Modelo T sem data augmentation otimizer Adam

Neste modelo optamos por escolher o ResNet50 em vez do VGG16 utilizado nas aulas, visto que Escolhemos o ResNet50 por sua arquitetura avançada com blocos residuais, que permitem redes mais profundas e eficientes, resultando em melhor desempenho e capacidade de generalização em comparação ao VGG16, e assim conseguiriamos testar um novo modelo. Além disso, O ResNet50 parece ser mais suportado na comunidade de deep learning.

```
from tensorflow.keras.metrics import Metric
from tensorflow.keras import backend as K
import json
import os
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import GlobalAveragePooling2D, Dropout,
Dense, BatchNormalization
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping,
ReduceLROnPlateau, CSVLogger
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import ResNet50
from tensorflow.keras.regularizers import l2
from tensorflow.keras.mixed_precision import set_global_policy
```

Usar float16 pode acelerar significativamente o treinamento do modelo e reduz também a memória necessária para o treino, sem perder grande precisão.

```
# MIX precision training -- facilita no treino!
set_global_policy('mixed_float16')

os.environ['TF_CPP_MIN_LOG_LEVEL'] = '2'

# CONSTANTES
BATCH_SIZE = 64
IMG_SIZE = 150
NUM_CLASSES = 10  # nº classes para identificar
NUM_EPOCHS = 60
LEARNING_RATE = 0.0001
DENSE_LAYERS = [1024, 512, 256, 128]
```

```
INFO:tensorflow:Mixed precision compatibility check (mixed_float16):
OK
Your GPU will likely run quickly with dtype policy mixed_float16 as it
has compute capability of at least 7.0. Your GPU: NVIDIA GeForce RTX
4070, compute capability 8.9
```

Dataset de treino, validação e teste

```
# Folders do dataset
train_dirs = ['./dataset/train/train1', './dataset/train/train2',
              './dataset/train/train3', './dataset/train/train5']
validation_dir = './dataset/validation'
test_dir = './dataset/test'
```

Data generators

```
train_datagen = ImageDataGenerator(rescale=1./255)
validation_datagen = ImageDataGenerator(rescale=1./255)
test_datagen = ImageDataGenerator(rescale=1./255)

# training generators
train_generators = [train_datagen.flow_from_directory(
    train_dir,
    target_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    class_mode='categorical') for train_dir in train_dirs]

# Necessário para juntar os trainning generators and repeat
def combined_generator(generators):
    while True:
        for generator in generators:
            for batch in generator:
                yield batch


train_generator = combined_generator(train_generators)

# Validation e test generators
validation_generator = validation_datagen.flow_from_directory(
    validation_dir,
    target_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    class_mode='categorical')

test_generator = test_datagen.flow_from_directory(
    test_dir,
    target_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    class_mode='categorical')

# Load the pre-trained ResNet50 model without the top layer and adjust
input shape
base_model = ResNet50(weights='imagenet', include_top=False,
                      input_shape=(IMG_SIZE, IMG_SIZE, 3))
```

```
Found 10000 images belonging to 10 classes.
Found 10000 images belonging to 10 classes.
Found 10000 images belonging to 10 classes.
Found 10000 images belonging to 10 classes.
Found 10000 images belonging to 10 classes.
Found 10000 images belonging to 10 classes.
```

UnFreeze layers

Para melhorar o modelo, foram descongeladas as últimas 50 camadas da rede base, permitindo que seus pesos sejam treinados. Isso ajuda o modelo a aprender melhor os padrões do novo conjunto de dados. Descongelar muitas camadas pode causar problemas, por isso mantivemos o número baixo. Com isso, equilibramos entre ajustar o modelo e evitar problemas de estabilidade. Essa técnica melhora o desempenho sem complicações.

(no modelo t com data augmentation testamos com 100 layers!)

```
# Descongelar camadas (nao meter valores demasiado altos)
for layer in base_model.layers[-50:]:
    layer.trainable = True
```

Métricas de Avaliação para Classificação Binária (Precision, Recall e F1 Score)

```
class Precision(Metric):
    def __init__(self, name='precision', **kwargs):
        super(Precision, self).__init__(name=name, **kwargs)
        self.true_positives = self.add_weight(name='tp',
initializer='zeros')
        self.predicted_positives = self.add_weight(
            name='pp', initializer='zeros')

    def update_state(self, y_true, y_pred, sample_weight=None):
        y_pred = K.round(y_pred)
        y_true = K.cast(y_true, 'float32')
        self.true_positives.assign_add(K.sum(y_true * y_pred))
        self.predicted_positives.assign_add(K.sum(y_pred))

    def result(self):
        return self.true_positives / (self.predicted_positives +
K.epsilon())

    def reset_states(self):
        self.true_positives.assign(0)
```

```
        self.predicted_positives.assign(0)


class Recall(Metric):
    def __init__(self, name='recall', **kwargs):
        super(Recall, self).__init__(name=name, **kwargs)
        self.true_positives = self.add_weight(name='tp',
initializer='zeros')
        self.actual_positives = self.add_weight(name='ap',
initializer='zeros')

    def update_state(self, y_true, y_pred, sample_weight=None):
        y_pred = K.round(y_pred)
        y_true = K.cast(y_true, 'float32')
        self.true_positives.assign_add(K.sum(y_true * y_pred))
        self.actual_positives.assign_add(K.sum(y_true))

    def result(self):
        return self.true_positives / (self.actual_positives +
K.epsilon())

    def reset_states(self):
        self.true_positives.assign(0)
        self.actual_positives.assign(0)


class F1Score(Metric):
    def __init__(self, name='f1_score', **kwargs):
        super(F1Score, self).__init__(name=name, **kwargs)
        self.precision = Precision()
        self.recall = Recall()

    def update_state(self, y_true, y_pred, sample_weight=None):
        self.precision.update_state(y_true, y_pred)
        self.recall.update_state(y_true, y_pred)

    def result(self):
        precision = self.precision.result()
        recall = self.recall.result()
        return 2 * ((precision * recall) / (precision + recall +
K.epsilon()))

    def reset_states(self):
        self.precision.reset_states()
        self.recall.reset_states()
```

Definir as layers do modelo

```
# Definir as layers do modelo com parametros ajustados para reduzir o
overfitting
model = Sequential([
    base_model,
    BatchNormalization(),
    GlobalAveragePooling2D(),
    # Increase model complexity
    Dense(DENSE_LAYERS[0], activation='relu',
kernel_regularizer=l2(0.03)),
    Dropout(0.5),  # High dropout rate for regularization
    BatchNormalization(),
    Dense(DENSE_LAYERS[1], activation='relu',
kernel_regularizer=l2(0.03)),
    Dropout(0.5),
    BatchNormalization(),
    Dense(DENSE_LAYERS[2], activation='relu',
kernel_regularizer=l2(0.03)),
    Dropout(0.5),
    Dense(DENSE_LAYERS[3], activation='relu',
kernel_regularizer=l2(0.03)),
    Dropout(0.5),
    BatchNormalization(),
    Dense(NUM_CLASSES, activation='softmax', dtype='float32')
])

# Compilar o modelo
model.compile(optimizer=Adam(learning_rate=LEARNING_RATE),
              loss='categorical_crossentropy',
              metrics=['accuracy', Precision(), Recall(), F1Score()])

model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 resnet50 (Functional)       (None, 5, 5, 2048)        23587712

 batch_normalization (BatchN  (None, 5, 5, 2048)       8192
 ormalization)

 global_average_pooling2d (G  (None, 2048)             0
 lobalAveragePooling2D)

 dense (Dense)               (None, 1024)              2098176

 dropout (Dropout)           (None, 1024)              0
```

```
 batch_normalization_1 (Batc  (None, 1024)              4096
 hNormalization)

 dense_1 (Dense)              (None, 512)               524800

 dropout_1 (Dropout)          (None, 512)               0

 batch_normalization_2 (Batc  (None, 512)               2048
 hNormalization)

 dense_2 (Dense)              (None, 256)               131328

 dropout_2 (Dropout)          (None, 256)               0

 dense_3 (Dense)              (None, 128)               32896

 dropout_3 (Dropout)          (None, 128)               0

 batch_normalization_3 (Batc  (None, 128)               512
 hNormalization)

 dense_4 (Dense)              (None, 10)                1290

=================================================================
Total params: 26,391,050
Trainable params: 26,330,506
Non-trainable params: 60,544
_________________________________________________________________
```

Definir callbacks

```
# CALLBACKS
os.makedirs('logs', exist_ok=True)
checkpoint =
ModelCheckpoint(f'models/modelo_T_sem_data_augmentation_adam.keras',
                              monitor='val_accuracy', verbose=1,
save_best_only=True, mode='max')
early_stopping = EarlyStopping(
    monitor='val_loss', patience=10, restore_best_weights=True)  #
Increased patience
reduce_lr = ReduceLROnPlateau(
    monitor='val_loss', factor=0.2, patience=4, min_lr=1e-7,
verbose=1)  # More aggressive schedule
csv_logger = CSVLogger(
    f'logs/modelo_T_sem_data_augmentation_adam.csv', separator=',',
append=False)

# calcular passos por epoch
```

```
steps_per_epoch = sum([gen.samples // BATCH_SIZE for gen in
train_generators])
validation_steps = validation_generator.samples // BATCH_SIZE
```

Treino e avaliação do modelo

```
# calcular passos por epoch
# Treinar o modelo - Nao tirar os callbacks
history = model.fit(
    train_generator,
    steps_per_epoch=steps_per_epoch,
    epochs=NUM_EPOCHS,
    validation_data=validation_generator,
    validation_steps=validation_steps,
    callbacks=[checkpoint, early_stopping, reduce_lr, csv_logger]
)

# Avaliar o modelo no test generator
results = model.evaluate(test_generator)
loss, accuracy, precision, recall, f1_score = results[:5]
print(f"Test Loss: {loss}")
print(f"Test Accuracy: {accuracy}")
print(f"Test Precision: {precision}")
print(f"Test Recall: {recall}")
print(f"Test F1 Score: {f1_score}")
```

```
Epoch 1/60
624/624 [==============================] - ETA: 0s - loss: 52.7605 -
accuracy: 0.4382 - precision: 0.6945 - recall: 0.2654 - f1_score:
0.3840

c:\Users\USER\.conda\envs\py310\lib\site-packages\keras\engine\
training.py:2319: UserWarning: Metric Precision implements a
`reset_states()` method; rename it to `reset_state()` (without the
final "s"). The name `reset_states()` has been deprecated to improve
API consistency.
  m.reset_state()
c:\Users\USER\.conda\envs\py310\lib\site-packages\keras\engine\
training.py:2319: UserWarning: Metric Recall implements a
`reset_states()` method; rename it to `reset_state()` (without the
final "s"). The name `reset_states()` has been deprecated to improve
API consistency.
  m.reset_state()
c:\Users\USER\.conda\envs\py310\lib\site-packages\keras\engine\
training.py:2319: UserWarning: Metric F1Score implements a
`reset_states()` method; rename it to `reset_state()` (without the
final "s"). The name `reset_states()` has been deprecated to improve
```

```
API consistency.
  m.reset_state()


Epoch 1: val_accuracy improved from -inf to 0.10407, saving model to
models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 86s 109ms/step - loss:
52.7605 - accuracy: 0.4382 - precision: 0.6945 - recall: 0.2654 -
f1_score: 0.3840 - val_loss: 32.3975 - val_accuracy: 0.1041 -
val_precision: 0.1317 - val_recall: 0.0958 - val_f1_score: 0.1109 -
lr: 1.0000e-04
Epoch 2/60
624/624 [==============================] - ETA: 0s - loss: 16.9773 -
accuracy: 0.9075 - precision: 0.9548 - recall: 0.8296 - f1_score:
0.8878
Epoch 2: val_accuracy improved from 0.10407 to 0.85787, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 62s 100ms/step - loss:
16.9773 - accuracy: 0.9075 - precision: 0.9548 - recall: 0.8296 -
f1_score: 0.8878 - val_loss: 8.1945 - val_accuracy: 0.8579 -
val_precision: 0.9110 - val_recall: 0.8041 - val_f1_score: 0.8542 -
lr: 1.0000e-04
Epoch 3/60
624/624 [==============================] - ETA: 0s - loss: 4.2308 -
accuracy: 0.9617 - precision: 0.9730 - recall: 0.9409 - f1_score:
0.9567
Epoch 3: val_accuracy did not improve from 0.85787
624/624 [==============================] - 62s 100ms/step - loss:
4.2308 - accuracy: 0.9617 - precision: 0.9730 - recall: 0.9409 -
f1_score: 0.9567 - val_loss: 2.3749 - val_accuracy: 0.8475 -
val_precision: 0.8771 - val_recall: 0.8221 - val_f1_score: 0.8487 -
lr: 1.0000e-04
Epoch 4/60
624/624 [==============================] - ETA: 0s - loss: 1.1813 -
accuracy: 0.9715 - precision: 0.9777 - recall: 0.9623 - f1_score:
0.9699
Epoch 4: val_accuracy improved from 0.85787 to 0.87210, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 63s 101ms/step - loss:
1.1813 - accuracy: 0.9715 - precision: 0.9777 - recall: 0.9623 -
f1_score: 0.9699 - val_loss: 1.0297 - val_accuracy: 0.8721 -
val_precision: 0.8898 - val_recall: 0.8586 - val_f1_score: 0.8739 -
lr: 1.0000e-04
Epoch 5/60
624/624 [==============================] - ETA: 0s - loss: 0.5047 -
accuracy: 0.9727 - precision: 0.9775 - recall: 0.9662 - f1_score:
0.9719
Epoch 5: val_accuracy did not improve from 0.87210
624/624 [==============================] - 63s 101ms/step - loss:
0.5047 - accuracy: 0.9727 - precision: 0.9775 - recall: 0.9662 -
```

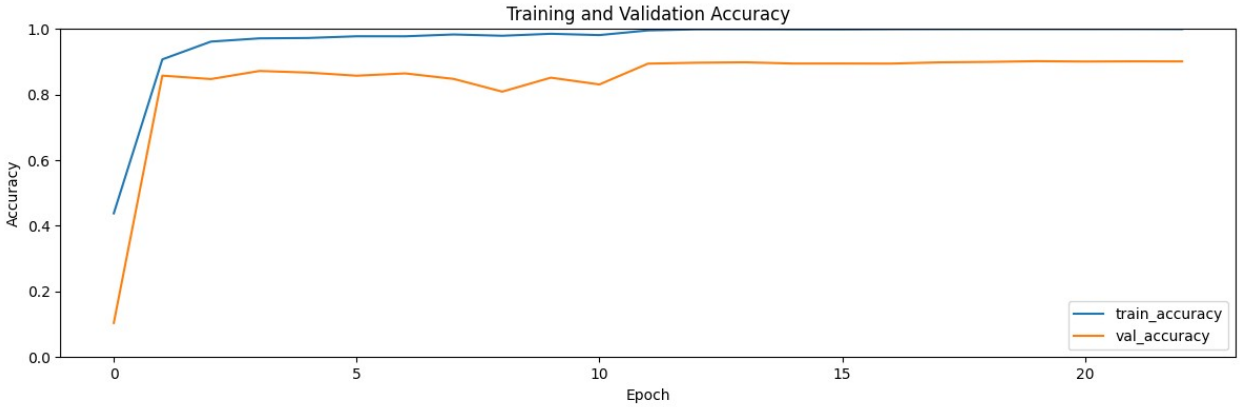
```
f1_score: 0.9719 - val_loss: 0.8315 - val_accuracy: 0.8672 -
val_precision: 0.8811 - val_recall: 0.8578 - val_f1_score: 0.8693 -
lr: 1.0000e-04
Epoch 6/60
624/624 [==============================] - ETA: 0s - loss: 0.3239 -
accuracy: 0.9779 - precision: 0.9816 - recall: 0.9734 - f1_score:
0.9775
Epoch 6: val_accuracy did not improve from 0.87210
624/624 [==============================] - 64s 102ms/step - loss:
0.3239 - accuracy: 0.9779 - precision: 0.9816 - recall: 0.9734 -
f1_score: 0.9775 - val_loss: 0.8259 - val_accuracy: 0.8577 -
val_precision: 0.8710 - val_recall: 0.8499 - val_f1_score: 0.8603 -
lr: 1.0000e-04
Epoch 7/60
624/624 [==============================] - ETA: 0s - loss: 0.2856 -
accuracy: 0.9778 - precision: 0.9814 - recall: 0.9739 - f1_score:
0.9776
Epoch 7: val_accuracy did not improve from 0.87210
624/624 [==============================] - 64s 102ms/step - loss:
0.2856 - accuracy: 0.9778 - precision: 0.9814 - recall: 0.9739 -
f1_score: 0.9776 - val_loss: 0.7655 - val_accuracy: 0.8647 -
val_precision: 0.8745 - val_recall: 0.8569 - val_f1_score: 0.8656 -
lr: 1.0000e-04
Epoch 8/60
624/624 [==============================] - ETA: 0s - loss: 0.2290 -
accuracy: 0.9834 - precision: 0.9859 - recall: 0.9802 - f1_score:
0.9831
Epoch 8: val_accuracy did not improve from 0.87210
624/624 [==============================] - 62s 99ms/step - loss:
0.2290 - accuracy: 0.9834 - precision: 0.9859 - recall: 0.9802 -
f1_score: 0.9831 - val_loss: 0.8915 - val_accuracy: 0.8479 -
val_precision: 0.8604 - val_recall: 0.8411 - val_f1_score: 0.8506 -
lr: 1.0000e-04
Epoch 9/60
624/624 [==============================] - ETA: 0s - loss: 0.2538 -
accuracy: 0.9794 - precision: 0.9826 - recall: 0.9758 - f1_score:
0.9792
Epoch 9: val_accuracy did not improve from 0.87210
624/624 [==============================] - 60s 97ms/step - loss:
0.2538 - accuracy: 0.9794 - precision: 0.9826 - recall: 0.9758 -
f1_score: 0.9792 - val_loss: 1.0544 - val_accuracy: 0.8091 -
val_precision: 0.8219 - val_recall: 0.8010 - val_f1_score: 0.8113 -
lr: 1.0000e-04
Epoch 10/60
624/624 [==============================] - ETA: 0s - loss: 0.2080 -
accuracy: 0.9854 - precision: 0.9875 - recall: 0.9835 - f1_score:
0.9855
Epoch 10: val_accuracy did not improve from 0.87210
624/624 [==============================] - 61s 98ms/step - loss:
```

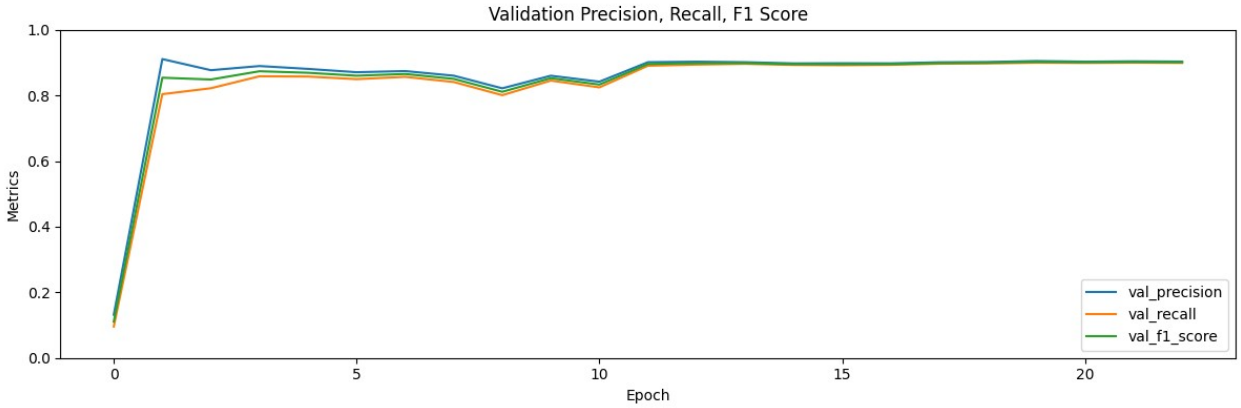
```
0.2080 - accuracy: 0.9854 - precision: 0.9875 - recall: 0.9835 -
f1_score: 0.9855 - val_loss: 0.8823 - val_accuracy: 0.8517 -
val_precision: 0.8603 - val_recall: 0.8455 - val_f1_score: 0.8528 -
lr: 1.0000e-04
Epoch 11/60
624/624 [==============================] - ETA: 0s - loss: 0.2397 -
accuracy: 0.9815 - precision: 0.9846 - recall: 0.9791 - f1_score:
0.9818
Epoch 11: val_accuracy did not improve from 0.87210

Epoch 11: ReduceLROnPlateau reducing learning rate to
1.9999999494757503e-05.
624/624 [==============================] - 66s 105ms/step - loss:
0.2397 - accuracy: 0.9815 - precision: 0.9846 - recall: 0.9791 -
f1_score: 0.9818 - val_loss: 0.9990 - val_accuracy: 0.8310 -
val_precision: 0.8421 - val_recall: 0.8247 - val_f1_score: 0.8333 -
lr: 1.0000e-04
Epoch 12/60
624/624 [==============================] - ETA: 0s - loss: 0.1360 -
accuracy: 0.9956 - precision: 0.9961 - recall: 0.9948 - f1_score:
0.9955
Epoch 12: val_accuracy improved from 0.87210 to 0.89443, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 64s 103ms/step - loss:
0.1360 - accuracy: 0.9956 - precision: 0.9961 - recall: 0.9948 -
f1_score: 0.9955 - val_loss: 0.6250 - val_accuracy: 0.8944 -
val_precision: 0.9015 - val_recall: 0.8906 - val_f1_score: 0.8960 -
lr: 2.0000e-05
Epoch 13/60
624/624 [==============================] - ETA: 0s - loss: 0.0781 -
accuracy: 0.9990 - precision: 0.9991 - recall: 0.9985 - f1_score:
0.9988
Epoch 13: val_accuracy improved from 0.89443 to 0.89724, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 63s 101ms/step - loss:
0.0781 - accuracy: 0.9990 - precision: 0.9991 - recall: 0.9985 -
f1_score: 0.9988 - val_loss: 0.6120 - val_accuracy: 0.8972 -
val_precision: 0.9031 - val_recall: 0.8941 - val_f1_score: 0.8986 -
lr: 2.0000e-05
Epoch 14/60
624/624 [==============================] - ETA: 0s - loss: 0.0587 -
accuracy: 0.9990 - precision: 0.9992 - recall: 0.9984 - f1_score:
0.9988
Epoch 14: val_accuracy improved from 0.89724 to 0.89854, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 61s 98ms/step - loss:
0.0587 - accuracy: 0.9990 - precision: 0.9992 - recall: 0.9984 -
f1_score: 0.9988 - val_loss: 0.6455 - val_accuracy: 0.8985 -
val_precision: 0.9015 - val_recall: 0.8964 - val_f1_score: 0.8990 -
```

```
lr: 2.0000e-05
Epoch 15/60
624/624 [==============================] - ETA: 0s - loss: 0.0527 -
accuracy: 0.9988 - precision: 0.9990 - recall: 0.9985 - f1_score:
0.9988
Epoch 15: val_accuracy did not improve from 0.89854
624/624 [==============================] - 62s 100ms/step - loss:
0.0527 - accuracy: 0.9988 - precision: 0.9990 - recall: 0.9985 -
f1_score: 0.9988 - val_loss: 0.6962 - val_accuracy: 0.8947 -
val_precision: 0.8978 - val_recall: 0.8930 - val_f1_score: 0.8954 -
lr: 2.0000e-05
Epoch 16/60
624/624 [==============================] - ETA: 0s - loss: 0.0533 -
accuracy: 0.9987 - precision: 0.9988 - recall: 0.9983 - f1_score:
0.9986
Epoch 16: val_accuracy did not improve from 0.89854
624/624 [==============================] - 64s 102ms/step - loss:
0.0533 - accuracy: 0.9987 - precision: 0.9988 - recall: 0.9983 -
f1_score: 0.9986 - val_loss: 0.6838 - val_accuracy: 0.8948 -
val_precision: 0.8983 - val_recall: 0.8923 - val_f1_score: 0.8953 -
lr: 2.0000e-05
Epoch 17/60
624/624 [==============================] - ETA: 0s - loss: 0.0428 -
accuracy: 0.9994 - precision: 0.9995 - recall: 0.9992 - f1_score:
0.9994
Epoch 17: val_accuracy did not improve from 0.89854

Epoch 17: ReduceLROnPlateau reducing learning rate to
3.999999898951501e-06.
624/624 [==============================] - 62s 100ms/step - loss:
0.0428 - accuracy: 0.9994 - precision: 0.9995 - recall: 0.9992 -
f1_score: 0.9994 - val_loss: 0.6887 - val_accuracy: 0.8945 -
val_precision: 0.8979 - val_recall: 0.8933 - val_f1_score: 0.8956 -
lr: 2.0000e-05
Epoch 18/60
624/624 [==============================] - ETA: 0s - loss: 0.0372 -
accuracy: 0.9997 - precision: 0.9997 - recall: 0.9996 - f1_score:
0.9997
Epoch 18: val_accuracy did not improve from 0.89854
624/624 [==============================] - 60s 97ms/step - loss:
0.0372 - accuracy: 0.9997 - precision: 0.9997 - recall: 0.9996 -
f1_score: 0.9997 - val_loss: 0.6674 - val_accuracy: 0.8983 -
val_precision: 0.9012 - val_recall: 0.8967 - val_f1_score: 0.8989 -
lr: 4.0000e-06
Epoch 19/60
624/624 [==============================] - ETA: 0s - loss: 0.0340 -
accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 - f1_score:
0.9998
Epoch 19: val_accuracy improved from 0.89854 to 0.89974, saving model
```

```
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 62s 99ms/step - loss:
0.0340 - accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 -
f1_score: 0.9998 - val_loss: 0.6616 - val_accuracy: 0.8997 -
val_precision: 0.9021 - val_recall: 0.8977 - val_f1_score: 0.8999 -
lr: 4.0000e-06
Epoch 20/60
624/624 [==============================] - ETA: 0s - loss: 0.0322 -
accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 - f1_score:
0.9998
Epoch 20: val_accuracy improved from 0.89974 to 0.90194, saving model
to models\modelo_T_sem_data_augmentation_adam.keras
624/624 [==============================] - 65s 103ms/step - loss:
0.0322 - accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 -
f1_score: 0.9998 - val_loss: 0.6464 - val_accuracy: 0.9019 -
val_precision: 0.9050 - val_recall: 0.8999 - val_f1_score: 0.9025 -
lr: 4.0000e-06
Epoch 21/60
624/624 [==============================] - ETA: 0s - loss: 0.0307 -
accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 - f1_score:
0.9998
Epoch 21: val_accuracy did not improve from 0.90194

Epoch 21: ReduceLROnPlateau reducing learning rate to
7.999999979801942e-07.
624/624 [==============================] - 63s 100ms/step - loss:
0.0307 - accuracy: 0.9998 - precision: 0.9999 - recall: 0.9997 -
f1_score: 0.9998 - val_loss: 0.6491 - val_accuracy: 0.9008 -
val_precision: 0.9031 - val_recall: 0.8992 - val_f1_score: 0.9012 -
lr: 4.0000e-06
Epoch 22/60
624/624 [==============================] - ETA: 0s - loss: 0.0295 -
accuracy: 0.9999 - precision: 1.0000 - recall: 0.9998 - f1_score:
0.9999
Epoch 22: val_accuracy did not improve from 0.90194
624/624 [==============================] - 61s 98ms/step - loss:
0.0295 - accuracy: 0.9999 - precision: 1.0000 - recall: 0.9998 -
f1_score: 0.9999 - val_loss: 0.6498 - val_accuracy: 0.9014 -
val_precision: 0.9041 - val_recall: 0.8999 - val_f1_score: 0.9020 -
lr: 8.0000e-07
Epoch 23/60
624/624 [==============================] - ETA: 0s - loss: 0.0294 -
accuracy: 0.9998 - precision: 0.9998 - recall: 0.9997 - f1_score:
0.9997
Epoch 23: val_accuracy did not improve from 0.90194
624/624 [==============================] - 62s 100ms/step - loss:
0.0294 - accuracy: 0.9998 - precision: 0.9998 - recall: 0.9997 -
f1_score: 0.9997 - val_loss: 0.6481 - val_accuracy: 0.9012 -
val_precision: 0.9033 - val_recall: 0.8993 - val_f1_score: 0.9013 -
```

```
lr: 8.0000e-07
157/157 [==============================] - 8s 52ms/step - loss: 0.6787
- accuracy: 0.8908 - precision: 0.8954 - recall: 0.8884 - f1_score:
0.8919
Test Loss: 0.6786661744117737
Test Accuracy: 0.8907999992370605
Test Precision: 0.8953840136528015
Test Recall: 0.8884000182151794
Test F1 Score: 0.8918782472610474

plt.figure(figsize=(12, 8))
plt.subplot(2, 1, 1)
plt.plot(history.history['accuracy'], label='train_accuracy')
plt.plot(history.history['val_accuracy'], label='val_accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.ylim([0, 1])
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(2, 1, 2)
plt.plot(history.history['val_precision'], label='val_precision')
plt.plot(history.history['val_recall'], label='val_recall')
plt.plot(history.history['val_f1_score'], label='val_f1_score')
plt.xlabel('Epoch')
plt.ylabel('Metrics')
plt.ylim([0, 1])
plt.legend(loc='lower right')
plt.title('Validation Precision, Recall, F1 Score')

plt.savefig(f'./plots/modelo_T_sem_data_augmentation_adam.png')
plt.tight_layout()
# plt.show()
```





Código para Extrair as Features

As features e as labels extraídos do modelo são concatenados e guardados em ficheiros NumPy.

```
# Function to extract features
import os
import numpy as np
from tensorflow.keras.models import Model
# Function to extract features
def extract_features_and_labels(generators, model):
    features = []
    labels = []
    total_samples = sum([gen.samples for gen in generators])
    batches_seen = 0

    for generator in generators:
        for inputs_batch, labels_batch in generator:
            features_batch = model.predict(inputs_batch)
            features.append(features_batch)
            labels.append(labels_batch)
            batches_seen += 1
            if batches_seen * generator.batch_size >= total_samples:
                break
```

```
    return np.concatenate(features), np.concatenate(labels)

# Extract features and labels
train_features, train_labels =
extract_features_and_labels(train_generators, feature_extractor_model)
validation_features, validation_labels =
extract_features_and_labels([validation_generator],
feature_extractor_model)
test_features, test_labels =
extract_features_and_labels([test_generator], feature_extractor_model)

# Ensure directories exist before saving
os.makedirs('features', exist_ok=True)
os.makedirs('labels', exist_ok=True)

# Save features and labels to files
np.save('features/modelo_T_sem_data_augmentation_train_features_adam.n
py', train_features)
np.save('labels/modelo_T_sem_data_augmentation_train_labels_adam.npy',
train_labels)
np.save('features/modelo_T_sem_data_augmentation_validation_features_a
dam.npy', validation_features)
np.save('labels/modelo_T_sem_data_augmentation_validation_labels_adam.
npy', validation_labels)
np.save('features/modelo_T_sem_data_augmentation_test_features_adam.np
y', test_features)
np.save('labels/modelo_T_sem_data_augmentation_test_labels_adam.npy',
test_labels)

print('Feature extraction completed.')
```

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