize_fit(history)
    return history
```

1 Contexto

Lo primeo que debemos tener en mente al abordar un problema como este, en el que tengamos procesado del lenguaje natural, es el proceso de tokenización. En este caso tenemos fijados bastantes de estos aspectos y quedan de nuestra mano el número de caracterisitcas que este representa y el tamaño de secuencia. En este sentido, hemos comprobado que el núméor de caracteristicas supone un aspecto muy importante en este problema, hemos visto que a partir de 5 000 caracteristicas no mejoramos los resultados, sin embargo, debemos tener en cuenta que para grandes corpus de texto se nos recomenda emplear un número muy superior del orden de 50 000 a 100 000, esto es un importante indicativo de la variabilidad de los datos y la complejidad de nuestro problema. Por ello, estamos ante un porblema que muy probablmemente este acotado al tipo de usuario que hace las reviws y los paises en los que se obtuvo por lo que no debemos esperar una buena generalización en otros contexto. En cuanto a la longitud de secuencia debemos ser cautos y generosos en este problema, las reviews son textos cortos por lo que no debemos cortarlos más

cuando puede supone un comportamiento inesperado del sistema, en definitiva, debemos emplear un tamaño suficientemente grande como 256 en el que quepan todas nuestras muestras, dado que esto no tiene un grave impacto computacional pero si lo puede tener en el comportamiento del sistema.

2 Recurrent Units

2.1 SimpleRNN

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.SimpleRNN(64, return_sequences=False)(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="simple.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 166)]             0

 embedding (Embedding)       (None, 166, 16)           80000
```

```
 simple_rnn (SimpleRNN)      (None, 64)                5184

 batch_normalization (BatchN  (None, 64)               256
 ormalization)

 dense (Dense)               (None, 1)                 65

=================================================================
Total params: 85,505
Trainable params: 85,377
Non-trainable params: 128

_________________________________________________________________
Epoch 1/20

2023-04-19 18:02:24.311930: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_blas.cc:630] TensorFloat-32
will be used for the matrix multiplication. This will only be logged once.
2023-04-19 18:02:24.330526: I tensorflow/compiler/xla/service/service.cc:173]
XLA service 0x7f61d8021940 initialized for platform CUDA (this does not
guarantee that XLA will be used). Devices:
2023-04-19 18:02:24.330543: I tensorflow/compiler/xla/service/service.cc:181]
StreamExecutor device (0): NVIDIA GeForce RTX 4090, Compute Capability 8.9
2023-04-19 18:02:24.333169: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:268] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
2023-04-19 18:02:24.366949: I tensorflow/tsl/platform/default/subprocess.cc:304]
Start cannot spawn child process: No such file or directory
2023-04-19 18:02:24.386670: I
tensorflow/compiler/jit/xla_compilation_cache.cc:477] Compiled cluster using
XLA!  This line is logged at most once for the lifetime of the process.

25/25 [==============================] - ETA: 0s - loss: 0.7077 - accuracy:
0.5467
Epoch 1: val_accuracy improved from -inf to 0.63524, saving model to
models/simple.h5
25/25 [==============================] - 4s 113ms/step - loss: 0.7077 -
accuracy: 0.5467 - val_loss: 0.6588 - val_accuracy: 0.6352 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.4827 - accuracy:
0.7758
Epoch 2: val_accuracy improved from 0.63524 to 0.81820, saving model to
models/simple.h5
25/25 [==============================] - 2s 99ms/step - loss: 0.4827 - accuracy:
0.7758 - val_loss: 0.5356 - val_accuracy: 0.8182 - lr: 0.0010
Epoch 3/20
25/25 [==============================] - ETA: 0s - loss: 0.2950 - accuracy:
0.8800
Epoch 3: val_accuracy improved from 0.81820 to 0.85308, saving model to
models/simple.h5
```

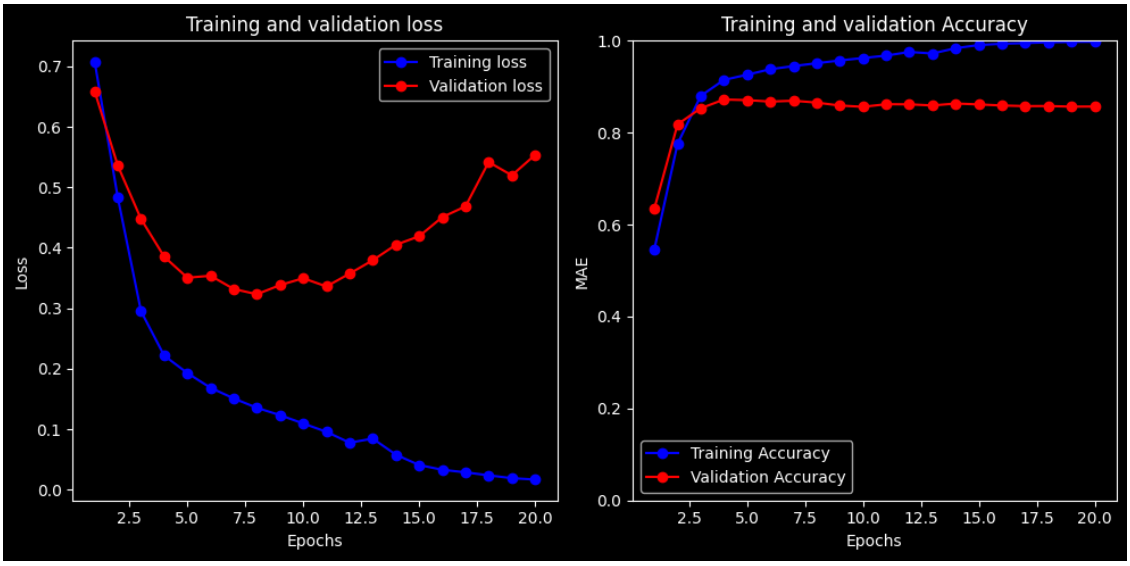
```
25/25 [==============================] - 2s 95ms/step - loss: 0.2950 - accuracy:
0.8800 - val_loss: 0.4475 - val_accuracy: 0.8531 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.2216 - accuracy:
0.9148
Epoch 4: val_accuracy improved from 0.85308 to 0.87216, saving model to
models/simple.h5
25/25 [==============================] - 2s 82ms/step - loss: 0.2216 - accuracy:
0.9148 - val_loss: 0.3852 - val_accuracy: 0.8722 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.1928 - accuracy:
0.9261
Epoch 5: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 64ms/step - loss: 0.1928 - accuracy:
0.9261 - val_loss: 0.3504 - val_accuracy: 0.8708 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1684 - accuracy:
0.9381
Epoch 6: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 76ms/step - loss: 0.1684 - accuracy:
0.9381 - val_loss: 0.3537 - val_accuracy: 0.8677 - lr: 0.0010
Epoch 7/20
25/25 [==============================] - ETA: 0s - loss: 0.1508 - accuracy:
0.9449
Epoch 7: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 67ms/step - loss: 0.1508 - accuracy:
0.9449 - val_loss: 0.3317 - val_accuracy: 0.8695 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.1353 - accuracy:
0.9512
Epoch 8: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 67ms/step - loss: 0.1353 - accuracy:
0.9512 - val_loss: 0.3231 - val_accuracy: 0.8655 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.1231 - accuracy:
0.9571
Epoch 9: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 68ms/step - loss: 0.1231 - accuracy:
0.9571 - val_loss: 0.3382 - val_accuracy: 0.8591 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.1094 - accuracy:
0.9624
Epoch 10: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 66ms/step - loss: 0.1094 - accuracy:
0.9624 - val_loss: 0.3496 - val_accuracy: 0.8563 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.0956 - accuracy:
0.9677
```

```
Epoch 11: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 62ms/step - loss: 0.0956 - accuracy:
0.9677 - val_loss: 0.3360 - val_accuracy: 0.8619 - lr: 0.0010
Epoch 12/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0777 - accuracy:
0.9758
Epoch 12: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 58ms/step - loss: 0.0777 - accuracy:
0.9757 - val_loss: 0.3572 - val_accuracy: 0.8617 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0844 - accuracy:
0.9722
Epoch 13: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 13: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 59ms/step - loss: 0.0844 - accuracy:
0.9722 - val_loss: 0.3793 - val_accuracy: 0.8592 - lr: 0.0010
Epoch 14/20
25/25 [==============================] - ETA: 0s - loss: 0.0577 - accuracy:
0.9839
Epoch 14: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 53ms/step - loss: 0.0577 - accuracy:
0.9839 - val_loss: 0.4049 - val_accuracy: 0.8635 - lr: 5.0000e-04
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0407 - accuracy:
0.9907
Epoch 15: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 64ms/step - loss: 0.0407 - accuracy:
0.9907 - val_loss: 0.4190 - val_accuracy: 0.8615 - lr: 5.0000e-04
Epoch 16/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0330 - accuracy:
0.9934
Epoch 16: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 53ms/step - loss: 0.0329 - accuracy:
0.9935 - val_loss: 0.4506 - val_accuracy: 0.8592 - lr: 5.0000e-04
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0286 - accuracy:
0.9949
Epoch 17: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 58ms/step - loss: 0.0286 - accuracy:
0.9949 - val_loss: 0.4684 - val_accuracy: 0.8578 - lr: 5.0000e-04
Epoch 18/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0237 - accuracy:
0.9967
Epoch 18: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 18: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 53ms/step - loss: 0.0237 - accuracy:
```

```
0.9966 - val_loss: 0.5416 - val_accuracy: 0.8580 - lr: 5.0000e-04
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0190 - accuracy:
0.9975
Epoch 19: val_accuracy did not improve from 0.87216
25/25 [==============================] - 1s 61ms/step - loss: 0.0190 - accuracy:
0.9975 - val_loss: 0.5197 - val_accuracy: 0.8567 - lr: 2.5000e-04
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0167 - accuracy:
0.9979
Epoch 20: val_accuracy did not improve from 0.87216
25/25 [==============================] - 2s 64ms/step - loss: 0.0167 - accuracy:
0.9979 - val_loss: 0.5534 - val_accuracy: 0.8569 - lr: 2.5000e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  35.81513690948486
```

[ ]:
```
model = keras.models.load_model(dir + "simple.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 5s 6ms/step - loss: 0.3852 -
accuracy: 0.8722
```

[ ]:
```
[0.38521212339401245, 0.872160017490387]
```

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)
```

```
reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.00000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.Bidirectional(layers.SimpleRNN(64, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="simple_bi.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 166)]             0

 embedding_1 (Embedding)     (None, 166, 16)           80000

 bidirectional (Bidirectiona  (None, 128)              10368
 l)

 batch_normalization_1 (Batc  (None, 128)              512
 hNormalization)

 dense_1 (Dense)             (None, 1)                 129

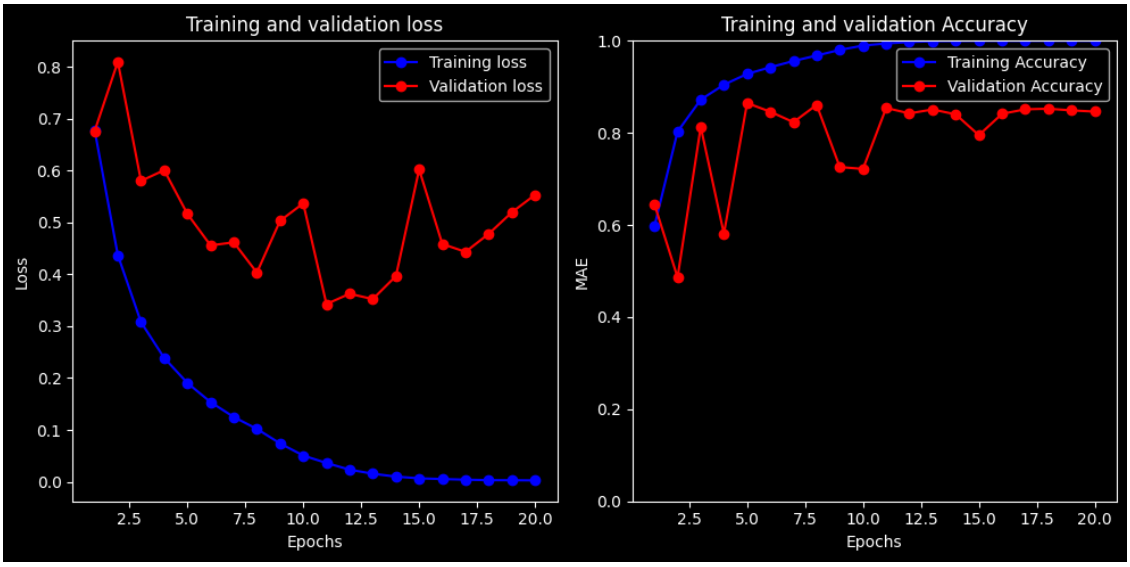
=================================================================
Total params: 91,009
Trainable params: 90,753
Non-trainable params: 256
_________________________________________________________________
```

```
Epoch 1/20
25/25 [==============================] - ETA: 0s - loss: 0.6776 - accuracy:
0.5968
Epoch 1: val_accuracy improved from -inf to 0.64556, saving model to
models/simple_bi.h5
25/25 [==============================] - 5s 139ms/step - loss: 0.6776 -
accuracy: 0.5968 - val_loss: 0.6760 - val_accuracy: 0.6456 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.4369 - accuracy:
0.8029
Epoch 2: val_accuracy did not improve from 0.64556
25/25 [==============================] - 3s 124ms/step - loss: 0.4369 -
accuracy: 0.8029 - val_loss: 0.8095 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 3/20
25/25 [==============================] - ETA: 0s - loss: 0.3077 - accuracy:
0.8722
Epoch 3: val_accuracy improved from 0.64556 to 0.81312, saving model to
models/simple_bi.h5
25/25 [==============================] - 3s 123ms/step - loss: 0.3077 -
accuracy: 0.8722 - val_loss: 0.5799 - val_accuracy: 0.8131 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.2387 - accuracy:
0.9047
Epoch 4: val_accuracy did not improve from 0.81312
25/25 [==============================] - 3s 113ms/step - loss: 0.2387 -
accuracy: 0.9047 - val_loss: 0.6006 - val_accuracy: 0.5810 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.1905 - accuracy:
0.9281
Epoch 5: val_accuracy improved from 0.81312 to 0.86484, saving model to
models/simple_bi.h5
25/25 [==============================] - 3s 102ms/step - loss: 0.1905 -
accuracy: 0.9281 - val_loss: 0.5164 - val_accuracy: 0.8648 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1537 - accuracy:
0.9426
Epoch 6: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 108ms/step - loss: 0.1537 -
accuracy: 0.9426 - val_loss: 0.4556 - val_accuracy: 0.8460 - lr: 0.0010
Epoch 7/20
25/25 [==============================] - ETA: 0s - loss: 0.1250 - accuracy:
0.9562
Epoch 7: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 105ms/step - loss: 0.1250 -
accuracy: 0.9562 - val_loss: 0.4615 - val_accuracy: 0.8233 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.1020 - accuracy:
0.9680
```

```
Epoch 8: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 105ms/step - loss: 0.1020 -
accuracy: 0.9680 - val_loss: 0.4032 - val_accuracy: 0.8609 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.0740 - accuracy:
0.9803
Epoch 9: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 104ms/step - loss: 0.0740 -
accuracy: 0.9803 - val_loss: 0.5030 - val_accuracy: 0.7259 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.0507 - accuracy:
0.9897
Epoch 10: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 104ms/step - loss: 0.0507 -
accuracy: 0.9897 - val_loss: 0.5367 - val_accuracy: 0.7218 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.0363 - accuracy:
0.9944
Epoch 11: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 103ms/step - loss: 0.0363 -
accuracy: 0.9944 - val_loss: 0.3425 - val_accuracy: 0.8542 - lr: 0.0010
Epoch 12/20
25/25 [==============================] - ETA: 0s - loss: 0.0234 - accuracy:
0.9973
Epoch 12: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 100ms/step - loss: 0.0234 -
accuracy: 0.9973 - val_loss: 0.3624 - val_accuracy: 0.8424 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0156 - accuracy:
0.9992
Epoch 13: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 99ms/step - loss: 0.0156 - accuracy:
0.9992 - val_loss: 0.3521 - val_accuracy: 0.8509 - lr: 0.0010
Epoch 14/20
25/25 [==============================] - ETA: 0s - loss: 0.0100 - accuracy:
0.9997
Epoch 14: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 95ms/step - loss: 0.0100 - accuracy:
0.9997 - val_loss: 0.3966 - val_accuracy: 0.8403 - lr: 0.0010
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0067 - accuracy:
1.0000
Epoch 15: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 103ms/step - loss: 0.0067 -
accuracy: 1.0000 - val_loss: 0.6020 - val_accuracy: 0.7951 - lr: 0.0010
Epoch 16/20
25/25 [==============================] - ETA: 0s - loss: 0.0054 - accuracy:
1.0000
```

```
Epoch 16: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 16: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 98ms/step - loss: 0.0054 - accuracy:
1.0000 - val_loss: 0.4583 - val_accuracy: 0.8415 - lr: 0.0010
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0041 - accuracy:
1.0000
Epoch 17: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 100ms/step - loss: 0.0041 -
accuracy: 1.0000 - val_loss: 0.4431 - val_accuracy: 0.8512 - lr: 5.0000e-04
Epoch 18/20
25/25 [==============================] - ETA: 0s - loss: 0.0032 - accuracy:
1.0000
Epoch 18: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 96ms/step - loss: 0.0032 - accuracy:
1.0000 - val_loss: 0.4778 - val_accuracy: 0.8526 - lr: 5.0000e-04
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0030 - accuracy:
1.0000
Epoch 19: val_accuracy did not improve from 0.86484
25/25 [==============================] - 2s 100ms/step - loss: 0.0030 -
accuracy: 1.0000 - val_loss: 0.5193 - val_accuracy: 0.8490 - lr: 5.0000e-04
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0028 - accuracy:
1.0000
Epoch 20: val_accuracy did not improve from 0.86484
25/25 [==============================] - 3s 104ms/step - loss: 0.0028 -
accuracy: 1.0000 - val_loss: 0.5531 - val_accuracy: 0.8463 - lr: 5.0000e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```



```
Elapsed time:  54.40829849243164
```

[ ]:
```
model = keras.models.load_model(dir + "simple_bi.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 9s 12ms/step - loss: 0.5164 -
accuracy: 0.8649
```

[ ]:
```
[0.5163887143135071, 0.8648800253868103]
```

2.2 GRU

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.GRU(64, return_sequences=False)(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)



model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="gru.h5", batch_size=1024, callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_3 (InputLayer)        [(None, 166)]             0
```

```
 embedding_2 (Embedding)     (None, 166, 16)           80000

 gru (GRU)                   (None, 64)                15744

 batch_normalization_2 (Batc  (None, 64)               256
 hNormalization)

 dense_2 (Dense)             (None, 1)                 65

=================================================================
Total params: 96,065
Trainable params: 95,937
Non-trainable params: 128

_________________________________________________________________
Epoch 1/20

2023-04-19 18:04:09.874587: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_dnn.cc:428] Loaded cuDNN
version 8100

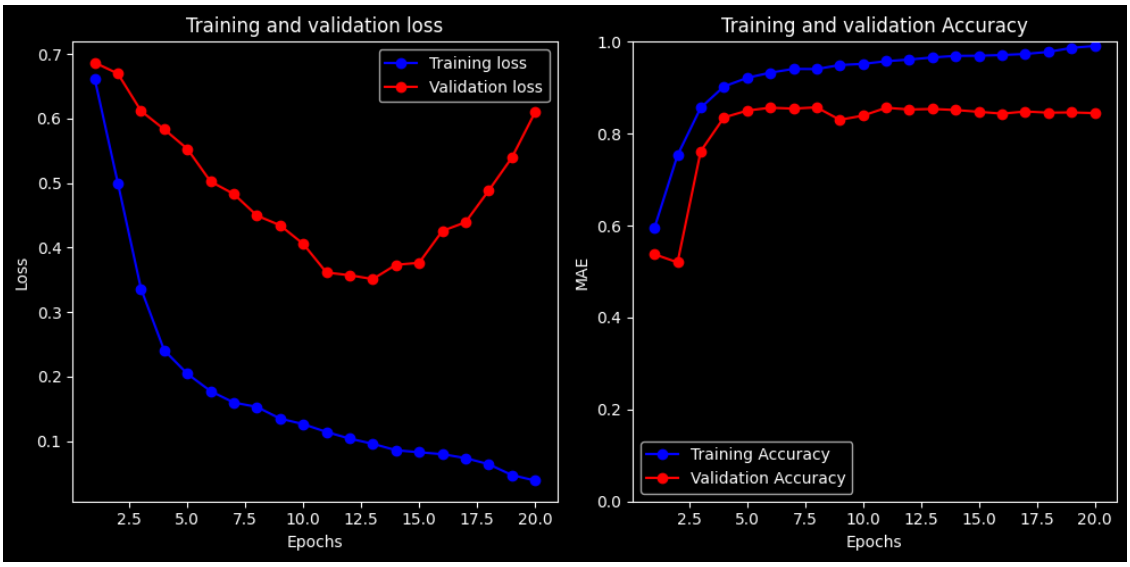
25/25 [==============================] - ETA: 0s - loss: 0.6621 - accuracy:
0.5944
Epoch 1: val_accuracy improved from -inf to 0.53772, saving model to
models/gru.h5
25/25 [==============================] - 4s 70ms/step - loss: 0.6621 - accuracy:
0.5944 - val_loss: 0.6868 - val_accuracy: 0.5377 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.5002 - accuracy:
0.7534
Epoch 2: val_accuracy did not improve from 0.53772
25/25 [==============================] - 1s 45ms/step - loss: 0.5002 - accuracy:
0.7534 - val_loss: 0.6699 - val_accuracy: 0.5200 - lr: 0.0010
Epoch 3/20
24/25 [===========================>..] - ETA: 0s - loss: 0.3364 - accuracy:
0.8564
Epoch 3: val_accuracy improved from 0.53772 to 0.76196, saving model to
models/gru.h5
25/25 [==============================] - 1s 44ms/step - loss: 0.3361 - accuracy:
0.8566 - val_loss: 0.6119 - val_accuracy: 0.7620 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.2407 - accuracy:
0.9026
Epoch 4: val_accuracy improved from 0.76196 to 0.83520, saving model to
models/gru.h5
25/25 [==============================] - 1s 37ms/step - loss: 0.2407 - accuracy:
0.9026 - val_loss: 0.5834 - val_accuracy: 0.8352 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.2043 - accuracy:
```

```
0.9214
Epoch 5: val_accuracy improved from 0.83520 to 0.85024, saving model to
models/gru.h5
25/25 [==============================] - 1s 23ms/step - loss: 0.2043 - accuracy:
0.9214 - val_loss: 0.5530 - val_accuracy: 0.8502 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1774 - accuracy:
0.9328
Epoch 6: val_accuracy improved from 0.85024 to 0.85644, saving model to
models/gru.h5
25/25 [==============================] - 1s 30ms/step - loss: 0.1774 - accuracy:
0.9328 - val_loss: 0.5025 - val_accuracy: 0.8564 - lr: 0.0010
Epoch 7/20
24/25 [===========================>..] - ETA: 0s - loss: 0.1587 - accuracy:
0.9412
Epoch 7: val_accuracy did not improve from 0.85644
25/25 [==============================] - 1s 25ms/step - loss: 0.1597 - accuracy:
0.9408 - val_loss: 0.4832 - val_accuracy: 0.8546 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.1529 - accuracy:
0.9406
Epoch 8: val_accuracy improved from 0.85644 to 0.85732, saving model to
models/gru.h5
25/25 [==============================] - 1s 26ms/step - loss: 0.1529 - accuracy:
0.9406 - val_loss: 0.4496 - val_accuracy: 0.8573 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.1348 - accuracy:
0.9493
Epoch 9: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 26ms/step - loss: 0.1348 - accuracy:
0.9493 - val_loss: 0.4345 - val_accuracy: 0.8302 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.1262 - accuracy:
0.9519
Epoch 10: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 25ms/step - loss: 0.1262 - accuracy:
0.9519 - val_loss: 0.4057 - val_accuracy: 0.8393 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.1141 - accuracy:
0.9576
Epoch 11: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 23ms/step - loss: 0.1141 - accuracy:
0.9576 - val_loss: 0.3613 - val_accuracy: 0.8564 - lr: 0.0010
Epoch 12/20
22/25 [========================>…] - ETA: 0s - loss: 0.1026 - accuracy:
0.9617
Epoch 12: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 18ms/step - loss: 0.1038 - accuracy:
```

```
0.9613 - val_loss: 0.3572 - val_accuracy: 0.8527 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0957 - accuracy:
0.9658
Epoch 13: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 19ms/step - loss: 0.0957 - accuracy:
0.9658 - val_loss: 0.3511 - val_accuracy: 0.8537 - lr: 0.0010
Epoch 14/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0857 - accuracy:
0.9694
Epoch 14: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 15ms/step - loss: 0.0858 - accuracy:
0.9693 - val_loss: 0.3733 - val_accuracy: 0.8515 - lr: 0.0010
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0826 - accuracy:
0.9696
Epoch 15: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 23ms/step - loss: 0.0826 - accuracy:
0.9696 - val_loss: 0.3764 - val_accuracy: 0.8476 - lr: 0.0010
Epoch 16/20
22/25 [========================>…] - ETA: 0s - loss: 0.0766 - accuracy:
0.9727
Epoch 16: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 18ms/step - loss: 0.0796 - accuracy:
0.9711 - val_loss: 0.4258 - val_accuracy: 0.8436 - lr: 0.0010
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0735 - accuracy:
0.9735
Epoch 17: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 19ms/step - loss: 0.0735 - accuracy:
0.9735 - val_loss: 0.4393 - val_accuracy: 0.8483 - lr: 0.0010
Epoch 18/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0641 - accuracy:
0.9780
Epoch 18: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 18: val_accuracy did not improve from 0.85732
25/25 [==============================] - 0s 16ms/step - loss: 0.0641 - accuracy:
0.9779 - val_loss: 0.4883 - val_accuracy: 0.8458 - lr: 0.0010
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0473 - accuracy:
0.9867
Epoch 19: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 21ms/step - loss: 0.0473 - accuracy:
0.9867 - val_loss: 0.5395 - val_accuracy: 0.8463 - lr: 5.0000e-04
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0387 - accuracy:
0.9909
```

```
Epoch 20: val_accuracy did not improve from 0.85732
25/25 [==============================] - 1s 23ms/step - loss: 0.0387 - accuracy:
0.9909 - val_loss: 0.6097 - val_accuracy: 0.8448 - lr: 5.0000e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  15.89973258972168
```

[ ]:
```
model = keras.models.load_model(dir + "gru.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 2s 2ms/step - loss: 0.4497 -
accuracy: 0.8573
```

[ ]:
```
[0.44965192675590515, 0.8572800159454346]
```

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.Bidirectional(layers.GRU(64, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
```

```
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="gru_bi.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_4 (InputLayer)        [(None, 166)]             0

 embedding_3 (Embedding)     (None, 166, 16)           80000

 bidirectional_1 (Bidirectio  (None, 128)              31488
 nal)

 batch_normalization_3 (Batc  (None, 128)              512
 hNormalization)

 dense_3 (Dense)             (None, 1)                 129

=================================================================
Total params: 112,129
Trainable params: 111,873
Non-trainable params: 256
_________________________________________________________________
Epoch 1/20
2023-04-19 18:04:29.218655: W
tensorflow/core/common_runtime/type_inference.cc:339] Type inference failed.
This indicates an invalid graph that escaped type checking. Error message:
INVALID_ARGUMENT: expected compatible input types, but input 1:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
  args {
    type_id: TFT_TENSOR
```

```
    args {
      type_id: TFT_INT32
    }
  }
}
 is neither a subtype nor a supertype of the combined inputs preceding it:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
  args {
    type_id: TFT_TENSOR
    args {
      type_id: TFT_FLOAT
    }
  }
}

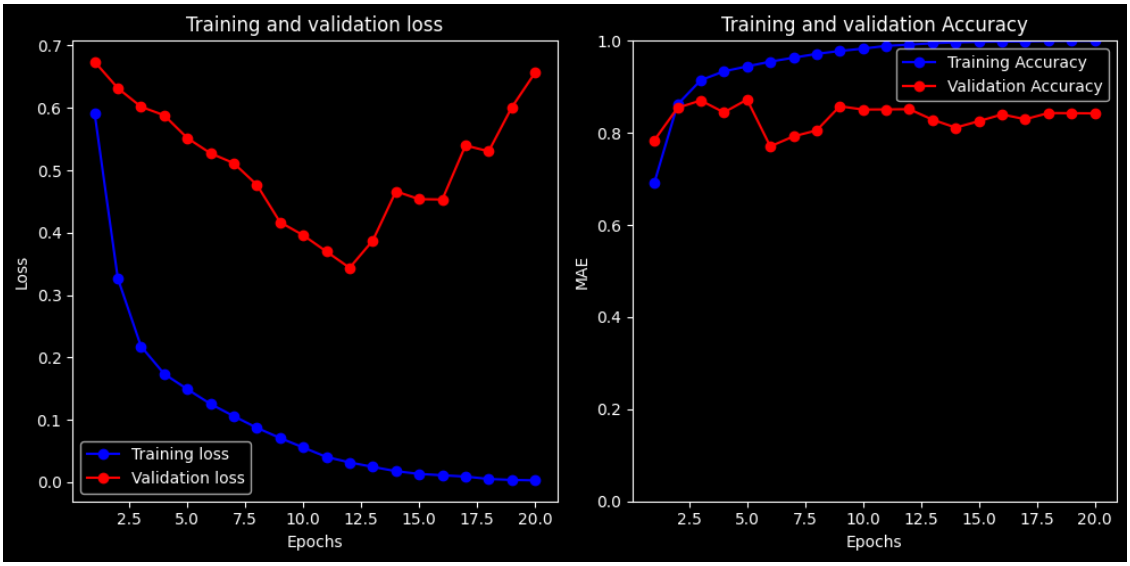
        while inferring type of node 'cond_41/output/_22'
25/25 [==============================] - ETA: 0s - loss: 0.5911 - accuracy:
0.6920
Epoch 1: val_accuracy improved from -inf to 0.78416, saving model to
models/gru_bi.h5
25/25 [==============================] - 5s 91ms/step - loss: 0.5911 - accuracy:
0.6920 - val_loss: 0.6740 - val_accuracy: 0.7842 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.3267 - accuracy:
0.8618
Epoch 2: val_accuracy improved from 0.78416 to 0.85444, saving model to
models/gru_bi.h5
25/25 [==============================] - 1s 52ms/step - loss: 0.3267 - accuracy:
0.8618 - val_loss: 0.6317 - val_accuracy: 0.8544 - lr: 0.0010
Epoch 3/20
25/25 [==============================] - ETA: 0s - loss: 0.2179 - accuracy:
0.9145
Epoch 3: val_accuracy improved from 0.85444 to 0.87052, saving model to
models/gru_bi.h5
25/25 [==============================] - 1s 50ms/step - loss: 0.2179 - accuracy:
0.9145 - val_loss: 0.6019 - val_accuracy: 0.8705 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.1736 - accuracy:
0.9338
Epoch 4: val_accuracy did not improve from 0.87052
25/25 [==============================] - 1s 42ms/step - loss: 0.1736 - accuracy:
0.9338 - val_loss: 0.5882 - val_accuracy: 0.8445 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.1491 - accuracy:
0.9444
```

```
Epoch 5: val_accuracy improved from 0.87052 to 0.87248, saving model to
models/gru_bi.h5
25/25 [==============================] - 1s 30ms/step - loss: 0.1491 - accuracy:
0.9444 - val_loss: 0.5516 - val_accuracy: 0.8725 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1254 - accuracy:
0.9548
Epoch 6: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 37ms/step - loss: 0.1254 - accuracy:
0.9548 - val_loss: 0.5273 - val_accuracy: 0.7707 - lr: 0.0010
Epoch 7/20
25/25 [==============================] - ETA: 0s - loss: 0.1060 - accuracy:
0.9633
Epoch 7: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 32ms/step - loss: 0.1060 - accuracy:
0.9633 - val_loss: 0.5115 - val_accuracy: 0.7925 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.0873 - accuracy:
0.9717
Epoch 8: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 32ms/step - loss: 0.0873 - accuracy:
0.9717 - val_loss: 0.4767 - val_accuracy: 0.8055 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.0709 - accuracy:
0.9780
Epoch 9: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 34ms/step - loss: 0.0709 - accuracy:
0.9780 - val_loss: 0.4169 - val_accuracy: 0.8579 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.0557 - accuracy:
0.9831
Epoch 10: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 32ms/step - loss: 0.0557 - accuracy:
0.9831 - val_loss: 0.3959 - val_accuracy: 0.8508 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.0405 - accuracy:
0.9890
Epoch 11: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 30ms/step - loss: 0.0405 - accuracy:
0.9890 - val_loss: 0.3698 - val_accuracy: 0.8511 - lr: 0.0010
Epoch 12/20
22/25 [========================>…] - ETA: 0s - loss: 0.0322 - accuracy:
0.9918
Epoch 12: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 27ms/step - loss: 0.0318 - accuracy:
0.9918 - val_loss: 0.3437 - val_accuracy: 0.8516 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0246 - accuracy:
```

```
0.9947
Epoch 13: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 28ms/step - loss: 0.0246 - accuracy:
0.9947 - val_loss: 0.3874 - val_accuracy: 0.8288 - lr: 0.0010
Epoch 14/20
25/25 [==============================] - ETA: 0s - loss: 0.0177 - accuracy:
0.9968
Epoch 14: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 24ms/step - loss: 0.0177 - accuracy:
0.9968 - val_loss: 0.4663 - val_accuracy: 0.8116 - lr: 0.0010
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0134 - accuracy:
0.9979
Epoch 15: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 31ms/step - loss: 0.0134 - accuracy:
0.9979 - val_loss: 0.4537 - val_accuracy: 0.8256 - lr: 0.0010
Epoch 16/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0112 - accuracy:
0.9984
Epoch 16: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 26ms/step - loss: 0.0111 - accuracy:
0.9984 - val_loss: 0.4532 - val_accuracy: 0.8402 - lr: 0.0010
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0091 - accuracy:
0.9986
Epoch 17: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 17: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 27ms/step - loss: 0.0091 - accuracy:
0.9986 - val_loss: 0.5399 - val_accuracy: 0.8298 - lr: 0.0010
Epoch 18/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0052 - accuracy:
0.9996
Epoch 18: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 24ms/step - loss: 0.0052 - accuracy:
0.9996 - val_loss: 0.5304 - val_accuracy: 0.8432 - lr: 5.0000e-04
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0037 - accuracy:
0.9999
Epoch 19: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 28ms/step - loss: 0.0037 - accuracy:
0.9999 - val_loss: 0.6011 - val_accuracy: 0.8429 - lr: 5.0000e-04
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0030 - accuracy:
0.9999
Epoch 20: val_accuracy did not improve from 0.87248
25/25 [==============================] - 1s 31ms/step - loss: 0.0030 - accuracy:
0.9999 - val_loss: 0.6564 - val_accuracy: 0.8426 - lr: 5.0000e-04
```

```
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  20.982495546340942
```

[ ]:
```
model = keras.models.load_model(dir + "gru_bi.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 4s 3ms/step - loss: 0.5516 -
accuracy: 0.8724
```

[ ]:
```
[0.551629364490509, 0.8723999857902527]
```

2.3 LSTM

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.LSTM(64, return_sequences=False)(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
```

```
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="lstm.h5", batch_size=1024, callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_5 (InputLayer)        [(None, 166)]             0

 embedding_4 (Embedding)     (None, 166, 16)           80000

 lstm (LSTM)                 (None, 64)                20736

 batch_normalization_4 (Batc  (None, 64)               256
 hNormalization)

 dense_4 (Dense)             (None, 1)                 65

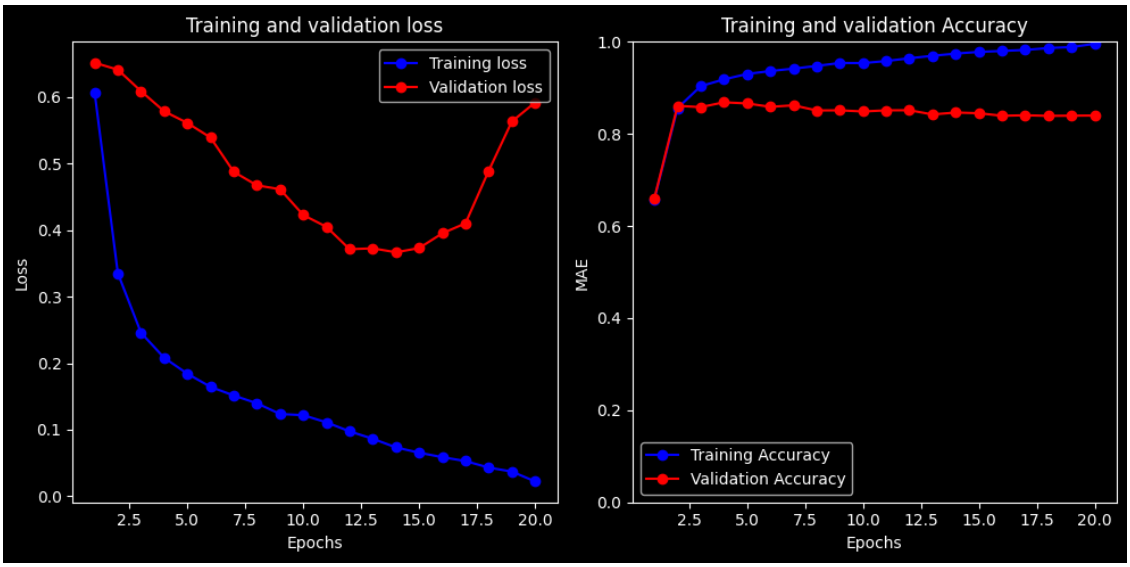
=================================================================
Total params: 101,057
Trainable params: 100,929
Non-trainable params: 128
_________________________________________________________________
Epoch 1/20
25/25 [==============================] - ETA: 0s - loss: 0.6067 - accuracy:
0.6582
Epoch 1: val_accuracy improved from -inf to 0.66028, saving model to
models/lstm.h5
25/25 [==============================] - 3s 72ms/step - loss: 0.6067 - accuracy:
0.6582 - val_loss: 0.6518 - val_accuracy: 0.6603 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.3353 - accuracy:
0.8561
Epoch 2: val_accuracy improved from 0.66028 to 0.86104, saving model to
models/lstm.h5
25/25 [==============================] - 1s 46ms/step - loss: 0.3353 - accuracy:
```

```
0.8561 - val_loss: 0.6414 - val_accuracy: 0.8610 - lr: 0.0010
Epoch 3/20
25/25 [==============================] - ETA: 0s - loss: 0.2459 - accuracy:
0.9037
Epoch 3: val_accuracy did not improve from 0.86104
25/25 [==============================] - 1s 44ms/step - loss: 0.2459 - accuracy:
0.9037 - val_loss: 0.6091 - val_accuracy: 0.8582 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.2082 - accuracy:
0.9184
Epoch 4: val_accuracy improved from 0.86104 to 0.86868, saving model to
models/lstm.h5
25/25 [==============================] - 1s 37ms/step - loss: 0.2082 - accuracy:
0.9184 - val_loss: 0.5788 - val_accuracy: 0.8687 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.1842 - accuracy:
0.9302
Epoch 5: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 24ms/step - loss: 0.1842 - accuracy:
0.9302 - val_loss: 0.5613 - val_accuracy: 0.8662 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1645 - accuracy:
0.9366
Epoch 6: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 31ms/step - loss: 0.1645 - accuracy:
0.9366 - val_loss: 0.5393 - val_accuracy: 0.8588 - lr: 0.0010
Epoch 7/20
25/25 [==============================] - ETA: 0s - loss: 0.1515 - accuracy:
0.9418
Epoch 7: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 25ms/step - loss: 0.1515 - accuracy:
0.9418 - val_loss: 0.4878 - val_accuracy: 0.8621 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.1398 - accuracy:
0.9476
Epoch 8: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 25ms/step - loss: 0.1398 - accuracy:
0.9476 - val_loss: 0.4675 - val_accuracy: 0.8510 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.1237 - accuracy:
0.9541
Epoch 9: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 27ms/step - loss: 0.1237 - accuracy:
0.9541 - val_loss: 0.4616 - val_accuracy: 0.8512 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.1219 - accuracy:
0.9538
Epoch 10: val_accuracy did not improve from 0.86868
```

```
25/25 [==============================] - 1s 25ms/step - loss: 0.1219 - accuracy:
0.9538 - val_loss: 0.4229 - val_accuracy: 0.8488 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.1111 - accuracy:
0.9583
Epoch 11: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 23ms/step - loss: 0.1111 - accuracy:
0.9583 - val_loss: 0.4051 - val_accuracy: 0.8512 - lr: 0.0010
Epoch 12/20
22/25 [=========================>...] - ETA: 0s - loss: 0.0967 - accuracy:
0.9647
Epoch 12: val_accuracy did not improve from 0.86868
25/25 [==============================] - 0s 20ms/step - loss: 0.0976 - accuracy:
0.9642 - val_loss: 0.3714 - val_accuracy: 0.8514 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0864 - accuracy:
0.9696
Epoch 13: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 21ms/step - loss: 0.0864 - accuracy:
0.9696 - val_loss: 0.3728 - val_accuracy: 0.8423 - lr: 0.0010
Epoch 14/20
25/25 [==============================] - ETA: 0s - loss: 0.0735 - accuracy:
0.9745
Epoch 14: val_accuracy did not improve from 0.86868
25/25 [==============================] - 0s 16ms/step - loss: 0.0735 - accuracy:
0.9745 - val_loss: 0.3668 - val_accuracy: 0.8465 - lr: 0.0010
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0655 - accuracy:
0.9781
Epoch 15: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 23ms/step - loss: 0.0655 - accuracy:
0.9781 - val_loss: 0.3732 - val_accuracy: 0.8450 - lr: 0.0010
Epoch 16/20
22/25 [=========================>...] - ETA: 0s - loss: 0.0555 - accuracy:
0.9816
Epoch 16: val_accuracy did not improve from 0.86868
25/25 [==============================] - 0s 18ms/step - loss: 0.0588 - accuracy:
0.9802 - val_loss: 0.3954 - val_accuracy: 0.8394 - lr: 0.0010
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0529 - accuracy:
0.9824
Epoch 17: val_accuracy did not improve from 0.86868
25/25 [==============================] - 0s 20ms/step - loss: 0.0529 - accuracy:
0.9824 - val_loss: 0.4104 - val_accuracy: 0.8405 - lr: 0.0010
Epoch 18/20
24/25 [==========================>..] - ETA: 0s - loss: 0.0429 - accuracy:
0.9867
Epoch 18: val_accuracy did not improve from 0.86868
```

```
25/25 [==============================] - 0s 16ms/step - loss: 0.0431 - accuracy:
0.9865 - val_loss: 0.4893 - val_accuracy: 0.8392 - lr: 0.0010
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0371 - accuracy:
0.9887
Epoch 19: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 19: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 22ms/step - loss: 0.0371 - accuracy:
0.9887 - val_loss: 0.5635 - val_accuracy: 0.8396 - lr: 0.0010
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0223 - accuracy:
0.9957
Epoch 20: val_accuracy did not improve from 0.86868
25/25 [==============================] - 1s 24ms/step - loss: 0.0223 - accuracy:
0.9957 - val_loss: 0.5920 - val_accuracy: 0.8400 - lr: 5.0000e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  15.766591787338257
```

[ ]:
```
model = keras.models.load_model(dir + "lstm.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 2s 2ms/step - loss: 0.5788 -
accuracy: 0.8687
```

[ ]:
```
[0.5788054466247559, 0.8686800003051758]
```

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 16, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = layers.Bidirectional(layers.LSTM(64, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=20, model_name="lstm_bi.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_6 (InputLayer)        [(None, 166)]             0

 embedding_5 (Embedding)     (None, 166, 16)           80000

 bidirectional_2 (Bidirectio  (None, 128)              41472
 nal)

 batch_normalization_5 (Batc  (None, 128)              512
 hNormalization)

 dense_5 (Dense)             (None, 1)                 129

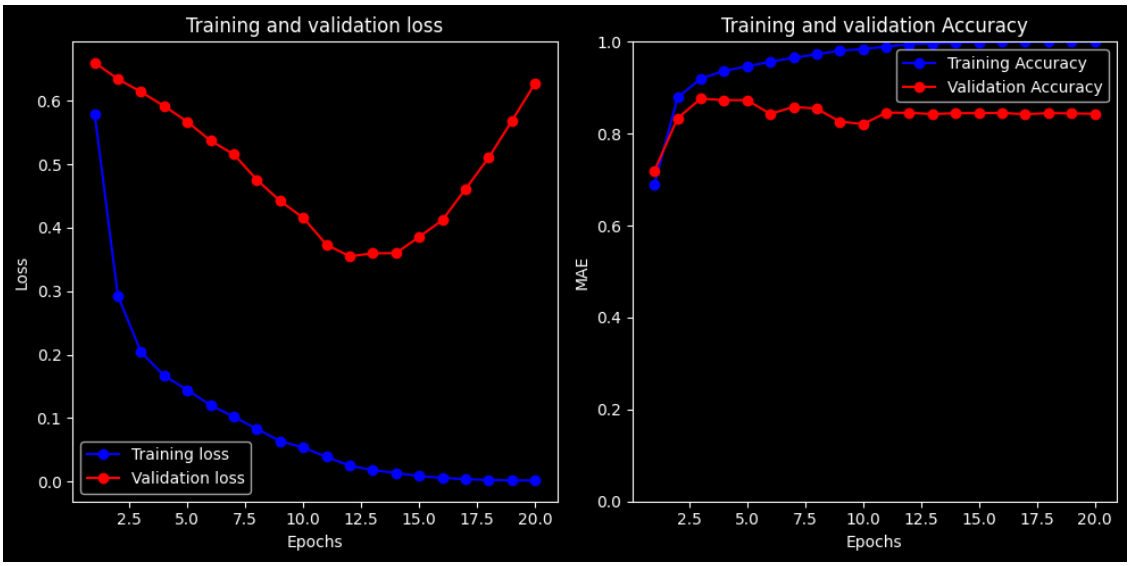
=================================================================
```

```
Total params: 122,113
Trainable params: 121,857
Non-trainable params: 256
_________________________________________________________________
Epoch 1/20
25/25 [==============================] - ETA: 0s - loss: 0.5797 - accuracy:
0.6893
Epoch 1: val_accuracy improved from -inf to 0.71900, saving model to
models/lstm_bi.h5
25/25 [==============================] - 5s 100ms/step - loss: 0.5797 -
accuracy: 0.6893 - val_loss: 0.6602 - val_accuracy: 0.7190 - lr: 0.0010
Epoch 2/20
25/25 [==============================] - ETA: 0s - loss: 0.2929 - accuracy:
0.8786
Epoch 2: val_accuracy improved from 0.71900 to 0.83356, saving model to
models/lstm_bi.h5
25/25 [==============================] - 1s 54ms/step - loss: 0.2929 - accuracy:
0.8786 - val_loss: 0.6344 - val_accuracy: 0.8336 - lr: 0.0010
Epoch 3/20
25/25 [==============================] - ETA: 0s - loss: 0.2040 - accuracy:
0.9198
Epoch 3: val_accuracy improved from 0.83356 to 0.87624, saving model to
models/lstm_bi.h5
25/25 [==============================] - 1s 52ms/step - loss: 0.2040 - accuracy:
0.9198 - val_loss: 0.6140 - val_accuracy: 0.8762 - lr: 0.0010
Epoch 4/20
25/25 [==============================] - ETA: 0s - loss: 0.1666 - accuracy:
0.9366
Epoch 4: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 44ms/step - loss: 0.1666 - accuracy:
0.9366 - val_loss: 0.5917 - val_accuracy: 0.8730 - lr: 0.0010
Epoch 5/20
25/25 [==============================] - ETA: 0s - loss: 0.1442 - accuracy:
0.9465
Epoch 5: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 32ms/step - loss: 0.1442 - accuracy:
0.9465 - val_loss: 0.5669 - val_accuracy: 0.8729 - lr: 0.0010
Epoch 6/20
25/25 [==============================] - ETA: 0s - loss: 0.1202 - accuracy:
0.9565
Epoch 6: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 39ms/step - loss: 0.1202 - accuracy:
0.9565 - val_loss: 0.5371 - val_accuracy: 0.8431 - lr: 0.0010
Epoch 7/20
25/25 [==============================] - ETA: 0s - loss: 0.1021 - accuracy:
0.9650
Epoch 7: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 34ms/step - loss: 0.1021 - accuracy:
```

```
0.9650 - val_loss: 0.5157 - val_accuracy: 0.8582 - lr: 0.0010
Epoch 8/20
25/25 [==============================] - ETA: 0s - loss: 0.0828 - accuracy:
0.9727
Epoch 8: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 35ms/step - loss: 0.0828 - accuracy:
0.9727 - val_loss: 0.4755 - val_accuracy: 0.8546 - lr: 0.0010
Epoch 9/20
25/25 [==============================] - ETA: 0s - loss: 0.0637 - accuracy:
0.9806
Epoch 9: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 36ms/step - loss: 0.0637 - accuracy:
0.9806 - val_loss: 0.4422 - val_accuracy: 0.8264 - lr: 0.0010
Epoch 10/20
25/25 [==============================] - ETA: 0s - loss: 0.0534 - accuracy:
0.9842
Epoch 10: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 34ms/step - loss: 0.0534 - accuracy:
0.9842 - val_loss: 0.4157 - val_accuracy: 0.8209 - lr: 0.0010
Epoch 11/20
25/25 [==============================] - ETA: 0s - loss: 0.0388 - accuracy:
0.9894
Epoch 11: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 32ms/step - loss: 0.0388 - accuracy:
0.9894 - val_loss: 0.3733 - val_accuracy: 0.8456 - lr: 0.0010
Epoch 12/20
22/25 [=========================>...] - ETA: 0s - loss: 0.0249 - accuracy:
0.9949
Epoch 12: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 29ms/step - loss: 0.0249 - accuracy:
0.9946 - val_loss: 0.3549 - val_accuracy: 0.8455 - lr: 0.0010
Epoch 13/20
25/25 [==============================] - ETA: 0s - loss: 0.0178 - accuracy:
0.9967
Epoch 13: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 28ms/step - loss: 0.0178 - accuracy:
0.9967 - val_loss: 0.3595 - val_accuracy: 0.8427 - lr: 0.0010
Epoch 14/20
25/25 [==============================] - ETA: 0s - loss: 0.0133 - accuracy:
0.9979
Epoch 14: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 25ms/step - loss: 0.0133 - accuracy:
0.9979 - val_loss: 0.3600 - val_accuracy: 0.8446 - lr: 0.0010
Epoch 15/20
25/25 [==============================] - ETA: 0s - loss: 0.0086 - accuracy:
0.9989
Epoch 15: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 32ms/step - loss: 0.0086 - accuracy:
```

```
0.9989 - val_loss: 0.3855 - val_accuracy: 0.8446 - lr: 0.0010
Epoch 16/20
22/25 [========================>…] - ETA: 0s - loss: 0.0055 - accuracy:
0.9997
Epoch 16: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 27ms/step - loss: 0.0057 - accuracy:
0.9996 - val_loss: 0.4119 - val_accuracy: 0.8453 - lr: 0.0010
Epoch 17/20
25/25 [==============================] - ETA: 0s - loss: 0.0037 - accuracy:
0.9998
Epoch 17: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 17: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 29ms/step - loss: 0.0037 - accuracy:
0.9998 - val_loss: 0.4609 - val_accuracy: 0.8423 - lr: 0.0010
Epoch 18/20
24/25 [===========================>..] - ETA: 0s - loss: 0.0023 - accuracy:
0.9999
Epoch 18: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 25ms/step - loss: 0.0023 - accuracy:
0.9999 - val_loss: 0.5103 - val_accuracy: 0.8448 - lr: 5.0000e-04
Epoch 19/20
25/25 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 19: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 30ms/step - loss: 0.0017 - accuracy:
1.0000 - val_loss: 0.5683 - val_accuracy: 0.8440 - lr: 5.0000e-04
Epoch 20/20
25/25 [==============================] - ETA: 0s - loss: 0.0015 - accuracy:
1.0000
Epoch 20: val_accuracy did not improve from 0.87624
25/25 [==============================] - 1s 34ms/step - loss: 0.0015 - accuracy:
1.0000 - val_loss: 0.6275 - val_accuracy: 0.8433 - lr: 5.0000e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  22.130324840545654
```

[ ]:
```
model = keras.models.load_model(dir + "lstm_bi.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 3s 3ms/step - loss: 0.6140 -
accuracy: 0.8762
```

[ ]:
```
[0.614045262336731, 0.8762400150299072]
```

3 Intentado mejorar el rendimiento

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 128, mask_zero=True)(inputs)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(512, return_sequences=True))(x)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(128, return_sequences=True))(x)
x = keras.layers.BatchNormalization()(x)
```

```
x = layers.Bidirectional(layers.GRU(16, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(128, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(32, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(8, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=50, model_name="gru_bi_a0.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 166)]             0

 embedding_1 (Embedding)     (None, 166, 128)          704000

 batch_normalization_7 (Batc  (None, 166, 128)         512
 hNormalization)

 bidirectional_3 (Bidirectio  (None, 166, 1024)        1972224
 nal)

 batch_normalization_8 (Batc  (None, 166, 1024)        4096
 hNormalization)

 bidirectional_4 (Bidirectio  (None, 166, 256)         886272
 nal)

 batch_normalization_9 (Batc  (None, 166, 256)         1024
 hNormalization)
```

```
 bidirectional_5 (Bidirectio  (None, 32)              26304
 nal)

 batch_normalization_10 (Bat  (None, 32)              128
 chNormalization)

 dense_4 (Dense)             (None, 128)              4224

 batch_normalization_11 (Bat  (None, 128)             512
 chNormalization)

 dense_5 (Dense)             (None, 32)               4128

 batch_normalization_12 (Bat  (None, 32)              128
 chNormalization)

 dense_6 (Dense)             (None, 8)                264

 batch_normalization_13 (Bat  (None, 8)               32
 chNormalization)

 dense_7 (Dense)             (None, 1)                9

=================================================================
Total params: 3,603,857
Trainable params: 3,600,641
Non-trainable params: 3,216
_________________________________________________________________
Epoch 1/50

2023-04-19 18:48:44.414353: W
tensorflow/core/common_runtime/type_inference.cc:339] Type inference failed.
This indicates an invalid graph that escaped type checking. Error message:
INVALID_ARGUMENT: expected compatible input types, but input 1:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
  args {
    type_id: TFT_TENSOR
    args {
      type_id: TFT_FLOAT
    }
  }
}
 is neither a subtype nor a supertype of the combined inputs preceding it:
type_id: TFT_OPTIONAL
args {
  type_id: TFT_PRODUCT
```

```
  args {
    type_id: TFT_TENSOR
    args {
      type_id: TFT_INT8
    }
  }
}

        while inferring type of node 'cond_43/output/_22'
2023-04-19 18:48:44.866746: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_dnn.cc:428] Loaded cuDNN
version 8100
2023-04-19 18:48:45.775788: I
tensorflow/compiler/xla/stream_executor/cuda/cuda_blas.cc:630] TensorFloat-32
will be used for the matrix multiplication. This will only be logged once.
2023-04-19 18:48:45.777527: I tensorflow/compiler/xla/service/service.cc:173]
XLA service 0x7f7950039440 initialized for platform CUDA (this does not
guarantee that XLA will be used). Devices:
2023-04-19 18:48:45.777537: I tensorflow/compiler/xla/service/service.cc:181]
StreamExecutor device (0): NVIDIA GeForce RTX 4090, Compute Capability 8.9
2023-04-19 18:48:45.779699: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:268] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
2023-04-19 18:48:45.813118: I tensorflow/tsl/platform/default/subprocess.cc:304]
Start cannot spawn child process: No such file or directory
2023-04-19 18:48:45.835131: I
tensorflow/compiler/jit/xla_compilation_cache.cc:477] Compiled cluster using
XLA!  This line is logged at most once for the lifetime of the process.

25/25 [==============================] - ETA: 0s - loss: 0.5844 - accuracy:
0.6955
Epoch 1: val_accuracy improved from -inf to 0.48628, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 18s 337ms/step - loss: 0.5844 -
accuracy: 0.6955 - val_loss: 0.6889 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 2/50
25/25 [==============================] - ETA: 0s - loss: 0.3149 - accuracy:
0.8714
Epoch 2: val_accuracy did not improve from 0.48628
25/25 [==============================] - 6s 229ms/step - loss: 0.3149 -
accuracy: 0.8714 - val_loss: 0.7445 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 3/50
25/25 [==============================] - ETA: 0s - loss: 0.1856 - accuracy:
0.9324
Epoch 3: val_accuracy did not improve from 0.48628
25/25 [==============================] - 6s 226ms/step - loss: 0.1856 -
accuracy: 0.9324 - val_loss: 0.8110 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 4/50
```

```
25/25 [==============================] - ETA: 0s - loss: 0.1056 - accuracy:
0.9694
Epoch 4: val_accuracy improved from 0.48628 to 0.48668, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 6s 230ms/step - loss: 0.1056 -
accuracy: 0.9694 - val_loss: 0.7903 - val_accuracy: 0.4867 - lr: 0.0010
Epoch 5/50
25/25 [==============================] - ETA: 0s - loss: 0.0633 - accuracy:
0.9854
Epoch 5: val_accuracy improved from 0.48668 to 0.49128, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 6s 224ms/step - loss: 0.0633 -
accuracy: 0.9854 - val_loss: 0.7562 - val_accuracy: 0.4913 - lr: 0.0010
Epoch 6/50
25/25 [==============================] - ETA: 0s - loss: 0.0355 - accuracy:
0.9941
Epoch 6: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 6: val_accuracy improved from 0.49128 to 0.52432, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 221ms/step - loss: 0.0355 -
accuracy: 0.9941 - val_loss: 0.7245 - val_accuracy: 0.5243 - lr: 0.0010
Epoch 7/50
25/25 [==============================] - ETA: 0s - loss: 0.0205 - accuracy:
0.9978
Epoch 7: val_accuracy improved from 0.52432 to 0.54636, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 216ms/step - loss: 0.0205 -
accuracy: 0.9978 - val_loss: 0.7324 - val_accuracy: 0.5464 - lr: 5.0000e-04
Epoch 8/50
25/25 [==============================] - ETA: 0s - loss: 0.0142 - accuracy:
0.9991
Epoch 8: val_accuracy improved from 0.54636 to 0.55388, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 216ms/step - loss: 0.0142 -
accuracy: 0.9991 - val_loss: 0.7996 - val_accuracy: 0.5539 - lr: 5.0000e-04
Epoch 9/50
25/25 [==============================] - ETA: 0s - loss: 0.0112 - accuracy:
0.9993
Epoch 9: val_accuracy improved from 0.55388 to 0.58840, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 214ms/step - loss: 0.0112 -
accuracy: 0.9993 - val_loss: 0.7922 - val_accuracy: 0.5884 - lr: 5.0000e-04
Epoch 10/50
25/25 [==============================] - ETA: 0s - loss: 0.0095 - accuracy:
0.9995
Epoch 10: val_accuracy improved from 0.58840 to 0.61616, saving model to
models/gru_bi_a0.h5
```

```
25/25 [==============================] - 5s 216ms/step - loss: 0.0095 -
accuracy: 0.9995 - val_loss: 0.8130 - val_accuracy: 0.6162 - lr: 5.0000e-04
Epoch 11/50
25/25 [==============================] - ETA: 0s - loss: 0.0082 - accuracy:
0.9995
Epoch 11: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 11: val_accuracy improved from 0.61616 to 0.65148, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 211ms/step - loss: 0.0082 -
accuracy: 0.9995 - val_loss: 0.7976 - val_accuracy: 0.6515 - lr: 5.0000e-04
Epoch 12/50
25/25 [==============================] - ETA: 0s - loss: 0.0073 - accuracy:
0.9996
Epoch 12: val_accuracy improved from 0.65148 to 0.69696, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 214ms/step - loss: 0.0073 -
accuracy: 0.9996 - val_loss: 0.7296 - val_accuracy: 0.6970 - lr: 2.5000e-04
Epoch 13/50
25/25 [==============================] - ETA: 0s - loss: 0.0069 - accuracy:
0.9996
Epoch 13: val_accuracy improved from 0.69696 to 0.73912, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 213ms/step - loss: 0.0069 -
accuracy: 0.9996 - val_loss: 0.6680 - val_accuracy: 0.7391 - lr: 2.5000e-04
Epoch 14/50
25/25 [==============================] - ETA: 0s - loss: 0.0065 - accuracy:
0.9997
Epoch 14: val_accuracy improved from 0.73912 to 0.76892, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 212ms/step - loss: 0.0065 -
accuracy: 0.9997 - val_loss: 0.6262 - val_accuracy: 0.7689 - lr: 2.5000e-04
Epoch 15/50
25/25 [==============================] - ETA: 0s - loss: 0.0061 - accuracy:
0.9997
Epoch 15: val_accuracy improved from 0.76892 to 0.79552, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 209ms/step - loss: 0.0061 -
accuracy: 0.9997 - val_loss: 0.5993 - val_accuracy: 0.7955 - lr: 2.5000e-04
Epoch 16/50
25/25 [==============================] - ETA: 0s - loss: 0.0058 - accuracy:
0.9997
Epoch 16: val_accuracy improved from 0.79552 to 0.81120, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 211ms/step - loss: 0.0058 -
accuracy: 0.9997 - val_loss: 0.5977 - val_accuracy: 0.8112 - lr: 2.5000e-04
Epoch 17/50
25/25 [==============================] - ETA: 0s - loss: 0.0055 - accuracy:
```

```
0.9998
Epoch 17: val_accuracy improved from 0.81120 to 0.82324, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 207ms/step - loss: 0.0055 -
accuracy: 0.9998 - val_loss: 0.5985 - val_accuracy: 0.8232 - lr: 2.5000e-04
Epoch 18/50
25/25 [==============================] - ETA: 0s - loss: 0.0050 - accuracy:
0.9998
Epoch 18: val_accuracy improved from 0.82324 to 0.83300, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 210ms/step - loss: 0.0050 -
accuracy: 0.9998 - val_loss: 0.6039 - val_accuracy: 0.8330 - lr: 2.5000e-04
Epoch 19/50
25/25 [==============================] - ETA: 0s - loss: 0.0048 - accuracy:
0.9998
Epoch 19: val_accuracy improved from 0.83300 to 0.84036, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 212ms/step - loss: 0.0048 -
accuracy: 0.9998 - val_loss: 0.6105 - val_accuracy: 0.8404 - lr: 2.5000e-04
Epoch 20/50
25/25 [==============================] - ETA: 0s - loss: 0.0046 - accuracy:
0.9998
Epoch 20: val_accuracy improved from 0.84036 to 0.84568, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 213ms/step - loss: 0.0046 -
accuracy: 0.9998 - val_loss: 0.6062 - val_accuracy: 0.8457 - lr: 2.5000e-04
Epoch 21/50
25/25 [==============================] - ETA: 0s - loss: 0.0043 - accuracy:
0.9998
Epoch 21: val_accuracy improved from 0.84568 to 0.85204, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 214ms/step - loss: 0.0043 -
accuracy: 0.9998 - val_loss: 0.5888 - val_accuracy: 0.8520 - lr: 2.5000e-04
Epoch 22/50
25/25 [==============================] - ETA: 0s - loss: 0.0042 - accuracy:
0.9998
Epoch 22: val_accuracy improved from 0.85204 to 0.85844, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 207ms/step - loss: 0.0042 -
accuracy: 0.9998 - val_loss: 0.5634 - val_accuracy: 0.8584 - lr: 2.5000e-04
Epoch 23/50
25/25 [==============================] - ETA: 0s - loss: 0.0039 - accuracy:
0.9998
Epoch 23: val_accuracy improved from 0.85844 to 0.86480, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 211ms/step - loss: 0.0039 -
accuracy: 0.9998 - val_loss: 0.5414 - val_accuracy: 0.8648 - lr: 2.5000e-04
Epoch 24/50
```

```
25/25 [==============================] - ETA: 0s - loss: 0.0037 - accuracy:
0.9998
Epoch 24: val_accuracy improved from 0.86480 to 0.87020, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 210ms/step - loss: 0.0037 -
accuracy: 0.9998 - val_loss: 0.5217 - val_accuracy: 0.8702 - lr: 2.5000e-04
Epoch 25/50
25/25 [==============================] - ETA: 0s - loss: 0.0036 - accuracy:
0.9999
Epoch 25: val_accuracy improved from 0.87020 to 0.87420, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 208ms/step - loss: 0.0036 -
accuracy: 0.9999 - val_loss: 0.5064 - val_accuracy: 0.8742 - lr: 2.5000e-04
Epoch 26/50
25/25 [==============================] - ETA: 0s - loss: 0.0034 - accuracy:
0.9999
Epoch 26: val_accuracy improved from 0.87420 to 0.87640, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 206ms/step - loss: 0.0034 -
accuracy: 0.9999 - val_loss: 0.4945 - val_accuracy: 0.8764 - lr: 2.5000e-04
Epoch 27/50
25/25 [==============================] - ETA: 0s - loss: 0.0033 - accuracy:
0.9999
Epoch 27: val_accuracy improved from 0.87640 to 0.87796, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 207ms/step - loss: 0.0033 -
accuracy: 0.9999 - val_loss: 0.4851 - val_accuracy: 0.8780 - lr: 2.5000e-04
Epoch 28/50
25/25 [==============================] - ETA: 0s - loss: 0.0032 - accuracy:
0.9999
Epoch 28: val_accuracy improved from 0.87796 to 0.87980, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 210ms/step - loss: 0.0032 -
accuracy: 0.9999 - val_loss: 0.4798 - val_accuracy: 0.8798 - lr: 2.5000e-04
Epoch 29/50
25/25 [==============================] - ETA: 0s - loss: 0.0031 - accuracy:
0.9999
Epoch 29: val_accuracy improved from 0.87980 to 0.88056, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 211ms/step - loss: 0.0031 -
accuracy: 0.9999 - val_loss: 0.4769 - val_accuracy: 0.8806 - lr: 2.5000e-04
Epoch 30/50
25/25 [==============================] - ETA: 0s - loss: 0.0029 - accuracy:
0.9999
Epoch 30: val_accuracy improved from 0.88056 to 0.88120, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 207ms/step - loss: 0.0029 -
accuracy: 0.9999 - val_loss: 0.4745 - val_accuracy: 0.8812 - lr: 2.5000e-04
```

```
Epoch 31/50
25/25 [==============================] - ETA: 0s - loss: 0.0028 - accuracy:
0.9999
Epoch 31: val_accuracy improved from 0.88120 to 0.88156, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 211ms/step - loss: 0.0028 -
accuracy: 0.9999 - val_loss: 0.4746 - val_accuracy: 0.8816 - lr: 2.5000e-04
Epoch 32/50
25/25 [==============================] - ETA: 0s - loss: 0.0028 - accuracy:
0.9999
Epoch 32: val_accuracy improved from 0.88156 to 0.88224, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 209ms/step - loss: 0.0028 -
accuracy: 0.9999 - val_loss: 0.4747 - val_accuracy: 0.8822 - lr: 2.5000e-04
Epoch 33/50
25/25 [==============================] - ETA: 0s - loss: 0.0026 - accuracy:
0.9999
Epoch 33: val_accuracy improved from 0.88224 to 0.88236, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 205ms/step - loss: 0.0026 -
accuracy: 0.9999 - val_loss: 0.4761 - val_accuracy: 0.8824 - lr: 2.5000e-04
Epoch 34/50
25/25 [==============================] - ETA: 0s - loss: 0.0025 - accuracy:
0.9999
Epoch 34: val_accuracy did not improve from 0.88236
25/25 [==============================] - 5s 206ms/step - loss: 0.0025 -
accuracy: 0.9999 - val_loss: 0.4761 - val_accuracy: 0.8820 - lr: 2.5000e-04
Epoch 35/50
25/25 [==============================] - ETA: 0s - loss: 0.0024 - accuracy:
0.9999
Epoch 35: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.

Epoch 35: val_accuracy improved from 0.88236 to 0.88276, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 204ms/step - loss: 0.0024 -
accuracy: 0.9999 - val_loss: 0.4791 - val_accuracy: 0.8828 - lr: 2.5000e-04
Epoch 36/50
25/25 [==============================] - ETA: 0s - loss: 0.0023 - accuracy:
0.9999
Epoch 36: val_accuracy improved from 0.88276 to 0.88280, saving model to
models/gru_bi_a0.h5
25/25 [==============================] - 5s 209ms/step - loss: 0.0023 -
accuracy: 0.9999 - val_loss: 0.4786 - val_accuracy: 0.8828 - lr: 1.2500e-04
Epoch 37/50
25/25 [==============================] - ETA: 0s - loss: 0.0023 - accuracy:
0.9999
Epoch 37: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 208ms/step - loss: 0.0023 -
```

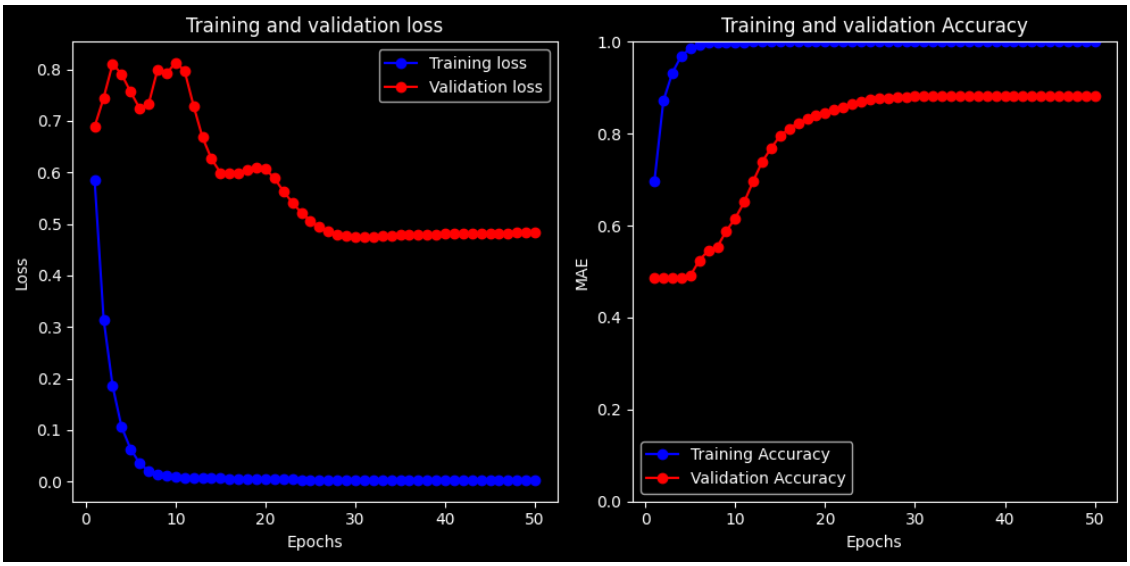
```
accuracy: 0.9999 - val_loss: 0.4785 - val_accuracy: 0.8821 - lr: 1.2500e-04
Epoch 38/50
25/25 [==============================] - ETA: 0s - loss: 0.0023 - accuracy:
0.9999
Epoch 38: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 207ms/step - loss: 0.0023 -
accuracy: 0.9999 - val_loss: 0.4789 - val_accuracy: 0.8819 - lr: 1.2500e-04
Epoch 39/50
25/25 [==============================] - ETA: 0s - loss: 0.0022 - accuracy:
0.9999
Epoch 39: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 207ms/step - loss: 0.0022 -
accuracy: 0.9999 - val_loss: 0.4795 - val_accuracy: 0.8816 - lr: 1.2500e-04
Epoch 40/50
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
0.9999
Epoch 40: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.

Epoch 40: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 202ms/step - loss: 0.0021 -
accuracy: 0.9999 - val_loss: 0.4804 - val_accuracy: 0.8818 - lr: 1.2500e-04
Epoch 41/50
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
0.9999
Epoch 41: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 208ms/step - loss: 0.0021 -
accuracy: 0.9999 - val_loss: 0.4807 - val_accuracy: 0.8819 - lr: 6.2500e-05
Epoch 42/50
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
0.9999
Epoch 42: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0021 -
accuracy: 0.9999 - val_loss: 0.4811 - val_accuracy: 0.8822 - lr: 6.2500e-05
Epoch 43/50
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
0.9999
Epoch 43: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0021 -
accuracy: 0.9999 - val_loss: 0.4815 - val_accuracy: 0.8818 - lr: 6.2500e-05
Epoch 44/50
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
0.9999
Epoch 44: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0021 -
accuracy: 0.9999 - val_loss: 0.4820 - val_accuracy: 0.8822 - lr: 6.2500e-05
Epoch 45/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
```

```
Epoch 45: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.

Epoch 45: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 204ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4823 - val_accuracy: 0.8819 - lr: 6.2500e-05
Epoch 46/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
Epoch 46: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 205ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4824 - val_accuracy: 0.8819 - lr: 3.1250e-05
Epoch 47/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
Epoch 47: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 204ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4825 - val_accuracy: 0.8819 - lr: 3.1250e-05
Epoch 48/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
Epoch 48: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4827 - val_accuracy: 0.8820 - lr: 3.1250e-05
Epoch 49/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
Epoch 49: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4829 - val_accuracy: 0.8820 - lr: 3.1250e-05
Epoch 50/50
25/25 [==============================] - ETA: 0s - loss: 0.0020 - accuracy:
0.9999
Epoch 50: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.

Epoch 50: val_accuracy did not improve from 0.88280
25/25 [==============================] - 5s 206ms/step - loss: 0.0020 -
accuracy: 0.9999 - val_loss: 0.4832 - val_accuracy: 0.8820 - lr: 3.1250e-05
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  275.1228439807892
```

[ ]:
```
model = keras.models.load_model(dir + "gru_bi_a0.h5")
results = model.evaluate(x_test_int, y_test)
print(results)
```

```
782/782 [==============================] - 11s 11ms/step - loss: 0.4786 -
accuracy: 0.8828
[0.4785896837711334, 0.8827999830245972]
```

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 128, mask_zero=True, input_length=256)(inputs)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(512, return_sequences=True))(x)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(256, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(128, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(32, activation="relu")(x)
```

```
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(8, activation="sigmoid")(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=40, model_name="gru_bi_a.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_10"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_11 (InputLayer)       [(None, 166)]             0

 embedding_10 (Embedding)    (None, 166, 128)          704000

 batch_normalization_25 (Bat  (None, 166, 128)         512
 chNormalization)

 bidirectional_8 (Bidirectio  (None, 166, 1024)        1972224
 nal)

 batch_normalization_26 (Bat  (None, 166, 1024)        4096
 chNormalization)

 bidirectional_9 (Bidirectio  (None, 512)              1969152
 nal)

 batch_normalization_27 (Bat  (None, 512)              2048
 chNormalization)

 dense_20 (Dense)            (None, 128)               65664

 batch_normalization_28 (Bat  (None, 128)              512
 chNormalization)
```

```
 dense_21 (Dense)            (None, 32)                4128

 batch_normalization_29 (Bat  (None, 32)               128
 chNormalization)

 dense_22 (Dense)            (None, 8)                 264

 batch_normalization_30 (Bat  (None, 8)                32
 chNormalization)

 dense_23 (Dense)            (None, 1)                 9

=================================================================
Total params: 4,722,769
Trainable params: 4,719,105
Non-trainable params: 3,664
_________________________________________________________________
Epoch 1/40
25/25 [==============================] - ETA: 0s - loss: 0.4815 - accuracy:
0.7684
Epoch 1: val_accuracy improved from -inf to 0.51372, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 13s 264ms/step - loss: 0.4815 -
accuracy: 0.7684 - val_loss: 0.7493 - val_accuracy: 0.5137 - lr: 0.0010
Epoch 2/40
25/25 [==============================] - ETA: 0s - loss: 0.2263 - accuracy:
0.9144
Epoch 2: val_accuracy did not improve from 0.51372
25/25 [==============================] - 5s 192ms/step - loss: 0.2263 -
accuracy: 0.9144 - val_loss: 0.7416 - val_accuracy: 0.5137 - lr: 0.0010
Epoch 3/40
25/25 [==============================] - ETA: 0s - loss: 0.1251 - accuracy:
0.9630
Epoch 3: val_accuracy did not improve from 0.51372
25/25 [==============================] - 5s 194ms/step - loss: 0.1251 -
accuracy: 0.9630 - val_loss: 0.7213 - val_accuracy: 0.5137 - lr: 0.0010
Epoch 4/40
25/25 [==============================] - ETA: 0s - loss: 0.0618 - accuracy:
0.9878
Epoch 4: val_accuracy did not improve from 0.51372
25/25 [==============================] - 5s 191ms/step - loss: 0.0618 -
accuracy: 0.9878 - val_loss: 0.7389 - val_accuracy: 0.5137 - lr: 0.0010
Epoch 5/40
25/25 [==============================] - ETA: 0s - loss: 0.0322 - accuracy:
0.9968
Epoch 5: val_accuracy improved from 0.51372 to 0.51376, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 188ms/step - loss: 0.0322 -
```

```
accuracy: 0.9968 - val_loss: 0.6925 - val_accuracy: 0.5138 - lr: 0.0010
Epoch 6/40
25/25 [==============================] - ETA: 0s - loss: 0.0178 - accuracy:
0.9992
Epoch 6: val_accuracy improved from 0.51376 to 0.51380, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 188ms/step - loss: 0.0178 -
accuracy: 0.9992 - val_loss: 0.7140 - val_accuracy: 0.5138 - lr: 0.0010
Epoch 7/40
25/25 [==============================] - ETA: 0s - loss: 0.0119 - accuracy:
0.9998
Epoch 7: val_accuracy improved from 0.51380 to 0.52916, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 189ms/step - loss: 0.0119 -
accuracy: 0.9998 - val_loss: 0.6385 - val_accuracy: 0.5292 - lr: 0.0010
Epoch 8/40
25/25 [==============================] - ETA: 0s - loss: 0.0091 - accuracy:
0.9999
Epoch 8: val_accuracy improved from 0.52916 to 0.57464, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 186ms/step - loss: 0.0091 -
accuracy: 0.9999 - val_loss: 0.6117 - val_accuracy: 0.5746 - lr: 0.0010
Epoch 9/40
25/25 [==============================] - ETA: 0s - loss: 0.0074 - accuracy:
1.0000
Epoch 9: val_accuracy improved from 0.57464 to 0.62336, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 187ms/step - loss: 0.0074 -
accuracy: 1.0000 - val_loss: 0.5964 - val_accuracy: 0.6234 - lr: 0.0010
Epoch 10/40
25/25 [==============================] - ETA: 0s - loss: 0.0063 - accuracy:
1.0000
Epoch 10: val_accuracy improved from 0.62336 to 0.69020, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 186ms/step - loss: 0.0063 -
accuracy: 1.0000 - val_loss: 0.5481 - val_accuracy: 0.6902 - lr: 0.0010
Epoch 11/40
25/25 [==============================] - ETA: 0s - loss: 0.0054 - accuracy:
1.0000
Epoch 11: val_accuracy improved from 0.69020 to 0.75192, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 188ms/step - loss: 0.0054 -
accuracy: 1.0000 - val_loss: 0.4864 - val_accuracy: 0.7519 - lr: 0.0010
Epoch 12/40
25/25 [==============================] - ETA: 0s - loss: 0.0047 - accuracy:
1.0000
Epoch 12: val_accuracy improved from 0.75192 to 0.78004, saving model to
models/gru_bi_a.h5
```

```
25/25 [==============================] - 5s 184ms/step - loss: 0.0047 -
accuracy: 1.0000 - val_loss: 0.4546 - val_accuracy: 0.7800 - lr: 0.0010
Epoch 13/40
25/25 [==============================] - ETA: 0s - loss: 0.0042 - accuracy:
1.0000
Epoch 13: val_accuracy improved from 0.78004 to 0.79536, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 186ms/step - loss: 0.0042 -
accuracy: 1.0000 - val_loss: 0.4414 - val_accuracy: 0.7954 - lr: 0.0010
Epoch 14/40
25/25 [==============================] - ETA: 0s - loss: 0.0037 - accuracy:
1.0000
Epoch 14: val_accuracy improved from 0.79536 to 0.80176, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 185ms/step - loss: 0.0037 -
accuracy: 1.0000 - val_loss: 0.4457 - val_accuracy: 0.8018 - lr: 0.0010
Epoch 15/40
25/25 [==============================] - ETA: 0s - loss: 0.0033 - accuracy:
1.0000
Epoch 15: val_accuracy improved from 0.80176 to 0.80612, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 185ms/step - loss: 0.0033 -
accuracy: 1.0000 - val_loss: 0.4610 - val_accuracy: 0.8061 - lr: 0.0010
Epoch 16/40
25/25 [==============================] - ETA: 0s - loss: 0.0030 - accuracy:
1.0000
Epoch 16: val_accuracy improved from 0.80612 to 0.81972, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 183ms/step - loss: 0.0030 -
accuracy: 1.0000 - val_loss: 0.4609 - val_accuracy: 0.8197 - lr: 0.0010
Epoch 17/40
25/25 [==============================] - ETA: 0s - loss: 0.0027 - accuracy:
1.0000
Epoch 17: val_accuracy did not improve from 0.81972
25/25 [==============================] - 4s 180ms/step - loss: 0.0027 -
accuracy: 1.0000 - val_loss: 0.5030 - val_accuracy: 0.8188 - lr: 0.0010
Epoch 18/40
25/25 [==============================] - ETA: 0s - loss: 0.0024 - accuracy:
1.0000
Epoch 18: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 18: val_accuracy improved from 0.81972 to 0.82316, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 4s 181ms/step - loss: 0.0024 -
accuracy: 1.0000 - val_loss: 0.5285 - val_accuracy: 0.8232 - lr: 0.0010
Epoch 19/40
25/25 [==============================] - ETA: 0s - loss: 0.0023 - accuracy:
1.0000
```

```
Epoch 19: val_accuracy improved from 0.82316 to 0.83380, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 185ms/step - loss: 0.0023 -
accuracy: 1.0000 - val_loss: 0.5339 - val_accuracy: 0.8338 - lr: 5.0000e-04
Epoch 20/40
25/25 [==============================] - ETA: 0s - loss: 0.0022 - accuracy:
1.0000
Epoch 20: val_accuracy improved from 0.83380 to 0.85104, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 185ms/step - loss: 0.0022 -
accuracy: 1.0000 - val_loss: 0.5162 - val_accuracy: 0.8510 - lr: 5.0000e-04
Epoch 21/40
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
1.0000
Epoch 21: val_accuracy did not improve from 0.85104
25/25 [==============================] - 5s 183ms/step - loss: 0.0021 -
accuracy: 1.0000 - val_loss: 0.5733 - val_accuracy: 0.8428 - lr: 5.0000e-04
Epoch 22/40
25/25 [==============================] - ETA: 0s - loss: 0.0021 - accuracy:
1.0000
Epoch 22: val_accuracy improved from 0.85104 to 0.85516, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 4s 182ms/step - loss: 0.0021 -
accuracy: 1.0000 - val_loss: 0.5446 - val_accuracy: 0.8552 - lr: 5.0000e-04
Epoch 23/40
25/25 [==============================] - ETA: 0s - loss: 0.0019 - accuracy:
1.0000
Epoch 23: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 23: val_accuracy improved from 0.85516 to 0.86480, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 183ms/step - loss: 0.0019 -
accuracy: 1.0000 - val_loss: 0.5269 - val_accuracy: 0.8648 - lr: 5.0000e-04
Epoch 24/40
25/25 [==============================] - ETA: 0s - loss: 0.0019 - accuracy:
1.0000
Epoch 24: val_accuracy did not improve from 0.86480
25/25 [==============================] - 4s 179ms/step - loss: 0.0019 -
accuracy: 1.0000 - val_loss: 0.5471 - val_accuracy: 0.8612 - lr: 2.5000e-04
Epoch 25/40
25/25 [==============================] - ETA: 0s - loss: 0.0018 - accuracy:
1.0000
Epoch 25: val_accuracy did not improve from 0.86480
25/25 [==============================] - 4s 181ms/step - loss: 0.0018 -
accuracy: 1.0000 - val_loss: 0.5435 - val_accuracy: 0.8635 - lr: 2.5000e-04
Epoch 26/40
25/25 [==============================] - ETA: 0s - loss: 0.0018 - accuracy:
1.0000
```

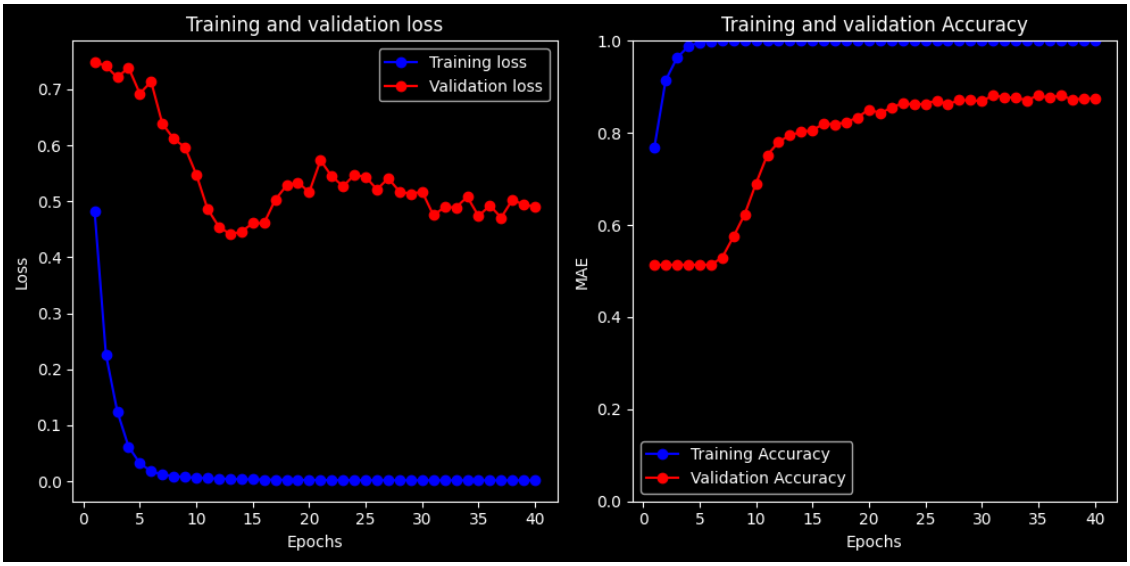
```
Epoch 26: val_accuracy improved from 0.86480 to 0.87060, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 183ms/step - loss: 0.0018 -
accuracy: 1.0000 - val_loss: 0.5213 - val_accuracy: 0.8706 - lr: 2.5000e-04
Epoch 27/40
25/25 [==============================] - ETA: 0s - loss: 0.0018 - accuracy:
1.0000
Epoch 27: val_accuracy did not improve from 0.87060
25/25 [==============================] - 4s 178ms/step - loss: 0.0018 -
accuracy: 1.0000 - val_loss: 0.5411 - val_accuracy: 0.8624 - lr: 2.5000e-04
Epoch 28/40
25/25 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 28: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.

Epoch 28: val_accuracy improved from 0.87060 to 0.87112, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 184ms/step - loss: 0.0017 -
accuracy: 1.0000 - val_loss: 0.5176 - val_accuracy: 0.8711 - lr: 2.5000e-04
Epoch 29/40
25/25 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 29: val_accuracy did not improve from 0.87112
25/25 [==============================] - 4s 180ms/step - loss: 0.0017 -
accuracy: 1.0000 - val_loss: 0.5133 - val_accuracy: 0.8711 - lr: 1.2500e-04
Epoch 30/40
25/25 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 30: val_accuracy did not improve from 0.87112
25/25 [==============================] - 4s 180ms/step - loss: 0.0017 -
accuracy: 1.0000 - val_loss: 0.5174 - val_accuracy: 0.8686 - lr: 1.2500e-04
Epoch 31/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 31: val_accuracy improved from 0.87112 to 0.88192, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 4s 181ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4752 - val_accuracy: 0.8819 - lr: 1.2500e-04
Epoch 32/40
25/25 [==============================] - ETA: 0s - loss: 0.0017 - accuracy:
1.0000
Epoch 32: val_accuracy did not improve from 0.88192
25/25 [==============================] - 4s 180ms/step - loss: 0.0017 -
accuracy: 1.0000 - val_loss: 0.4896 - val_accuracy: 0.8772 - lr: 1.2500e-04
Epoch 33/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 33: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.
```

```
Epoch 33: val_accuracy did not improve from 0.88192
25/25 [==============================] - 4s 180ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4892 - val_accuracy: 0.8770 - lr: 1.2500e-04
Epoch 34/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 34: val_accuracy did not improve from 0.88192
25/25 [==============================] - 4s 178ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.5079 - val_accuracy: 0.8707 - lr: 6.2500e-05
Epoch 35/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 35: val_accuracy did not improve from 0.88192
25/25 [==============================] - 4s 181ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4737 - val_accuracy: 0.8817 - lr: 6.2500e-05
Epoch 36/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 36: val_accuracy did not improve from 0.88192
25/25 [==============================] - 4s 181ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4926 - val_accuracy: 0.8760 - lr: 6.2500e-05
Epoch 37/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 37: val_accuracy improved from 0.88192 to 0.88200, saving model to
models/gru_bi_a.h5
25/25 [==============================] - 5s 184ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.4709 - val_accuracy: 0.8820 - lr: 6.2500e-05
Epoch 38/40
25/25 [==============================] - ETA: 0s - loss: 0.0016 - accuracy:
1.0000
Epoch 38: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.

Epoch 38: val_accuracy did not improve from 0.88200
25/25 [==============================] - 4s 180ms/step - loss: 0.0016 -
accuracy: 1.0000 - val_loss: 0.5029 - val_accuracy: 0.8721 - lr: 6.2500e-05
Epoch 39/40
25/25 [==============================] - ETA: 0s - loss: 0.0015 - accuracy:
1.0000
Epoch 39: val_accuracy did not improve from 0.88200
25/25 [==============================] - 4s 180ms/step - loss: 0.0015 -
accuracy: 1.0000 - val_loss: 0.4937 - val_accuracy: 0.8746 - lr: 3.1250e-05
Epoch 40/40
25/25 [==============================] - ETA: 0s - loss: 0.0015 - accuracy:
1.0000
Epoch 40: val_accuracy did not improve from 0.88200
25/25 [==============================] - 4s 181ms/step - loss: 0.0015 -
```

```
accuracy: 1.0000 - val_loss: 0.4907 - val_accuracy: 0.8752 - lr: 3.1250e-05
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  191.2750096321106
```

```
[ ]: model = keras.models.load_model(dir + "gru_bi_a.h5")
results = model.evaluate(x_test_int, y_test)
print(results)
```

```
782/782 [==============================] - 9s 9ms/step - loss: 0.4556 -
accuracy: 0.8867
[0.4556419849395752, 0.8867200016975403]
```

Pasando a los modelos en si mismos debemos distinguir tres etapas de nuestro pipeline:

El Embedding que trata de obtener la mejor representación para cada token en el espcaio vectorial dejinido a través de los parámetros propuestos, concretamente sera un espacio de la forma longitud_de_secuencia x embbeding_size. De este capa obtendremos un vector para cada token introduci en la entrada del modelo, debemos utilizar un tamaño de embbeding que sea duficientemente grande como para representar la varibilidad de nuestro corpus. Si el tamño del embbeding es demasiado pequeño aunque intentemos aumentar la complejidad del resto de nuestro modelo no seremos capaces de mjorar su comportamiento ya que estamos perdiendo demasiada infromación en este paso.

Con la salida del embedding debemos aplicar la capa recurrente, aqui existen tres cuestiones de especial impacto en nuestro problema. La primera cuestión es el tipo de unidades recurrentes, debemos tener en cuenta que a diferencia de otros paradigmas de deep Learning como las convoluciones, las unidades recurrentes no son equivalentes a un conjunto de caps densas apiladas, además las puertas que implementan muestra comportamientos distintos que serán mas o menos adecuados a nuestro problema. En este caso, al tratarse de texto es de esperar que el mejor comportamiento los muestren las LSTM o GRU, claramente mas compleajs que las SimpleRNN. El

segunodo aspecto a tener en cuenta es el número de unidades que se introducen, que representan los pasos que se están empleando al procesar el texto, un número muy bajo será insuficiente para captar los distintos bloques con significado dentro del fragmento de texto procesad y un número muy elevado no nos aprotará una mejora en el rendimiento y puede suponer un obstáculo en el proceso de entrenamiento. Este está muy condicinodo por el tamño de secuencia que estamos empleando y en definitiva el tamaño de fragmentos de textos que estamos empleando, dado que necesitaremos más etapas si nuestro fragmento es de mayor longitud. En nuestro caso observamos un comportamiento razonablemente bueno desde valores bajos, como 6, dado que nuestros fragmentos son pequeños y observamos lijeras mejoras hasta tamaños de 16 o 32. Esto realizando un diseño contenido y razonable sobre nuestro problema, ya que no debemos olvidar que otros aspectos como el tamaño de embedding o el número de caracteristictics juegan roles importantes y pueden contribuir a cambiar el comportamiento de esta etapa. Además al tratarse de un problema relativamente pequeño podriamos observar un comportamiento relativamente bueno al añadir más complejidad en otros elementos de nuestro modelo, sin que estas decisiones sean justificadas con una adecuada compresnión del modelo.

Del mismo modo, destacamos la aleatoriedad caracteristica del proceso de entrenamiento. Hemos visto como en alguna ocasion el modelo inciaial o tras una única época muestra un comportamiento extraordinariamente bueno sin una justificación a priori y pequeños cambios en la semilla hacen que no sea repetible un comportamiento global similar. A nuestro juicio, debemos intentar enteder porque surgen estos casos pero no deberiamos tomarlos como conclusiones válidas al ser puramente anecdóticos. En este sentido, conviene destacar que sobre nuestro problema no hemos percibido una mejora relevante al introducir varias capas recurrentes apiladas.

Por último, la tercera etapa de este tipo de modelos son la capa des salida y capas densas. Hemos visto como

4 Modelos pequeños

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 4, mask_zero=True, input_length=256)(inputs)
x = keras.layers.BatchNormalization()(x)
x = layers.GRU(8, return_sequences=False)(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
```

```
optimizer = keras.optimizers.Adam(learning_rate=0.001)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=80, model_name="gru_bi_r.h5", batch_size=1024,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_23"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_24 (InputLayer)       [(None, 166)]             0

 embedding_23 (Embedding)    (None, 166, 4)            22000

 batch_normalization_55 (Bat  (None, 166, 4)           16
 chNormalization)

 gru_19 (GRU)                (None, 8)                 336

 batch_normalization_56 (Bat  (None, 8)                32
 chNormalization)

 dense_36 (Dense)            (None, 1)                 9

=================================================================
Total params: 22,393
Trainable params: 22,369
Non-trainable params: 24
_________________________________________________________________
Epoch 1/80
25/25 [==============================] - ETA: 0s - loss: 0.7437 - accuracy:
0.5478
Epoch 1: val_accuracy improved from -inf to 0.51372, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 4s 100ms/step - loss: 0.7437 -
accuracy: 0.5478 - val_loss: 0.6913 - val_accuracy: 0.5137 - lr: 0.0010
Epoch 2/80
25/25 [==============================] - ETA: 0s - loss: 0.6139 - accuracy:
0.6630
Epoch 2: val_accuracy improved from 0.51372 to 0.51424, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 2s 61ms/step - loss: 0.6139 - accuracy:
```

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0.6630 - val_loss: 0.6898 - val_accuracy: 0.5142 - lr: 0.0010
Epoch 3/80
25/25 [==============================] - ETA: 0s - loss: 0.5543 - accuracy:
0.7220
Epoch 3: val_accuracy improved from 0.51424 to 0.65596, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 1s 54ms/step - loss: 0.5543 - accuracy:
0.7220 - val_loss: 0.6882 - val_accuracy: 0.6560 - lr: 0.0010
Epoch 4/80
25/25 [==============================] - ETA: 0s - loss: 0.5009 - accuracy:
0.7644
Epoch 4: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 58ms/step - loss: 0.5009 - accuracy:
0.7644 - val_loss: 0.6884 - val_accuracy: 0.4889 - lr: 0.0010
Epoch 5/80
25/25 [==============================] - ETA: 0s - loss: 0.4544 - accuracy:
0.7996
Epoch 5: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 50ms/step - loss: 0.4544 - accuracy:
0.7996 - val_loss: 0.7003 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 6/80
25/25 [==============================] - ETA: 0s - loss: 0.4115 - accuracy:
0.8234
Epoch 6: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 44ms/step - loss: 0.4115 - accuracy:
0.8234 - val_loss: 0.7313 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 7/80
25/25 [==============================] - ETA: 0s - loss: 0.3636 - accuracy:
0.8542
Epoch 7: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 30ms/step - loss: 0.3636 - accuracy:
0.8542 - val_loss: 0.7636 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 8/80
25/25 [==============================] - ETA: 0s - loss: 0.3042 - accuracy:
0.8894
Epoch 8: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 8: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 29ms/step - loss: 0.3042 - accuracy:
0.8894 - val_loss: 0.7737 - val_accuracy: 0.4863 - lr: 0.0010
Epoch 9/80
25/25 [==============================] - ETA: 0s - loss: 0.2543 - accuracy:
0.9134
Epoch 9: val_accuracy did not improve from 0.65596
25/25 [==============================] - 1s 27ms/step - loss: 0.2543 - accuracy:
0.9134 - val_loss: 0.7136 - val_accuracy: 0.4892 - lr: 5.0000e-04
Epoch 10/80
25/25 [==============================] - ETA: 0s - loss: 0.2302 - accuracy:
```

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0.9235
Epoch 10: val_accuracy improved from 0.65596 to 0.77124, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 1s 30ms/step - loss: 0.2302 - accuracy:
0.9235 - val_loss: 0.5495 - val_accuracy: 0.7712 - lr: 5.0000e-04
Epoch 11/80
25/25 [==============================] - ETA: 0s - loss: 0.2096 - accuracy:
0.9304
Epoch 11: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 24ms/step - loss: 0.2096 - accuracy:
0.9304 - val_loss: 0.5547 - val_accuracy: 0.7294 - lr: 5.0000e-04
Epoch 12/80
25/25 [==============================] - ETA: 0s - loss: 0.1924 - accuracy:
0.9366
Epoch 12: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 27ms/step - loss: 0.1924 - accuracy:
0.9366 - val_loss: 0.7742 - val_accuracy: 0.6217 - lr: 5.0000e-04
Epoch 13/80
25/25 [==============================] - ETA: 0s - loss: 0.1777 - accuracy:
0.9418
Epoch 13: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 23ms/step - loss: 0.1777 - accuracy:
0.9418 - val_loss: 0.8485 - val_accuracy: 0.6242 - lr: 5.0000e-04
Epoch 14/80
25/25 [==============================] - ETA: 0s - loss: 0.1641 - accuracy:
0.9478
Epoch 14: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 21ms/step - loss: 0.1641 - accuracy:
0.9478 - val_loss: 1.0109 - val_accuracy: 0.6024 - lr: 5.0000e-04
Epoch 15/80
22/25 [=========================>...] - ETA: 0s - loss: 0.1504 - accuracy:
0.9530
Epoch 15: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 15: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 17ms/step - loss: 0.1524 - accuracy:
0.9518 - val_loss: 1.1097 - val_accuracy: 0.5985 - lr: 5.0000e-04
Epoch 16/80
25/25 [==============================] - ETA: 0s - loss: 0.1398 - accuracy:
0.9583
Epoch 16: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 23ms/step - loss: 0.1398 - accuracy:
0.9583 - val_loss: 1.2156 - val_accuracy: 0.5898 - lr: 2.5000e-04
Epoch 17/80
25/25 [==============================] - ETA: 0s - loss: 0.1347 - accuracy:
0.9607
Epoch 17: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 17ms/step - loss: 0.1347 - accuracy:
```

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0.9607 - val_loss: 1.2943 - val_accuracy: 0.5867 - lr: 2.5000e-04
Epoch 18/80
25/25 [==============================] - ETA: 0s - loss: 0.1286 - accuracy:
0.9633
Epoch 18: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 21ms/step - loss: 0.1286 - accuracy:
0.9633 - val_loss: 1.2655 - val_accuracy: 0.6000 - lr: 2.5000e-04
Epoch 19/80
25/25 [==============================] - ETA: 0s - loss: 0.1267 - accuracy:
0.9621
Epoch 19: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 23ms/step - loss: 0.1267 - accuracy:
0.9621 - val_loss: 1.2011 - val_accuracy: 0.6211 - lr: 2.5000e-04
Epoch 20/80
25/25 [==============================] - ETA: 0s - loss: 0.1207 - accuracy:
0.9656
Epoch 20: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.

Epoch 20: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 26ms/step - loss: 0.1207 - accuracy:
0.9656 - val_loss: 1.1686 - val_accuracy: 0.6360 - lr: 2.5000e-04
Epoch 21/80
25/25 [==============================] - ETA: 0s - loss: 0.1151 - accuracy:
0.9680
Epoch 21: val_accuracy did not improve from 0.77124
25/25 [==============================] - 1s 26ms/step - loss: 0.1151 - accuracy:
0.9680 - val_loss: 1.1637 - val_accuracy: 0.6428 - lr: 1.2500e-04
Epoch 22/80
25/25 [==============================] - ETA: 0s - loss: 0.1118 - accuracy:
0.9694
Epoch 22: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 18ms/step - loss: 0.1118 - accuracy:
0.9694 - val_loss: 1.0419 - val_accuracy: 0.6744 - lr: 1.2500e-04
Epoch 23/80
25/25 [==============================] - ETA: 0s - loss: 0.1092 - accuracy:
0.9706
Epoch 23: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 20ms/step - loss: 0.1092 - accuracy:
0.9706 - val_loss: 0.9522 - val_accuracy: 0.6999 - lr: 1.2500e-04
Epoch 24/80
25/25 [==============================] - ETA: 0s - loss: 0.1068 - accuracy:
0.9712
Epoch 24: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 18ms/step - loss: 0.1068 - accuracy:
0.9712 - val_loss: 0.8408 - val_accuracy: 0.7299 - lr: 1.2500e-04
Epoch 25/80
25/25 [==============================] - ETA: 0s - loss: 0.1046 - accuracy:
0.9724
```

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Epoch 25: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.

Epoch 25: val_accuracy did not improve from 0.77124
25/25 [==============================] - 0s 15ms/step - loss: 0.1046 - accuracy:
0.9724 - val_loss: 0.7966 - val_accuracy: 0.7433 - lr: 1.2500e-04
Epoch 26/80
25/25 [==============================] - ETA: 0s - loss: 0.1022 - accuracy:
0.9730
Epoch 26: val_accuracy improved from 0.77124 to 0.77592, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 15ms/step - loss: 0.1022 - accuracy:
0.9730 - val_loss: 0.6747 - val_accuracy: 0.7759 - lr: 6.2500e-05
Epoch 27/80
25/25 [==============================] - ETA: 0s - loss: 0.1020 - accuracy:
0.9730
Epoch 27: val_accuracy improved from 0.77592 to 0.79716, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 15ms/step - loss: 0.1020 - accuracy:
0.9730 - val_loss: 0.6005 - val_accuracy: 0.7972 - lr: 6.2500e-05
Epoch 28/80
25/25 [==============================] - ETA: 0s - loss: 0.1007 - accuracy:
0.9737
Epoch 28: val_accuracy improved from 0.79716 to 0.81768, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 1s 21ms/step - loss: 0.1007 - accuracy:
0.9737 - val_loss: 0.5266 - val_accuracy: 0.8177 - lr: 6.2500e-05
Epoch 29/80
25/25 [==============================] - ETA: 0s - loss: 0.0988 - accuracy:
0.9746
Epoch 29: val_accuracy improved from 0.81768 to 0.83040, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 1s 21ms/step - loss: 0.0988 - accuracy:
0.9746 - val_loss: 0.4806 - val_accuracy: 0.8304 - lr: 6.2500e-05
Epoch 30/80
25/25 [==============================] - ETA: 0s - loss: 0.0974 - accuracy:
0.9755
Epoch 30: val_accuracy improved from 0.83040 to 0.83868, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 15ms/step - loss: 0.0974 - accuracy:
0.9755 - val_loss: 0.4541 - val_accuracy: 0.8387 - lr: 6.2500e-05
Epoch 31/80
25/25 [==============================] - ETA: 0s - loss: 0.0962 - accuracy:
0.9750
Epoch 31: val_accuracy improved from 0.83868 to 0.84976, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 20ms/step - loss: 0.0962 - accuracy:
0.9750 - val_loss: 0.4233 - val_accuracy: 0.8498 - lr: 6.2500e-05
Epoch 32/80
```

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25/25 [==============================] - ETA: 0s - loss: 0.0963 - accuracy:
0.9749
Epoch 32: val_accuracy improved from 0.84976 to 0.85336, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 1s 21ms/step - loss: 0.0963 - accuracy:
0.9749 - val_loss: 0.4108 - val_accuracy: 0.8534 - lr: 6.2500e-05
Epoch 33/80
21/25 [========================>...] - ETA: 0s - loss: 0.0938 - accuracy:
0.9772
Epoch 33: val_accuracy improved from 0.85336 to 0.85424, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 15ms/step - loss: 0.0945 - accuracy:
0.9766 - val_loss: 0.4060 - val_accuracy: 0.8542 - lr: 6.2500e-05
Epoch 34/80
25/25 [==============================] - ETA: 0s - loss: 0.0938 - accuracy:
0.9763
Epoch 34: val_accuracy improved from 0.85424 to 0.85588, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 20ms/step - loss: 0.0938 - accuracy:
0.9763 - val_loss: 0.3987 - val_accuracy: 0.8559 - lr: 6.2500e-05
Epoch 35/80
21/25 [========================>...] - ETA: 0s - loss: 0.0934 - accuracy:
0.9762
Epoch 35: val_accuracy improved from 0.85588 to 0.85712, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 12ms/step - loss: 0.0928 - accuracy:
0.9766 - val_loss: 0.3934 - val_accuracy: 0.8571 - lr: 6.2500e-05
Epoch 36/80
25/25 [==============================] - ETA: 0s - loss: 0.0916 - accuracy:
0.9772
Epoch 36: val_accuracy improved from 0.85712 to 0.85852, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 18ms/step - loss: 0.0916 - accuracy:
0.9772 - val_loss: 0.3914 - val_accuracy: 0.8585 - lr: 6.2500e-05
Epoch 37/80
25/25 [==============================] - ETA: 0s - loss: 0.0905 - accuracy:
0.9778
Epoch 37: val_accuracy did not improve from 0.85852
25/25 [==============================] - 0s 18ms/step - loss: 0.0905 - accuracy:
0.9778 - val_loss: 0.3940 - val_accuracy: 0.8580 - lr: 6.2500e-05
Epoch 38/80
25/25 [==============================] - ETA: 0s - loss: 0.0905 - accuracy:
0.9771
Epoch 38: val_accuracy did not improve from 0.85852
25/25 [==============================] - 0s 18ms/step - loss: 0.0905 - accuracy:
0.9771 - val_loss: 0.3934 - val_accuracy: 0.8581 - lr: 6.2500e-05
Epoch 39/80
25/25 [==============================] - ETA: 0s - loss: 0.0887 - accuracy:
```

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0.9779
Epoch 39: val_accuracy improved from 0.85852 to 0.85948, saving model to
models/gru_bi_r.h5
25/25 [==============================] - 0s 20ms/step - loss: 0.0887 - accuracy:
0.9779 - val_loss: 0.3918 - val_accuracy: 0.8595 - lr: 6.2500e-05
Epoch 40/80
21/25 [========================>…] - ETA: 0s - loss: 0.0874 - accuracy:
0.9784
Epoch 40: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0876 - accuracy:
0.9782 - val_loss: 0.3946 - val_accuracy: 0.8590 - lr: 6.2500e-05
Epoch 41/80
25/25 [==============================] - ETA: 0s - loss: 0.0869 - accuracy:
0.9787
Epoch 41: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.

Epoch 41: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 20ms/step - loss: 0.0869 - accuracy:
0.9787 - val_loss: 0.3945 - val_accuracy: 0.8588 - lr: 6.2500e-05
Epoch 42/80
25/25 [==============================] - ETA: 0s - loss: 0.0862 - accuracy:
0.9791
Epoch 42: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0862 - accuracy:
0.9791 - val_loss: 0.3959 - val_accuracy: 0.8586 - lr: 3.1250e-05
Epoch 43/80
25/25 [==============================] - ETA: 0s - loss: 0.0861 - accuracy:
0.9788
Epoch 43: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 18ms/step - loss: 0.0861 - accuracy:
0.9788 - val_loss: 0.3970 - val_accuracy: 0.8583 - lr: 3.1250e-05
Epoch 44/80
25/25 [==============================] - ETA: 0s - loss: 0.0856 - accuracy:
0.9786
Epoch 44: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 18ms/step - loss: 0.0856 - accuracy:
0.9786 - val_loss: 0.3982 - val_accuracy: 0.8581 - lr: 3.1250e-05
Epoch 45/80
25/25 [==============================] - ETA: 0s - loss: 0.0846 - accuracy:
0.9789
Epoch 45: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0846 - accuracy:
0.9789 - val_loss: 0.3981 - val_accuracy: 0.8579 - lr: 3.1250e-05
Epoch 46/80
25/25 [==============================] - ETA: 0s - loss: 0.0842 - accuracy:
0.9797
Epoch 46: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.
```

```
Epoch 46: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0842 - accuracy:
0.9797 - val_loss: 0.3992 - val_accuracy: 0.8580 - lr: 3.1250e-05
Epoch 47/80
25/25 [==============================] - ETA: 0s - loss: 0.0836 - accuracy:
0.9800
Epoch 47: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0836 - accuracy:
0.9800 - val_loss: 0.3990 - val_accuracy: 0.8579 - lr: 1.5625e-05
Epoch 48/80
25/25 [==============================] - ETA: 0s - loss: 0.0838 - accuracy:
0.9794
Epoch 48: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 18ms/step - loss: 0.0838 - accuracy:
0.9794 - val_loss: 0.3996 - val_accuracy: 0.8577 - lr: 1.5625e-05
Epoch 49/80
25/25 [==============================] - ETA: 0s - loss: 0.0836 - accuracy:
0.9795
Epoch 49: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 18ms/step - loss: 0.0836 - accuracy:
0.9795 - val_loss: 0.3986 - val_accuracy: 0.8580 - lr: 1.5625e-05
Epoch 50/80
25/25 [==============================] - ETA: 0s - loss: 0.0829 - accuracy:
0.9801
Epoch 50: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 20ms/step - loss: 0.0829 - accuracy:
0.9801 - val_loss: 0.3999 - val_accuracy: 0.8575 - lr: 1.5625e-05
Epoch 51/80
21/25 [========================>...] - ETA: 0s - loss: 0.0819 - accuracy:
0.9802
Epoch 51: ReduceLROnPlateau reducing learning rate to 7.812500371073838e-06.

Epoch 51: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0828 - accuracy:
0.9801 - val_loss: 0.4004 - val_accuracy: 0.8578 - lr: 1.5625e-05
Epoch 52/80
21/25 [========================>...] - ETA: 0s - loss: 0.0824 - accuracy:
0.9804
Epoch 52: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0831 - accuracy:
0.9800 - val_loss: 0.4002 - val_accuracy: 0.8577 - lr: 7.8125e-06
Epoch 53/80
25/25 [==============================] - ETA: 0s - loss: 0.0828 - accuracy:
0.9804
Epoch 53: val_accuracy did not improve from 0.85948
25/25 [==============================] - 1s 18ms/step - loss: 0.0828 - accuracy:
0.9804 - val_loss: 0.4004 - val_accuracy: 0.8577 - lr: 7.8125e-06
Epoch 54/80
```

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21/25 [=======================>…] - ETA: 0s - loss: 0.0819 - accuracy:
0.9808
Epoch 54: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0824 - accuracy:
0.9802 - val_loss: 0.4006 - val_accuracy: 0.8577 - lr: 7.8125e-06
Epoch 55/80
25/25 [==============================] - ETA: 0s - loss: 0.0825 - accuracy:
0.9800
Epoch 55: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0825 - accuracy:
0.9800 - val_loss: 0.4006 - val_accuracy: 0.8579 - lr: 7.8125e-06
Epoch 56/80
21/25 [========================>…] - ETA: 0s - loss: 0.0810 - accuracy:
0.9804
Epoch 56: ReduceLROnPlateau reducing learning rate to 3.906250185536919e-06.

Epoch 56: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0821 - accuracy:
0.9802 - val_loss: 0.4010 - val_accuracy: 0.8577 - lr: 7.8125e-06
Epoch 57/80
22/25 [=========================>…] - ETA: 0s - loss: 0.0815 - accuracy:
0.9806
Epoch 57: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0817 - accuracy:
0.9804 - val_loss: 0.4011 - val_accuracy: 0.8577 - lr: 3.9063e-06
Epoch 58/80
25/25 [==============================] - ETA: 0s - loss: 0.0819 - accuracy:
0.9802
Epoch 58: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0819 - accuracy:
0.9802 - val_loss: 0.4011 - val_accuracy: 0.8578 - lr: 3.9063e-06
Epoch 59/80
25/25 [==============================] - ETA: 0s - loss: 0.0819 - accuracy:
0.9806
Epoch 59: val_accuracy did not improve from 0.85948
25/25 [==============================] - 1s 18ms/step - loss: 0.0819 - accuracy:
0.9806 - val_loss: 0.4014 - val_accuracy: 0.8576 - lr: 3.9063e-06
Epoch 60/80
22/25 [=========================>…] - ETA: 0s - loss: 0.0822 - accuracy:
0.9808
Epoch 60: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0817 - accuracy:
0.9808 - val_loss: 0.4013 - val_accuracy: 0.8577 - lr: 3.9063e-06
Epoch 61/80
25/25 [==============================] - ETA: 0s - loss: 0.0817 - accuracy:
0.9808
Epoch 61: ReduceLROnPlateau reducing learning rate to 1.9531250927684596e-06.
```

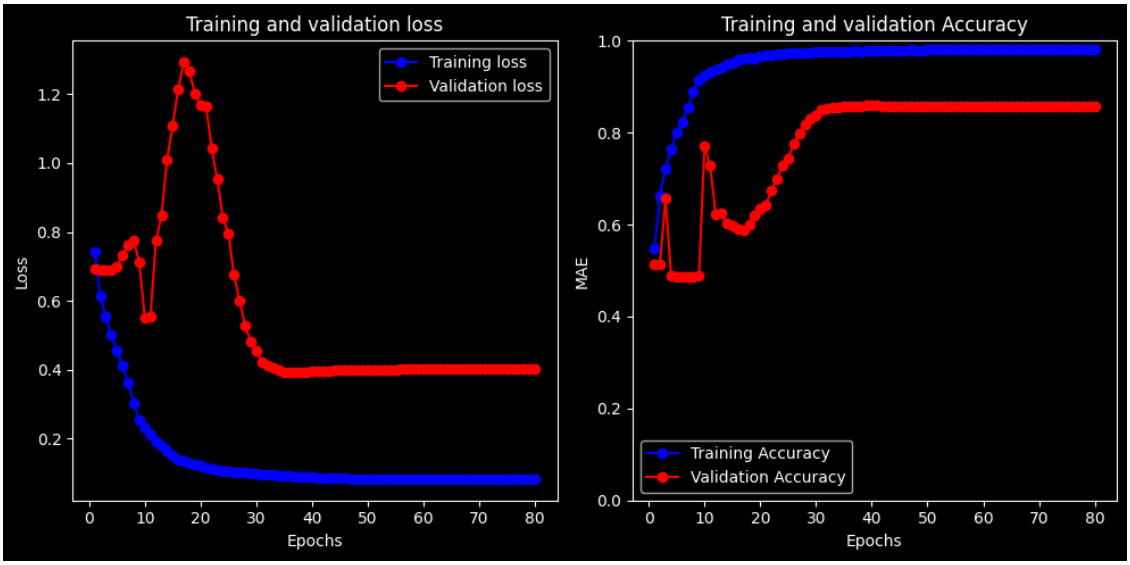
```
Epoch 61: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0817 - accuracy:
0.9808 - val_loss: 0.4014 - val_accuracy: 0.8577 - lr: 3.9063e-06
Epoch 62/80
22/25 [=========================>…] - ETA: 0s - loss: 0.0816 - accuracy:
0.9802
Epoch 62: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0814 - accuracy:
0.9802 - val_loss: 0.4014 - val_accuracy: 0.8578 - lr: 1.9531e-06
Epoch 63/80
25/25 [==============================] - ETA: 0s - loss: 0.0813 - accuracy:
0.9804
Epoch 63: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0813 - accuracy:
0.9804 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 1.9531e-06
Epoch 64/80
20/25 [=======================>…] - ETA: 0s - loss: 0.0815 - accuracy:
0.9808
Epoch 64: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0817 - accuracy:
0.9804 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 1.9531e-06
Epoch 65/80
25/25 [==============================] - ETA: 0s - loss: 0.0821 - accuracy:
0.9800
Epoch 65: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0821 - accuracy:
0.9800 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 1.9531e-06
Epoch 66/80
21/25 [========================>…] - ETA: 0s - loss: 0.0818 - accuracy:
0.9808
Epoch 66: ReduceLROnPlateau reducing learning rate to 9.765625463842298e-07.

Epoch 66: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0819 - accuracy:
0.9807 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 1.9531e-06
Epoch 67/80
22/25 [=========================>…] - ETA: 0s - loss: 0.0824 - accuracy:
0.9802
Epoch 67: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0822 - accuracy:
0.9802 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 9.7656e-07
Epoch 68/80
25/25 [==============================] - ETA: 0s - loss: 0.0816 - accuracy:
0.9802
Epoch 68: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0816 - accuracy:
0.9802 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 9.7656e-07
Epoch 69/80
```

```
25/25 [==============================] - ETA: 0s - loss: 0.0816 - accuracy:
0.9804
Epoch 69: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0816 - accuracy:
0.9804 - val_loss: 0.4015 - val_accuracy: 0.8578 - lr: 9.7656e-07
Epoch 70/80
25/25 [==============================] - ETA: 0s - loss: 0.0817 - accuracy:
0.9805
Epoch 70: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0817 - accuracy:
0.9805 - val_loss: 0.4017 - val_accuracy: 0.8578 - lr: 9.7656e-07
Epoch 71/80
25/25 [==============================] - ETA: 0s - loss: 0.0815 - accuracy:
0.9804
Epoch 71: ReduceLROnPlateau reducing learning rate to 4.882812731921149e-07.

Epoch 71: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0815 - accuracy:
0.9804 - val_loss: 0.4016 - val_accuracy: 0.8578 - lr: 9.7656e-07
Epoch 72/80
21/25 [========================>...] - ETA: 0s - loss: 0.0816 - accuracy:
0.9805
Epoch 72: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0814 - accuracy:
0.9807 - val_loss: 0.4015 - val_accuracy: 0.8576 - lr: 4.8828e-07
Epoch 73/80
25/25 [==============================] - ETA: 0s - loss: 0.0826 - accuracy:
0.9803
Epoch 73: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0826 - accuracy:
0.9803 - val_loss: 0.4015 - val_accuracy: 0.8576 - lr: 4.8828e-07
Epoch 74/80
25/25 [==============================] - ETA: 0s - loss: 0.0816 - accuracy:
0.9805
Epoch 74: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0816 - accuracy:
0.9805 - val_loss: 0.4016 - val_accuracy: 0.8576 - lr: 4.8828e-07
Epoch 75/80
25/25 [==============================] - ETA: 0s - loss: 0.0814 - accuracy:
0.9804
Epoch 75: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 17ms/step - loss: 0.0814 - accuracy:
0.9804 - val_loss: 0.4016 - val_accuracy: 0.8578 - lr: 4.8828e-07
Epoch 76/80
21/25 [========================>...] - ETA: 0s - loss: 0.0807 - accuracy:
0.9806
Epoch 76: ReduceLROnPlateau reducing learning rate to 2.4414063659605745e-07.
```

```
Epoch 76: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0815 - accuracy:
0.9804 - val_loss: 0.4017 - val_accuracy: 0.8578 - lr: 4.8828e-07
Epoch 77/80
20/25 [=====================>…] - ETA: 0s - loss: 0.0814 - accuracy:
0.9804
Epoch 77: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0813 - accuracy:
0.9807 - val_loss: 0.4017 - val_accuracy: 0.8578 - lr: 2.4414e-07
Epoch 78/80
21/25 [========================>…] - ETA: 0s - loss: 0.0819 - accuracy:
0.9800
Epoch 78: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 12ms/step - loss: 0.0813 - accuracy:
0.9804 - val_loss: 0.4017 - val_accuracy: 0.8578 - lr: 2.4414e-07
Epoch 79/80
25/25 [==============================] - ETA: 0s - loss: 0.0812 - accuracy:
0.9806
Epoch 79: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0812 - accuracy:
0.9806 - val_loss: 0.4016 - val_accuracy: 0.8578 - lr: 2.4414e-07
Epoch 80/80
25/25 [==============================] - ETA: 0s - loss: 0.0814 - accuracy:
0.9804
Epoch 80: val_accuracy did not improve from 0.85948
25/25 [==============================] - 0s 15ms/step - loss: 0.0814 - accuracy:
0.9804 - val_loss: 0.4016 - val_accuracy: 0.8578 - lr: 2.4414e-07
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```



```
Elapsed time:  43.26756191253662
```

[ ]:
```
model = keras.models.load_model(dir + "gru_bi_r.h5")
results = model.evaluate(x_test_int, y_test)
print(results)
```

```
782/782 [==============================] - 2s 2ms/step - loss: 0.3918 -
accuracy: 0.8595
[0.39175620675086975, 0.8594800233840942]
```

5 El impacto de los hiperparámetros

Batch size muy muy grande

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 64, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(256, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(256, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(256, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.01)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=30, model_name="gru_bi_a.h5", batch_size=512,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
```

```
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_24"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_25 (InputLayer)       [(None, 166)]             0

 embedding_24 (Embedding)    (None, 166, 64)           352000

 batch_normalization_57 (Bat  (None, 166, 64)          256
 chNormalization)

 bidirectional_15 (Bidirecti  (None, 512)              494592
 onal)

 batch_normalization_58 (Bat  (None, 512)              2048
 chNormalization)

 dense_37 (Dense)            (None, 256)               131328

 batch_normalization_59 (Bat  (None, 256)              1024
 chNormalization)

 dense_38 (Dense)            (None, 256)               65792

 batch_normalization_60 (Bat  (None, 256)              1024
 chNormalization)

 dense_39 (Dense)            (None, 1)                 257

=================================================================
Total params: 1,048,321
Trainable params: 1,046,145
Non-trainable params: 2,176
_________________________________________________________________
Epoch 1/30
49/49 [==============================] - ETA: 0s - loss: 0.4865 - accuracy:
0.8219
Epoch 1: val_accuracy improved from -inf to 0.57620, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 8s 92ms/step - loss: 0.4865 - accuracy:
0.8219 - val_loss: 1.6123 - val_accuracy: 0.5762 - lr: 0.0100
Epoch 2/30
49/49 [==============================] - ETA: 0s - loss: 0.1753 - accuracy:
0.9312
Epoch 2: val_accuracy improved from 0.57620 to 0.65072, saving model to
```

```
models/gru_bi_a.h5
49/49 [==============================] - 3s 60ms/step - loss: 0.1753 - accuracy:
0.9312 - val_loss: 0.5930 - val_accuracy: 0.6507 - lr: 0.0100
Epoch 3/30
49/49 [==============================] - ETA: 0s - loss: 0.0985 - accuracy:
0.9643
Epoch 3: val_accuracy improved from 0.65072 to 0.79664, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 4s 73ms/step - loss: 0.0985 - accuracy:
0.9643 - val_loss: 0.4437 - val_accuracy: 0.7966 - lr: 0.0100
Epoch 4/30
49/49 [==============================] - ETA: 0s - loss: 0.0678 - accuracy:
0.9751
Epoch 4: val_accuracy improved from 0.79664 to 0.83320, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 2s 49ms/step - loss: 0.0678 - accuracy:
0.9751 - val_loss: 0.4149 - val_accuracy: 0.8332 - lr: 0.0100
Epoch 5/30
49/49 [==============================] - ETA: 0s - loss: 0.0573 - accuracy:
0.9796
Epoch 5: val_accuracy did not improve from 0.83320
49/49 [==============================] - 2s 46ms/step - loss: 0.0573 - accuracy:
0.9796 - val_loss: 1.2609 - val_accuracy: 0.6974 - lr: 0.0100
Epoch 6/30
49/49 [==============================] - ETA: 0s - loss: 0.0442 - accuracy:
0.9837
Epoch 6: val_accuracy improved from 0.83320 to 0.87512, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 2s 45ms/step - loss: 0.0442 - accuracy:
0.9837 - val_loss: 0.4240 - val_accuracy: 0.8751 - lr: 0.0100
Epoch 7/30
49/49 [==============================] - ETA: 0s - loss: 0.0453 - accuracy:
0.9827
Epoch 7: val_accuracy did not improve from 0.87512
49/49 [==============================] - 2s 35ms/step - loss: 0.0453 - accuracy:
0.9827 - val_loss: 0.4793 - val_accuracy: 0.8743 - lr: 0.0100
Epoch 8/30
49/49 [==============================] - ETA: 0s - loss: 0.0390 - accuracy:
0.9847
Epoch 8: val_accuracy improved from 0.87512 to 0.87832, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 2s 36ms/step - loss: 0.0390 - accuracy:
0.9847 - val_loss: 0.5515 - val_accuracy: 0.8783 - lr: 0.0100
Epoch 9/30
49/49 [==============================] - ETA: 0s - loss: 0.0398 - accuracy:
0.9856
Epoch 9: ReduceLROnPlateau reducing learning rate to 0.004999999888241291.
```

```
Epoch 9: val_accuracy did not improve from 0.87832
49/49 [==============================] - 2s 35ms/step - loss: 0.0398 - accuracy:
0.9856 - val_loss: 0.8223 - val_accuracy: 0.8510 - lr: 0.0100
Epoch 10/30
49/49 [==============================] - ETA: 0s - loss: 0.0281 - accuracy:
0.9896
Epoch 10: val_accuracy improved from 0.87832 to 0.88092, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 2s 32ms/step - loss: 0.0281 - accuracy:
0.9896 - val_loss: 0.6342 - val_accuracy: 0.8809 - lr: 0.0050
Epoch 11/30
49/49 [==============================] - ETA: 0s - loss: 0.0064 - accuracy:
0.9982
Epoch 11: val_accuracy did not improve from 0.88092
49/49 [==============================] - 2s 32ms/step - loss: 0.0064 - accuracy:
0.9982 - val_loss: 0.7341 - val_accuracy: 0.8799 - lr: 0.0050
Epoch 12/30
49/49 [==============================] - ETA: 0s - loss: 0.0028 - accuracy:
0.9993
Epoch 12: val_accuracy did not improve from 0.88092
49/49 [==============================] - 1s 30ms/step - loss: 0.0028 - accuracy:
0.9993 - val_loss: 0.7708 - val_accuracy: 0.8793 - lr: 0.0050
Epoch 13/30
49/49 [==============================] - ETA: 0s - loss: 0.0012 - accuracy:
0.9997
Epoch 13: val_accuracy did not improve from 0.88092
49/49 [==============================] - 1s 31ms/step - loss: 0.0012 - accuracy:
0.9997 - val_loss: 0.8693 - val_accuracy: 0.8720 - lr: 0.0050
Epoch 14/30
49/49 [==============================] - ETA: 0s - loss: 0.0012 - accuracy:
0.9996
Epoch 14: ReduceLROnPlateau reducing learning rate to 0.0024999999441206455.

Epoch 14: val_accuracy did not improve from 0.88092
49/49 [==============================] - 2s 32ms/step - loss: 0.0012 - accuracy:
0.9996 - val_loss: 0.8420 - val_accuracy: 0.8799 - lr: 0.0050
Epoch 15/30
48/49 [============================>.] - ETA: 0s - loss: 9.9746e-04 - accuracy:
0.9997
Epoch 15: val_accuracy did not improve from 0.88092
49/49 [==============================] - 1s 29ms/step - loss: 9.9294e-04 -
accuracy: 0.9997 - val_loss: 0.8318 - val_accuracy: 0.8787 - lr: 0.0025
Epoch 16/30
49/49 [==============================] - ETA: 0s - loss: 3.9106e-04 - accuracy:
0.9999
Epoch 16: val_accuracy did not improve from 0.88092
49/49 [==============================] - 1s 28ms/step - loss: 3.9106e-04 -
accuracy: 0.9999 - val_loss: 0.8478 - val_accuracy: 0.8798 - lr: 0.0025
```

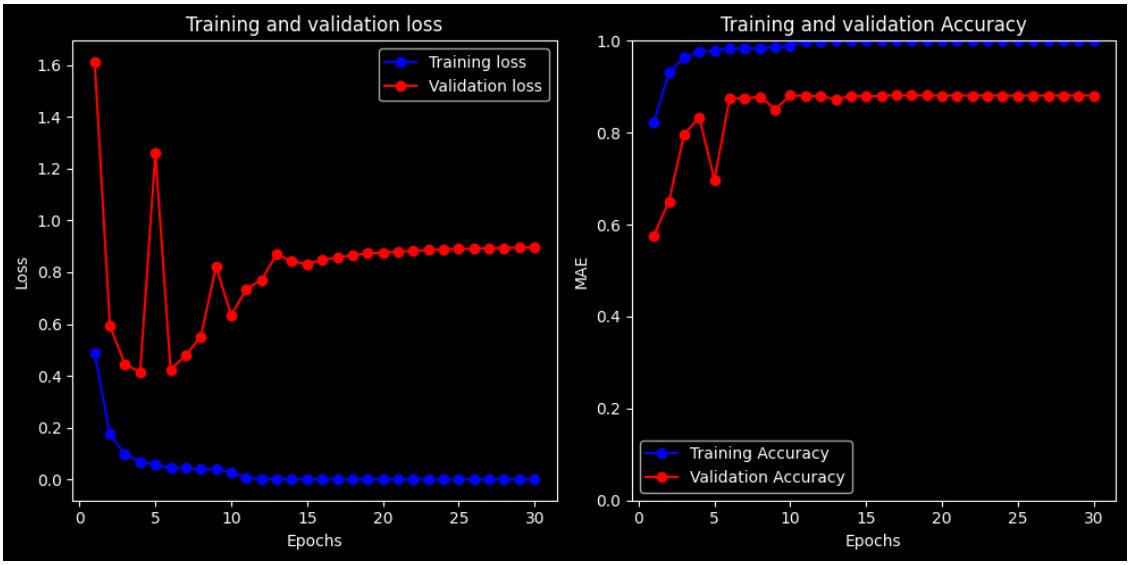
```
Epoch 17/30
49/49 [==============================] - ETA: 0s - loss: 1.3930e-04 - accuracy:
1.0000
Epoch 17: val_accuracy improved from 0.88092 to 0.88148, saving model to
models/gru_bi_a.h5
49/49 [==============================] - 2s 32ms/step - loss: 1.3930e-04 -
accuracy: 1.0000 - val_loss: 0.8563 - val_accuracy: 0.8815 - lr: 0.0025
Epoch 18/30
49/49 [==============================] - ETA: 0s - loss: 7.7433e-05 - accuracy:
1.0000
Epoch 18: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 30ms/step - loss: 7.7433e-05 -
accuracy: 1.0000 - val_loss: 0.8650 - val_accuracy: 0.8810 - lr: 0.0025
Epoch 19/30
49/49 [==============================] - ETA: 0s - loss: 7.0266e-05 - accuracy:
1.0000
Epoch 19: ReduceLROnPlateau reducing learning rate to 0.0012499999720603228.

Epoch 19: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 29ms/step - loss: 7.0266e-05 -
accuracy: 1.0000 - val_loss: 0.8723 - val_accuracy: 0.8810 - lr: 0.0025
Epoch 20/30
49/49 [==============================] - ETA: 0s - loss: 6.7383e-05 - accuracy:
1.0000
Epoch 20: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 29ms/step - loss: 6.7383e-05 -
accuracy: 1.0000 - val_loss: 0.8756 - val_accuracy: 0.8808 - lr: 0.0012
Epoch 21/30
49/49 [==============================] - ETA: 0s - loss: 6.0121e-05 - accuracy:
1.0000
Epoch 21: val_accuracy did not improve from 0.88148
49/49 [==============================] - 2s 31ms/step - loss: 6.0121e-05 -
accuracy: 1.0000 - val_loss: 0.8789 - val_accuracy: 0.8808 - lr: 0.0012
Epoch 22/30
49/49 [==============================] - ETA: 0s - loss: 5.5817e-05 - accuracy:
1.0000
Epoch 22: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 30ms/step - loss: 5.5817e-05 -
accuracy: 1.0000 - val_loss: 0.8821 - val_accuracy: 0.8807 - lr: 0.0012
Epoch 23/30
49/49 [==============================] - ETA: 0s - loss: 5.3781e-05 - accuracy:
1.0000
Epoch 23: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 30ms/step - loss: 5.3781e-05 -
accuracy: 1.0000 - val_loss: 0.8853 - val_accuracy: 0.8808 - lr: 0.0012
Epoch 24/30
49/49 [==============================] - ETA: 0s - loss: 4.0637e-05 - accuracy:
1.0000
```

```
Epoch 24: ReduceLROnPlateau reducing learning rate to 0.0006249999860301614.

Epoch 24: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 28ms/step - loss: 4.0637e-05 -
accuracy: 1.0000 - val_loss: 0.8883 - val_accuracy: 0.8806 - lr: 0.0012
Epoch 25/30
49/49 [==============================] - ETA: 0s - loss: 3.6544e-05 - accuracy:
1.0000
Epoch 25: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 27ms/step - loss: 3.6544e-05 -
accuracy: 1.0000 - val_loss: 0.8896 - val_accuracy: 0.8807 - lr: 6.2500e-04
Epoch 26/30
47/49 [===========================>..] - ETA: 0s - loss: 3.6520e-05 - accuracy:
1.0000
Epoch 26: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 28ms/step - loss: 3.6114e-05 -
accuracy: 1.0000 - val_loss: 0.8909 - val_accuracy: 0.8807 - lr: 6.2500e-04
Epoch 27/30
49/49 [==============================] - ETA: 0s - loss: 4.1561e-05 - accuracy:
1.0000
Epoch 27: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 27ms/step - loss: 4.1561e-05 -
accuracy: 1.0000 - val_loss: 0.8925 - val_accuracy: 0.8807 - lr: 6.2500e-04
Epoch 28/30
49/49 [==============================] - ETA: 0s - loss: 4.0223e-05 - accuracy:
1.0000
Epoch 28: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 28ms/step - loss: 4.0223e-05 -
accuracy: 1.0000 - val_loss: 0.8939 - val_accuracy: 0.8807 - lr: 6.2500e-04
Epoch 29/30
49/49 [==============================] - ETA: 0s - loss: 3.5334e-05 - accuracy:
1.0000
Epoch 29: ReduceLROnPlateau reducing learning rate to 0.0003124999930150807.

Epoch 29: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 30ms/step - loss: 3.5334e-05 -
accuracy: 1.0000 - val_loss: 0.8952 - val_accuracy: 0.8809 - lr: 6.2500e-04
Epoch 30/30
49/49 [==============================] - ETA: 0s - loss: 3.3663e-05 - accuracy:
1.0000
Epoch 30: val_accuracy did not improve from 0.88148
49/49 [==============================] - 1s 27ms/step - loss: 3.3663e-05 -
accuracy: 1.0000 - val_loss: 0.8959 - val_accuracy: 0.8808 - lr: 3.1250e-04
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```




```
Elapsed time:  57.49917149543762
```

[ ]:
```
model = keras.models.load_model(dir + "lstm_bi_a.h5")
model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 4s 5ms/step - loss: 0.7453 -
accuracy: 0.7994
```

[ ]:
```
[0.7452947497367859, 0.7993999719619751]
```

[ ]:
```
from tensorflow.keras.callbacks import ReduceLROnPlateau

np.random.seed(423423)
tf.random.set_seed(1232413)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=5,␣
 ↪min_lr=0.000000000000000000001, verbose=1)

start_time = time.time()
inputs = keras.Input(shape=(seqLength, ))
x = layers.Embedding(maxFeatures, 64, mask_zero=True,␣
 ↪input_length=seqLength)(inputs)
x = keras.layers.BatchNormalization()(x)
x = layers.Bidirectional(layers.GRU(256, return_sequences=False))(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(256, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
x = keras.layers.Dense(256, activation="relu")(x)
x = keras.layers.BatchNormalization()(x)
```

```
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)


model.summary()
optimizer = keras.optimizers.Adam(learning_rate=0.04)
model.compile(optimizer=optimizer, loss="binary_crossentropy",␣
 ↪metrics=["accuracy"])

result = fitModel(model, x_train_int, y_train, (x_test_int, y_test),␣
 ↪num_epochs=30, model_name="gru_bi_a.h5", batch_size=4096,␣
 ↪callbacks=[reduce_lr])

end_time = time.time()
print("Elapsed time: ", end_time - start_time)
```

```
Model: "model_25"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_26 (InputLayer)       [(None, 166)]             0

 embedding_25 (Embedding)    (None, 166, 64)           352000

 batch_normalization_61 (Bat  (None, 166, 64)          256
 chNormalization)

 bidirectional_16 (Bidirecti  (None, 512)              494592
 onal)

 batch_normalization_62 (Bat  (None, 512)              2048
 chNormalization)

 dense_40 (Dense)            (None, 256)               131328

 batch_normalization_63 (Bat  (None, 256)              1024
 chNormalization)

 dense_41 (Dense)            (None, 256)               65792

 batch_normalization_64 (Bat  (None, 256)              1024
 chNormalization)

 dense_42 (Dense)            (None, 1)                 257

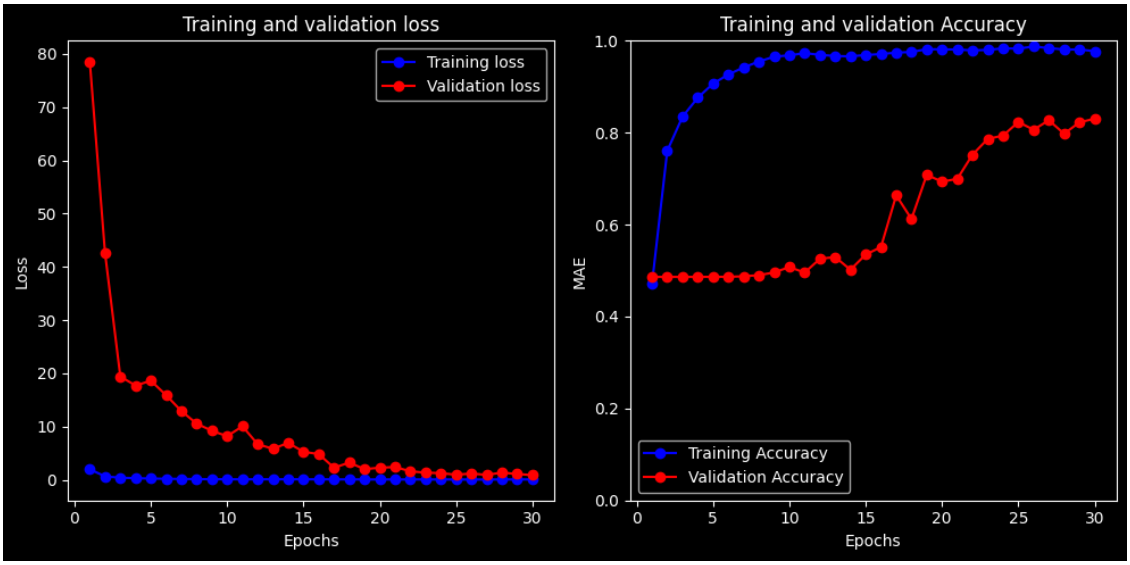
=================================================================
Total params: 1,048,321
```

```
Trainable params: 1,046,145
Non-trainable params: 2,176
_________________________________________________________________
Epoch 1/30
7/7 [==============================] - ETA: 0s - loss: 1.9577 - accuracy: 0.4715
Epoch 1: val_accuracy improved from -inf to 0.48628, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 5s 261ms/step - loss: 1.9577 - accuracy:
0.4715 - val_loss: 78.5632 - val_accuracy: 0.4863 - lr: 0.0400
Epoch 2/30
7/7 [==============================] - ETA: 0s - loss: 0.6317 - accuracy: 0.7608
Epoch 2: val_accuracy did not improve from 0.48628
7/7 [==============================] - 1s 126ms/step - loss: 0.6317 - accuracy:
0.7608 - val_loss: 42.5607 - val_accuracy: 0.4863 - lr: 0.0400
Epoch 3/30
7/7 [==============================] - ETA: 0s - loss: 0.3743 - accuracy: 0.8348
Epoch 3: val_accuracy did not improve from 0.48628
7/7 [==============================] - 1s 124ms/step - loss: 0.3743 - accuracy:
0.8348 - val_loss: 19.3976 - val_accuracy: 0.4863 - lr: 0.0400
Epoch 4/30
7/7 [==============================] - ETA: 0s - loss: 0.2892 - accuracy: 0.8761
Epoch 4: val_accuracy did not improve from 0.48628
7/7 [==============================] - 1s 137ms/step - loss: 0.2892 - accuracy:
0.8761 - val_loss: 17.6954 - val_accuracy: 0.4863 - lr: 0.0400
Epoch 5/30
7/7 [==============================] - ETA: 0s - loss: 0.2221 - accuracy: 0.9068
Epoch 5: val_accuracy improved from 0.48628 to 0.48644, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 126ms/step - loss: 0.2221 - accuracy:
0.9068 - val_loss: 18.6081 - val_accuracy: 0.4864 - lr: 0.0400
Epoch 6/30
7/7 [==============================] - ETA: 0s - loss: 0.1797 - accuracy: 0.9266
Epoch 6: val_accuracy improved from 0.48644 to 0.48648, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 126ms/step - loss: 0.1797 - accuracy:
0.9266 - val_loss: 15.8909 - val_accuracy: 0.4865 - lr: 0.0400
Epoch 7/30
7/7 [==============================] - ETA: 0s - loss: 0.1502 - accuracy: 0.9419
Epoch 7: val_accuracy improved from 0.48648 to 0.48760, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 130ms/step - loss: 0.1502 - accuracy:
0.9419 - val_loss: 12.9067 - val_accuracy: 0.4876 - lr: 0.0400
Epoch 8/30
7/7 [==============================] - ETA: 0s - loss: 0.1189 - accuracy: 0.9548
Epoch 8: val_accuracy improved from 0.48760 to 0.49012, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 123ms/step - loss: 0.1189 - accuracy:
0.9548 - val_loss: 10.5438 - val_accuracy: 0.4901 - lr: 0.0400
```

```
Epoch 9/30
7/7 [==============================] - ETA: 0s - loss: 0.0964 - accuracy: 0.9653
Epoch 9: val_accuracy improved from 0.49012 to 0.49584, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 126ms/step - loss: 0.0964 - accuracy:
0.9653 - val_loss: 9.1974 - val_accuracy: 0.4958 - lr: 0.0400
Epoch 10/30
7/7 [==============================] - ETA: 0s - loss: 0.0871 - accuracy: 0.9683
Epoch 10: val_accuracy improved from 0.49584 to 0.50780, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 121ms/step - loss: 0.0871 - accuracy:
0.9683 - val_loss: 8.1805 - val_accuracy: 0.5078 - lr: 0.0400
Epoch 11/30
7/7 [==============================] - ETA: 0s - loss: 0.0754 - accuracy: 0.9730
Epoch 11: val_accuracy did not improve from 0.50780
7/7 [==============================] - 1s 119ms/step - loss: 0.0754 - accuracy:
0.9730 - val_loss: 10.0494 - val_accuracy: 0.4956 - lr: 0.0400
Epoch 12/30
7/7 [==============================] - ETA: 0s - loss: 0.0802 - accuracy: 0.9694
Epoch 12: val_accuracy improved from 0.50780 to 0.52568, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 120ms/step - loss: 0.0802 - accuracy:
0.9694 - val_loss: 6.6698 - val_accuracy: 0.5257 - lr: 0.0400
Epoch 13/30
7/7 [==============================] - ETA: 0s - loss: 0.0857 - accuracy: 0.9668
Epoch 13: val_accuracy improved from 0.52568 to 0.52952, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 124ms/step - loss: 0.0857 - accuracy:
0.9668 - val_loss: 5.8164 - val_accuracy: 0.5295 - lr: 0.0400
Epoch 14/30
7/7 [==============================] - ETA: 0s - loss: 0.0884 - accuracy: 0.9662
Epoch 14: val_accuracy did not improve from 0.52952
7/7 [==============================] - 1s 118ms/step - loss: 0.0884 - accuracy:
0.9662 - val_loss: 6.9252 - val_accuracy: 0.5019 - lr: 0.0400
Epoch 15/30
6/7 [========================>…] - ETA: 0s - loss: 0.0802 - accuracy: 0.9692
Epoch 15: val_accuracy improved from 0.52952 to 0.53488, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 115ms/step - loss: 0.0811 - accuracy:
0.9689 - val_loss: 5.2468 - val_accuracy: 0.5349 - lr: 0.0400
Epoch 16/30
7/7 [==============================] - ETA: 0s - loss: 0.0770 - accuracy: 0.9712
Epoch 16: val_accuracy improved from 0.53488 to 0.55112, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 123ms/step - loss: 0.0770 - accuracy:
0.9712 - val_loss: 4.8231 - val_accuracy: 0.5511 - lr: 0.0400
Epoch 17/30
7/7 [==============================] - ETA: 0s - loss: 0.0695 - accuracy: 0.9742
```

```
Epoch 17: val_accuracy improved from 0.55112 to 0.66372, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 122ms/step - loss: 0.0695 - accuracy:
0.9742 - val_loss: 2.2540 - val_accuracy: 0.6637 - lr: 0.0400
Epoch 18/30
7/7 [==============================] - ETA: 0s - loss: 0.0641 - accuracy: 0.9756
Epoch 18: val_accuracy did not improve from 0.66372
7/7 [==============================] - 1s 119ms/step - loss: 0.0641 - accuracy:
0.9756 - val_loss: 3.2242 - val_accuracy: 0.6122 - lr: 0.0400
Epoch 19/30
7/7 [==============================] - ETA: 0s - loss: 0.0507 - accuracy: 0.9817
Epoch 19: val_accuracy improved from 0.66372 to 0.70828, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 124ms/step - loss: 0.0507 - accuracy:
0.9817 - val_loss: 1.9893 - val_accuracy: 0.7083 - lr: 0.0400
Epoch 20/30
7/7 [==============================] - ETA: 0s - loss: 0.0517 - accuracy: 0.9814
Epoch 20: val_accuracy did not improve from 0.70828
7/7 [==============================] - 1s 121ms/step - loss: 0.0517 - accuracy:
0.9814 - val_loss: 2.2629 - val_accuracy: 0.6935 - lr: 0.0400
Epoch 21/30
7/7 [==============================] - ETA: 0s - loss: 0.0518 - accuracy: 0.9810
Epoch 21: val_accuracy did not improve from 0.70828
7/7 [==============================] - 1s 118ms/step - loss: 0.0518 - accuracy:
0.9810 - val_loss: 2.3855 - val_accuracy: 0.6995 - lr: 0.0400
Epoch 22/30
7/7 [==============================] - ETA: 0s - loss: 0.0530 - accuracy: 0.9790
Epoch 22: val_accuracy improved from 0.70828 to 0.75224, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 122ms/step - loss: 0.0530 - accuracy:
0.9790 - val_loss: 1.5846 - val_accuracy: 0.7522 - lr: 0.0400
Epoch 23/30
7/7 [==============================] - ETA: 0s - loss: 0.0520 - accuracy: 0.9802
Epoch 23: val_accuracy improved from 0.75224 to 0.78652, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 121ms/step - loss: 0.0520 - accuracy:
0.9802 - val_loss: 1.3314 - val_accuracy: 0.7865 - lr: 0.0400
Epoch 24/30
7/7 [==============================] - ETA: 0s - loss: 0.0458 - accuracy: 0.9834
Epoch 24: val_accuracy improved from 0.78652 to 0.79368, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 123ms/step - loss: 0.0458 - accuracy:
0.9834 - val_loss: 1.2335 - val_accuracy: 0.7937 - lr: 0.0400
Epoch 25/30
7/7 [==============================] - ETA: 0s - loss: 0.0455 - accuracy: 0.9829
Epoch 25: val_accuracy improved from 0.79368 to 0.82328, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 121ms/step - loss: 0.0455 - accuracy:
```

```
0.9829 - val_loss: 0.9464 - val_accuracy: 0.8233 - lr: 0.0400
Epoch 26/30
6/7 [=======================>…] - ETA: 0s - loss: 0.0348 - accuracy: 0.9876
Epoch 26: val_accuracy did not improve from 0.82328
7/7 [==============================] - 1s 112ms/step - loss: 0.0350 - accuracy:
0.9874 - val_loss: 1.1635 - val_accuracy: 0.8064 - lr: 0.0400
Epoch 27/30
7/7 [==============================] - ETA: 0s - loss: 0.0422 - accuracy: 0.9841
Epoch 27: val_accuracy improved from 0.82328 to 0.82704, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 123ms/step - loss: 0.0422 - accuracy:
0.9841 - val_loss: 0.9156 - val_accuracy: 0.8270 - lr: 0.0400
Epoch 28/30
7/7 [==============================] - ETA: 0s - loss: 0.0502 - accuracy: 0.9810
Epoch 28: val_accuracy did not improve from 0.82704
7/7 [==============================] - 1s 118ms/step - loss: 0.0502 - accuracy:
0.9810 - val_loss: 1.3372 - val_accuracy: 0.7977 - lr: 0.0400
Epoch 29/30
7/7 [==============================] - ETA: 0s - loss: 0.0494 - accuracy: 0.9811
Epoch 29: val_accuracy did not improve from 0.82704
7/7 [==============================] - 1s 123ms/step - loss: 0.0494 - accuracy:
0.9811 - val_loss: 1.0785 - val_accuracy: 0.8225 - lr: 0.0400
Epoch 30/30
7/7 [==============================] - ETA: 0s - loss: 0.0582 - accuracy: 0.9773
Epoch 30: val_accuracy improved from 0.82704 to 0.83040, saving model to
models/gru_bi_a.h5
7/7 [==============================] - 1s 123ms/step - loss: 0.0582 - accuracy:
0.9773 - val_loss: 0.8671 - val_accuracy: 0.8304 - lr: 0.0400
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy', 'lr'])
```



```
Elapsed time:  30.094652891159058
```

```
[ ]: model = keras.models.load_model(dir + "lstm_bi_a.h5")
     model.evaluate(x_test_int, y_test)
```

```
782/782 [==============================] - 4s 5ms/step - loss: 0.7453 -
accuracy: 0.7994
```

```
[ ]: [0.7452947497367859, 0.7993999719619751]
```

6 Conclusiones

En general, lo primero que debemos tener en cuenta a la hora de proponer una solución a este problema es que estamos ante datos textuales por lo que el proceso de tokenización tiene un importante impacto en los resultados. En nuestro caso lo primero es el número de caracteristicas, que defini el dominio de las entradas del embedding y que tiene un importante impacto en el rendimiento pero bajo en la complejidad computacional, es mejor idea por exceso que por defecto. El segundo aspecto es la longitud de secuencai que deberemos ajustar al tamaño de los fragmentos de texto que queremos clasificar. en nuestro caso no es necesario que sea elevado y tiene un impacto importante en la complejidad computacional. Estos aspectos no sonn solo sensibles al problema sino tambien al modelo que vayamos a aplicar.

Respecto al diseño de la red es fundamental el empleo de una capa de Embedding y otra recurrente. En cuanto a la capa de embedding debemos tener especial cuidado con el tamaño que empleamos tine un importante imapcto en la complejidad computacional y en en los resultados al encargarse de representar la distacia semantica de de los tokens. Se debe cuidar la normalización, ua que esta capa tiene a sobreajustarse. Respecto a la etapa recurrente los mejores resultados se alcanzan con las unidades GRU de forma bidir3eccional, para este problema obtenemos resultados buenos con un número pequeño de 16 unidades, debemos ser cautos si deseamos redducirlo porque podriamos perder demasiada información contextual.

Respecto a las capas densas antes de la salida, hemos visto que no son necesaria para alcanzar el objetivo de este trabajo alcanzando un 85.6 % de accuracy de forma repetible. Para mejorar los resultados hemos visto que es necesario aumentar mucho la complejidad general de la red, aumentando tamañode embedding, unidades recurrentes, etc. Con esta estrategia hemos alcanzado un 88.6 % de accuracy. Se debe destacar que hemos pareciado una cierta tendencia al overfitting si aumentamos las caps densas y no las etapas anteriores.