

IF702 - REDES NEURAIS

Grupo:

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Reconhecimento de Dígitos com CNN

Importação de datasets e tratamento dos dados

```
In [ ]:
!pip install keras-tuner --quiet
!pip install optuna --quiet
!pip install ipython-autotime --quiet
from keras_tuner import RandomSearch
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
import keras
import optuna

#Loading Data
(train_images,train_labels),(test_images,test_labels)=tf.keras.datasets.mnist.load_data()

#Reshape data
train_images=train_images.reshape((60000,28,28,1))
test_images=test_images.reshape((10000,28,28,1))

#Normalize
train_images=train_images/255.0 ,test_images/test_images/255.0
```

Construindo a CNN

```
In [ ]:
#Building a CNN Model
model=tf.keras.models.Sequential()
model.add(tf.keras.layers.Conv2D(32, (3,3),activation='relu',input_shape=(28,28,1)))
model.add(tf.keras.layers.MaxPooling2D((2,2)))
model.add(tf.keras.layers.Conv2D(64, (3,3),activation='relu'))
model.add(tf.keras.layers.MaxPooling2D((2,2)))
model.add(tf.keras.layers.Conv2D(64,(3,3),activation='relu'))
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(64, activation='relu'))
model.add(tf.keras.layers.Dense(10, activation='softmax'))

model.summary()
model.compile(optimizer='adam',loss='sparse_categorical_crossentropy',metrics='accuracy')
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 26, 26, 32)	320
max_pooling2d (MaxPooling2D)	(None, 13, 13, 32)	0
conv2d_1 (Conv2D)	(None, 11, 11, 64)	18496
max_pooling2d_1 (MaxPooling2D)	(None, 5, 5, 64)	0
conv2d_2 (Conv2D)	(None, 3, 3, 64)	36928
flatten (Flatten)	(None, 576)	0
dense (Dense)	(None, 64)	36928
dense_1 (Dense)	(None, 10)	650
Total params: 93,322		
Trainable params: 93,322		
Non-trainable params: 0		

```
In [ ]:
model.fit(train_images,train_labels,epochs=1,batch_size=10)
scores = model.evaluate(test_images,test_labels, verbose=0)

6000/6000 [=====] - 16s 2ms/step - loss: 0.1172 - accuracy: 0.9637
```

```
In [ ]:
def build_model(hp):
    # create model object
    model=tf.keras.models.Sequential()
    model.add(tf.keras.layers.Conv2D(32, (3,3),activation='relu',input_shape=(28,28,1)))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(64, (3,3),activation='relu'))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(64,(3,3),activation='relu'))
    model.add(tf.keras.layers.Flatten())
    model.add(tf.keras.layers.Dense(64, activation='relu'))
    model.add(tf.keras.layers.Dense(10, activation='softmax'))

    model.summary()
    model.compile(optimizer='adam',loss='sparse_categorical_crossentropy',metrics='accuracy')
    return model
```

```
In [ ]:
#creating randomsearch object
tuner = RandomSearch(build_model,
                     objective='val_accuracy',
                     max_trials = 5, directory='./untitled_project/trial/')
# search best parameter
tuner.search(train_images,train_labels,epochs=3,validation_data=(train_images,train_labels))
```

INFO:tensorflow:Reloading Oracle from existing project ./untitled_project/trial/untitled_project/oracle.json

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 26, 26, 32)	320
max_pooling2d (MaxPooling2D)	(None, 13, 13, 32)	0
conv2d_1 (Conv2D)	(None, 11, 11, 64)	18496
max_pooling2d_1 (MaxPooling2D)	(None, 5, 5, 64)	0

conv2d_2 (Conv2D)	(None, 3, 3, 64)	36928
flatten (Flatten)	(None, 576)	0
dense (Dense)	(None, 64)	36928
dense_1 (Dense)	(None, 10)	650

=====
Total params: 93,322
Trainable params: 93,322
Non-trainable params: 0

INFO:tensorflow:Reloading Tuner from ./untitled_project/trial/untitled_project/tuner0.json
INFO:tensorflow:Oracle triggered exit

```
In [ ]: best_hps=tuner.get_best_hyperparameters(num_trials=1)[0]
best_hps.values
```

```
In [ ]: # Sugestão de Adriano (128 layers na 3a CNN)
def build_model2(hp):
    # create model object
    model=tf.keras.models.Sequential()
    model.add(tf.keras.layers.Conv2D(32, (3,3),activation='relu',input_shape=(28,28,1)))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(64, (3,3),activation='relu'))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(128,(3,3),activation='relu'))
    model.add(tf.keras.layers.Flatten())
    model.add(tf.keras.layers.Dense(128, activation='relu'))
    model.add(tf.keras.layers.Dense(10, activation='softmax'))

    model.summary()
    model.compile(optimizer='adam', loss='sparse_categorical_crossentropy', metrics='accuracy')
    return model

tuner2 = RandomSearch(build_model2,
                      objective='val_accuracy',
                      max_trials = 5,directory='./untitled_project/trial2/')

tuner2.search(train_images,train_labels,epochs=3,validation_data=(train_images,train_labels))
```

INFO:tensorflow:Reloading Oracle from existing project ./untitled_project/trial2/untitled_project/oracle.json
Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 26, 26, 32)	320
max_pooling2d (MaxPooling2D)	(None, 13, 13, 32)	0
conv2d_1 (Conv2D)	(None, 11, 11, 64)	18496
max_pooling2d_1 (MaxPooling2D)	(None, 5, 5, 64)	0
conv2d_2 (Conv2D)	(None, 3, 3, 128)	73856
flatten (Flatten)	(None, 1152)	0
dense (Dense)	(None, 128)	147584
dense_1 (Dense)	(None, 10)	1290

=====
Total params: 241,546
Trainable params: 241,546
Non-trainable params: 0

INFO:tensorflow:Reloading Tuner from ./untitled_project/trial2/untitled_project/tuner0.json
INFO:tensorflow:Oracle triggered exit

```
In [ ]: # Sugestão de Adriano (128 layers na 3a CNN com dilation_rate menor=2)
def build_model3(hp):
    # create model object
    model=tf.keras.models.Sequential()
    model.add(tf.keras.layers.Conv2D(32, (2,2),activation='relu',input_shape=(28,28,1)))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(64, (2,2),activation='relu'))
    model.add(tf.keras.layers.MaxPooling2D((2,2)))
    model.add(tf.keras.layers.Conv2D(128,(2,2),activation='relu'))
    model.add(tf.keras.layers.Flatten())
    model.add(tf.keras.layers.Dense(128, activation='relu'))
    model.add(tf.keras.layers.Dense(10, activation='softmax'))

    model.summary()
    model.compile(optimizer='adam', loss='sparse_categorical_crossentropy', metrics='accuracy')
    return model

tuner3 = RandomSearch(build_model3,
                      objective='val_accuracy',
                      max_trials = 5, directory='./untitled_project/trial3/')

tuner3.search(train_images,train_labels,epochs=3,validation_data=(train_images,train_labels))
```

INFO:tensorflow:Reloading Oracle from existing project ./untitled_project/trial3/untitled_project/oracle.json
Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 27, 27, 32)	160
max_pooling2d (MaxPooling2D)	(None, 13, 13, 32)	0
conv2d_1 (Conv2D)	(None, 12, 12, 64)	8256
max_pooling2d_1 (MaxPooling2D)	(None, 6, 6, 64)	0
conv2d_2 (Conv2D)	(None, 5, 5, 128)	32896
flatten (Flatten)	(None, 3200)	0
dense (Dense)	(None, 128)	409728
dense_1 (Dense)	(None, 10)	1290

=====
Total params: 452,330
Trainable params: 452,330
Non-trainable params: 0

INFO:tensorflow:Reloading Tuner from ./untitled_project/trial3/untitled_project/tuner0.json
INFO:tensorflow:Oracle triggered exit

```
In [ ]: from keras.layers import LSTM
from sklearn.metrics import accuracy_score, plot_confusion_matrix, confusion_matrix, classification_report

(train_images,train_labels),(test_images,test_labels)=tf.keras.datasets.mnist.load_data()
```

```
#Reshape data
train_images=train_images.reshape((60000,28,28,1))
test_images=test_images.reshape((10000,28,28,1))

#Normalize
train_images,test_images=train_images/255.0 ,test_images/255.0
```

Redes utilizadas

- Camadas finais de adensamento com função de ativação 'relu' e de categorização com função de ativação 'softmax'.

CNN1:

- Neurônios: 32 à 128
- Dilatação: 1 ou 2
- Camadas CNN: 2

CNN2:

- Neurônios: 32 à 128
- Dilatação: 1 ou 2
- Camadas CNN: 3

CNN3:

- Neurônios: 32 à 128
- Dilatação: 1
- Camadas CNN: 5

```
In [ ]: def cnn(trial):
        (x_train, y_train), (x_test, y_test) = (train_images,train_labels),(test_images,test_labels)

        activation = trial.suggest_categorical('activation', ['sigmoid', 'softmax', 'tanh', 'relu','softplus','softsign','selu','elu','exponential'])

        n_neurons = trial.suggest_int('n_neurons', 16, 64)
        dilation = trial.suggest_int('dilation', 1, 2)
        loss = trial.suggest_categorical('loss', ['sparse_categorical_crossentropy'])
        optimizer = trial.suggest_categorical('optimizer', ['sgd', 'adam','rmsprop','adamax'])

        print("Função de ativação: {} \nNúmero de neurônios: {} \nOtimizador: {}".format(activation,n_neurons,optimizer))
        model = keras.models.Sequential()

        model.add(tf.keras.layers.Conv2D(n_neurons, (dilation,dilation),activation=activation,input_shape=(28,28,1)))
        model.add(tf.keras.layers.MaxPooling2D((dilation,dilation)))
        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation,dilation),activation=activation))
        model.add(tf.keras.layers.Flatten())
        model.add(tf.keras.layers.Dense(n_neurons*2, activation='relu'))
        model.add(tf.keras.layers.Dense(10, activation='softmax'))
        model.compile(loss=loss,optimizer=optimizer,metrics=["accuracy"])

        history = model.fit(x_train, y_train, epochs=8, verbose=1)
        y_pred = np.argmax(model.predict(x_test), axis=-1)
        y_true = y_test
        return accuracy_score(y_true, y_pred)
```

```
In [ ]: study_1 = optuna.create_study(direction='maximize')
        study_1.optimize(cnn, n_trials=16)
```

```
[I 2021-11-05 13:13:11,446] A new study created in memory with name: no-name-0212a617-dc7d-4797-b20d-8c84dd82265d
Função de ativação: selu
Número de neurônios: 32
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.3251 - accuracy: 0.9087
Epoch 2/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1599 - accuracy: 0.9535
Epoch 3/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1184 - accuracy: 0.9643
Epoch 4/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0939 - accuracy: 0.9720
Epoch 5/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0782 - accuracy: 0.9766
Epoch 6/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0670 - accuracy: 0.9797
Epoch 7/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0577 - accuracy: 0.9825
Epoch 8/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0505 - accuracy: 0.9842
[I 2021-11-05 13:13:49,505] Trial 0 finished with value: 0.9729 and parameters: {'activation': 'selu', 'n_neurons': 32, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 0 with value: 0.9729.
Função de ativação: softplus
Número de neurônios: 24
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 6s 3ms/step - loss: 2.4701 - accuracy: 0.1115
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
[I 2021-11-05 13:14:32,475] Trial 1 finished with value: 0.1135 and parameters: {'activation': 'softplus', 'n_neurons': 24, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 0 with value: 0.9729.
Função de ativação: selu
Número de neurônios: 20
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.2900 - accuracy: 0.9158
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1507 - accuracy: 0.9556
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1080 - accuracy: 0.9675
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0821 - accuracy: 0.9762
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0661 - accuracy: 0.9802
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0534 - accuracy: 0.9839
```

```
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0443 - accuracy: 0.9865
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0360 - accuracy: 0.9891
[I 2021-11-05 13:15:04,483] Trial 2 finished with value: 0.9794 and parameters: {'activation': 'selu', 'n_neurons': 20, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 2 with value: 0.9794.
Função de ativação: softplus
Número de neurônios: 61
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.6075 - accuracy: 0.1106
Epoch 2/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 9s 5ms/step - loss: 2.3012 - accuracy: 0.1124
[I 2021-11-05 13:16:19,574] Trial 3 finished with value: 0.1135 and parameters: {'activation': 'softplus', 'n_neurons': 61, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 2 with value: 0.9794.
Função de ativação: softsign
Número de neurônios: 39
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.5266 - accuracy: 0.8632
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.2326 - accuracy: 0.9309
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1798 - accuracy: 0.9467
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1489 - accuracy: 0.9560
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1286 - accuracy: 0.9615
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1136 - accuracy: 0.9665
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1025 - accuracy: 0.9700
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0937 - accuracy: 0.9723
[I 2021-11-05 13:16:51,268] Trial 4 finished with value: 0.9689 and parameters: {'activation': 'softsign', 'n_neurons': 39, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 2 with value: 0.9794.
Função de ativação: softsign
Número de neurônios: 39
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1654 - accuracy: 0.9506
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0634 - accuracy: 0.9801
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0464 - accuracy: 0.9858
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0346 - accuracy: 0.9889
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0272 - accuracy: 0.9908
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0220 - accuracy: 0.9931
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0193 - accuracy: 0.9935
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0175 - accuracy: 0.9942
[I 2021-11-05 13:17:24,593] Trial 5 finished with value: 0.9823 and parameters: {'activation': 'softsign', 'n_neurons': 39, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 5 with value: 0.9823.
Função de ativação: relu
Número de neurônios: 21
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1621 - accuracy: 0.9503
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0589 - accuracy: 0.9821
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0427 - accuracy: 0.9874
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0349 - accuracy: 0.9892
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0289 - accuracy: 0.9915
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0258 - accuracy: 0.9925
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0224 - accuracy: 0.9938
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0197 - accuracy: 0.9940
[I 2021-11-05 13:18:00,618] Trial 6 finished with value: 0.987 and parameters: {'activation': 'relu', 'n_neurons': 21, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 6 with value: 0.987.
Função de ativação: softsign
Número de neurônios: 42
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.2303 - accuracy: 0.9307
Epoch 2/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.1269 - accuracy: 0.9637
Epoch 3/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.1018 - accuracy: 0.9710
Epoch 4/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0848 - accuracy: 0.9756
Epoch 5/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0757 - accuracy: 0.9779
Epoch 6/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0679 - accuracy: 0.9804
Epoch 7/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0633 - accuracy: 0.9819
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0595 - accuracy: 0.9838
[I 2021-11-05 13:19:04,305] Trial 7 finished with value: 0.9704 and parameters: {'activation': 'softsign', 'n_neurons': 42, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 6 with value: 0.987.
Função de ativação: selu
Número de neurônios: 17
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.2846 - accuracy: 0.9161
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1798 - accuracy: 0.9464
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1489 - accuracy: 0.9559
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1279 - accuracy: 0.9622
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1163 - accuracy: 0.9648
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1066 - accuracy: 0.9677
```

```
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0976 - accuracy: 0.9704
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0898 - accuracy: 0.9722
[I 2021-11-05 13:19:39,487] Trial 8 finished with value: 0.9591 and parameters: {'activation': 'selu', 'n_neurons': 17, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 6 with value: 0.987.
Função de ativação: exponential
Número de neurônios: 34
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.5519 - accuracy: 0.8497
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1497 - accuracy: 0.9552
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1068 - accuracy: 0.9675
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0886 - accuracy: 0.9735
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0768 - accuracy: 0.9769
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0700 - accuracy: 0.9790
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0641 - accuracy: 0.9809
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0601 - accuracy: 0.9825
[I 2021-11-05 13:20:15,531] Trial 9 finished with value: 0.9809 and parameters: {'activation': 'exponential', 'n_neurons': 34, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 6 with value: 0.987.
Função de ativação: relu
Número de neurônios: 51
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1215 - accuracy: 0.9631
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0409 - accuracy: 0.9875
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0242 - accuracy: 0.9921
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0168 - accuracy: 0.9944
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0120 - accuracy: 0.9962
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0095 - accuracy: 0.9968
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0070 - accuracy: 0.9976
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0060 - accuracy: 0.9979
[I 2021-11-05 13:20:51,066] Trial 10 finished with value: 0.9882 and parameters: {'activation': 'relu', 'n_neurons': 51, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 10 with value: 0.9882.
Função de ativação: relu
Número de neurônios: 53
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1203 - accuracy: 0.9638
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0412 - accuracy: 0.9872
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0228 - accuracy: 0.9926
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0158 - accuracy: 0.9948
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0116 - accuracy: 0.9962
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0092 - accuracy: 0.9970
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0066 - accuracy: 0.9980
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0054 - accuracy: 0.9981
[I 2021-11-05 13:21:26,741] Trial 11 finished with value: 0.9886 and parameters: {'activation': 'relu', 'n_neurons': 53, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 11 with value: 0.9886.
Função de ativação: relu
Número de neurônios: 56
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1241 - accuracy: 0.9613
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0410 - accuracy: 0.9875
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0250 - accuracy: 0.9919
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0175 - accuracy: 0.9944
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0123 - accuracy: 0.9961
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0088 - accuracy: 0.9972
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0081 - accuracy: 0.9972
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0061 - accuracy: 0.9981
[I 2021-11-05 13:22:03,102] Trial 12 finished with value: 0.9893 and parameters: {'activation': 'relu', 'n_neurons': 56, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 12 with value: 0.9893.
Função de ativação: relu
Número de neurônios: 62
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1140 - accuracy: 0.9655
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0387 - accuracy: 0.9877
Epoch 3/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0228 - accuracy: 0.9927
Epoch 4/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0157 - accuracy: 0.9946
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0112 - accuracy: 0.9962
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0095 - accuracy: 0.9969
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0074 - accuracy: 0.9972
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0057 - accuracy: 0.9983
[I 2021-11-05 13:22:39,955] Trial 13 finished with value: 0.9862 and parameters: {'activation': 'relu', 'n_neurons': 62, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 12 with value: 0.9893.
Função de ativação: elu
Número de neurônios: 52
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1505 - accuracy: 0.9547
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0621 - accuracy: 0.9810
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0421 - accuracy: 0.9866
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0361 - accuracy: 0.9883
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0280 - accuracy: 0.9911
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0227 - accuracy: 0.9926
```

```
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0220 - accuracy: 0.9928
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0185 - accuracy: 0.9941
[I 2021-11-05 13:23:14,891] Trial 14 finished with value: 0.9822 and parameters: {'activation': 'elu', 'n_neurons': 52, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 12 with value: 0.9893.
Função de ativação: tanh
Número de neurônios: 53
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1474 - accuracy: 0.9549
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0628 - accuracy: 0.9804
Epoch 3/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0419 - accuracy: 0.9865
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0340 - accuracy: 0.9890
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0287 - accuracy: 0.9908
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0219 - accuracy: 0.9927
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0205 - accuracy: 0.9934
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0166 - accuracy: 0.9949
[I 2021-11-05 13:23:50,908] Trial 15 finished with value: 0.9828 and parameters: {'activation': 'tanh', 'n_neurons': 53, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 12 with value: 0.9893.
```

```
In [ ]: def cnn2(trial):
        (x_train, y_train), (x_test, y_test) = (train_images, train_labels), (test_images, test_labels)

        activation = trial.suggest_categorical('activation', ['sigmoid', 'softmax', 'tanh', 'relu', 'softplus', 'softsign', 'selu', 'elu', 'exponential'])

        n_neurons = trial.suggest_int('n_neurons', 16, 64)
        dilation = trial.suggest_int('dilation', 1, 2)
        loss = trial.suggest_categorical('loss', ['sparse_categorical_crossentropy'])
        optimizer = trial.suggest_categorical('optimizer', ['sgd', 'adam', 'rmsprop', 'adamax'])

        print("Função de ativação: {} \n Número de neurônios: {} \n Otimizador: {}".format(activation, n_neurons, optimizer))
        model = keras.models.Sequential()

        model.add(tf.keras.layers.Conv2D(n_neurons, (dilation, dilation), activation=activation, input_shape=(28, 28, 1)))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))

        # ----- ADICIONAMOS MAIS UMA CAMADA CNN ----- #
        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))
        # ----- ADICIONAMOS MAIS UMA CAMADA CNN ----- #

        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.Flatten())
        model.add(tf.keras.layers.Dense(n_neurons*2, activation='relu'))
        model.add(tf.keras.layers.Dense(10, activation='softmax'))
        model.compile(loss=loss, optimizer=optimizer, metrics=["accuracy"])

        history = model.fit(x_train, y_train, epochs=8, verbose=1)
        y_pred = np.argmax(model.predict(x_test), axis=-1)
        y_true = y_test
        return accuracy_score(y_true, y_pred)
```

```
In [ ]: study_2 = optuna.create_study(direction='maximize')
study_2.optimize(cnn2, n_trials=16)
```

```
[I 2021-11-05 13:23:50,941] A new study created in memory with name: no-name-fd4b0ef8-84d3-496c-9361-d91ac0a9eb1f
Função de ativação: softmax
Número de neurônios: 20
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3023 - accuracy: 0.1119
Epoch 2/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 7s 4ms/step - loss: 2.3014 - accuracy: 0.1124
[I 2021-11-05 13:24:45,081] Trial 0 finished with value: 0.1135 and parameters: {'activation': 'softmax', 'n_neurons': 20, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 0 with value: 0.1135.
Função de ativação: selu
Número de neurônios: 36
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.2375 - accuracy: 0.9299
Epoch 2/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.1321 - accuracy: 0.9595
Epoch 3/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0994 - accuracy: 0.9701
Epoch 4/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0822 - accuracy: 0.9750
Epoch 5/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0676 - accuracy: 0.9788
Epoch 6/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0559 - accuracy: 0.9821
Epoch 7/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0483 - accuracy: 0.9845
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0416 - accuracy: 0.9865
[I 2021-11-05 13:25:46,116] Trial 1 finished with value: 0.9689 and parameters: {'activation': 'selu', 'n_neurons': 36, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 1 with value: 0.9689.
Função de ativação: softplus
Número de neurônios: 45
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 11s 6ms/step - loss: 1.4710 - accuracy: 0.6766
Epoch 2/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.3919 - accuracy: 0.8848
Epoch 3/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.3430 - accuracy: 0.8993
Epoch 4/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.3180 - accuracy: 0.9072
Epoch 5/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.3034 - accuracy: 0.9124
Epoch 6/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.2923 - accuracy: 0.9146
Epoch 7/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.2843 - accuracy: 0.9153
```

Epoch 8/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.2780 - accuracy: 0.9183
[I 2021-11-05 13:27:13,336] Trial 2 finished with value: 0.9213 and parameters: {'activation': 'softplus', 'n_neurons': 45, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 1 with value: 0.9689.
Função de ativação: exponential
Número de neurônios: 16
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 1.0665 - accuracy: 0.6704
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.3611 - accuracy: 0.8900
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.2351 - accuracy: 0.9291
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1743 - accuracy: 0.9471
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1379 - accuracy: 0.9580
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1161 - accuracy: 0.9638
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1019 - accuracy: 0.9689
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0904 - accuracy: 0.9724
[I 2021-11-05 13:27:49,889] Trial 3 finished with value: 0.9751 and parameters: {'activation': 'exponential', 'n_neurons': 16, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 3 with value: 0.9751.
Função de ativação: selu
Número de neurônios: 41
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.1678 - accuracy: 0.9504
Epoch 2/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0572 - accuracy: 0.9830
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0401 - accuracy: 0.9877
Epoch 4/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0299 - accuracy: 0.9911
Epoch 5/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0234 - accuracy: 0.9927
Epoch 6/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0183 - accuracy: 0.9945
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0142 - accuracy: 0.9958
Epoch 8/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0111 - accuracy: 0.9966
[I 2021-11-05 13:28:28,012] Trial 4 finished with value: 0.9893 and parameters: {'activation': 'selu', 'n_neurons': 41, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 4 with value: 0.9893.
Função de ativação: tanh
Número de neurônios: 20
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 7s 3ms/step - loss: 0.2742 - accuracy: 0.9190
Epoch 2/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1547 - accuracy: 0.9554
Epoch 3/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1275 - accuracy: 0.9624
Epoch 4/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1114 - accuracy: 0.9679
Epoch 5/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0990 - accuracy: 0.9707
Epoch 6/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0908 - accuracy: 0.9742
Epoch 7/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0836 - accuracy: 0.9758
Epoch 8/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0775 - accuracy: 0.9780
[I 2021-11-05 13:29:16,820] Trial 5 finished with value: 0.9695 and parameters: {'activation': 'tanh', 'n_neurons': 20, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 4 with value: 0.9893.
Função de ativação: softplus
Número de neurônios: 53
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 1.2615 - accuracy: 0.5430
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.1927 - accuracy: 0.9420
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.1027 - accuracy: 0.9682
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0716 - accuracy: 0.9783
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0562 - accuracy: 0.9833
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0443 - accuracy: 0.9857
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0356 - accuracy: 0.9888
Epoch 8/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0302 - accuracy: 0.9899
[I 2021-11-05 13:29:58,533] Trial 6 finished with value: 0.9879 and parameters: {'activation': 'softplus', 'n_neurons': 53, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 4 with value: 0.9893.
Função de ativação: sigmoid
Número de neurônios: 63
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3220 - accuracy: 0.1121
Epoch 2/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 10s 5ms/step - loss: 2.3013 - accuracy: 0.1124
[I 2021-11-05 13:31:18,595] Trial 7 finished with value: 0.1135 and parameters: {'activation': 'sigmoid', 'n_neurons': 63, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 4 with value: 0.9893.
Função de ativação: exponential
Número de neurônios: 63
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 12s 6ms/step - loss: 2.2449 - accuracy: 0.8125
Epoch 2/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.2702 - accuracy: 0.9238
Epoch 3/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.2185 - accuracy: 0.9388
Epoch 4/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.1784 - accuracy: 0.9499
Epoch 5/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.1528 - accuracy: 0.9570
Epoch 6/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.1329 - accuracy: 0.9614
Epoch 7/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.1188 - accuracy: 0.9653

Epoch 8/8
1875/1875 [=====] - 11s 6ms/step - loss: 0.1057 - accuracy: 0.9687
[I 2021-11-05 13:32:47,390] Trial 8 finished with value: 0.961 and parameters: {'activation': 'exponential', 'n_neurons': 63, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 4 with value: 0.9893.
Função de ativação: elu
Número de neurônios: 19
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.3001 - accuracy: 0.9099
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1013 - accuracy: 0.9699
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0705 - accuracy: 0.9783
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0550 - accuracy: 0.9830
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0465 - accuracy: 0.9859
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0403 - accuracy: 0.9878
Epoch 7/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0354 - accuracy: 0.9892
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0307 - accuracy: 0.9906
[I 2021-11-05 13:33:23,811] Trial 9 finished with value: 0.9878 and parameters: {'activation': 'elu', 'n_neurons': 19, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 4 with value: 0.9893.
Função de ativação: selu
Número de neurônios: 35
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.4111 - accuracy: 0.8804
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.1319 - accuracy: 0.9608
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0902 - accuracy: 0.9733
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0707 - accuracy: 0.9790
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0587 - accuracy: 0.9826
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0508 - accuracy: 0.9844
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0448 - accuracy: 0.9863
Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0397 - accuracy: 0.9879
[I 2021-11-05 13:33:57,578] Trial 10 finished with value: 0.9843 and parameters: {'activation': 'selu', 'n_neurons': 35, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 4 with value: 0.9893.
Função de ativação: softplus
Número de neurônios: 49
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3054 - accuracy: 0.1103
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 5s 3ms/step - loss: 2.3012 - accuracy: 0.1124
[I 2021-11-05 13:34:38,332] Trial 11 finished with value: 0.1135 and parameters: {'activation': 'softplus', 'n_neurons': 49, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 4 with value: 0.9893.
Função de ativação: softsign
Número de neurônios: 53
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.2033 - accuracy: 0.9384
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0616 - accuracy: 0.9813
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0401 - accuracy: 0.9879
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0304 - accuracy: 0.9908
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0242 - accuracy: 0.9927
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0190 - accuracy: 0.9942
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0154 - accuracy: 0.9952
Epoch 8/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0127 - accuracy: 0.9961
[I 2021-11-05 13:35:20,639] Trial 12 finished with value: 0.9917 and parameters: {'activation': 'softsign', 'n_neurons': 53, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 12 with value: 0.9917.
Função de ativação: softsign
Número de neurônios: 55
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.1319 - accuracy: 0.9592
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0500 - accuracy: 0.9847
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0400 - accuracy: 0.9873
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0314 - accuracy: 0.9898
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0273 - accuracy: 0.9915
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0243 - accuracy: 0.9925
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0224 - accuracy: 0.9933
Epoch 8/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0198 - accuracy: 0.9937
[I 2021-11-05 13:36:01,848] Trial 13 finished with value: 0.9813 and parameters: {'activation': 'softsign', 'n_neurons': 55, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 12 with value: 0.9917.
Função de ativação: softsign
Número de neurônios: 31
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.2554 - accuracy: 0.9264
Epoch 2/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0827 - accuracy: 0.9759
Epoch 3/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0575 - accuracy: 0.9829
Epoch 4/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0450 - accuracy: 0.9864
Epoch 5/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0370 - accuracy: 0.9889
Epoch 6/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0315 - accuracy: 0.9906
Epoch 7/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0274 - accuracy: 0.9917


```

Epoch 8/8
1875/1875 [=====] - 4s 2ms/step - loss: 0.0238 - accuracy: 0.9930
[I 2021-11-05 13:36:43,751] Trial 14 finished with value: 0.99 and parameters: {'activation': 'softsign', 'n_neurons': 31, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 12 with value: 0.9917.
Função de ativação: softsign
Número de neurônios: 29
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.2614 - accuracy: 0.9236
Epoch 2/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0841 - accuracy: 0.9745
Epoch 3/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0599 - accuracy: 0.9824
Epoch 4/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0471 - accuracy: 0.9858
Epoch 5/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0388 - accuracy: 0.9882
Epoch 6/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0328 - accuracy: 0.9902
Epoch 7/8
1875/1875 [=====] - 5s 3ms/step - loss: 0.0283 - accuracy: 0.9914
Epoch 8/8
1875/1875 [=====] - 5s 2ms/step - loss: 0.0246 - accuracy: 0.9924
[I 2021-11-05 13:37:22,545] Trial 15 finished with value: 0.9886 and parameters: {'activation': 'softsign', 'n_neurons': 29, 'dilation': 2, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 12 with value: 0.9917.

```

```

In [ ]: def cnn3(trial):
        (x_train, y_train), (x_test, y_test) = (train_images, train_labels), (test_images, test_labels)

        activation = trial.suggest_categorical('activation', ['sigmoid', 'softmax', 'tanh', 'relu', 'softplus', 'softsign', 'selu', 'elu', 'exponential'])

        n_neurons = trial.suggest_int('n_neurons', 16, 64)
        # Redução de dilatação
        dilation = trial.suggest_int('dilation', 1, 1)
        loss = trial.suggest_categorical('loss', ['sparse_categorical_crossentropy'])
        optimizer = trial.suggest_categorical('optimizer', ['sgd', 'adam', 'rmsprop', 'adamax'])

        print("Função de ativação: {} \n Número de neurônios: {} \n Otimizador: {}".format(activation, n_neurons, optimizer))
        model = keras.models.Sequential()

        model.add(tf.keras.layers.Conv2D(n_neurons, (dilation, dilation), activation=activation, input_shape=(28, 28, 1)))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))

        # ----- ADICIONAMOS MAIS TRÊS CAMADAS CNN ----- #
        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))
        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))
        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.MaxPooling2D((dilation, dilation)))
        # ----- ADICIONAMOS MAIS TRÊS CAMADAS CNN ----- #

        model.add(tf.keras.layers.Conv2D(n_neurons*2, (dilation, dilation), activation=activation))
        model.add(tf.keras.layers.Flatten())
        model.add(tf.keras.layers.Dense(n_neurons*2, activation='relu'))
        model.add(tf.keras.layers.Dense(10, activation='softmax'))
        model.compile(loss=loss, optimizer=optimizer, metrics=['accuracy'])

        history = model.fit(x_train, y_train, epochs=8, verbose=1)
        y_pred = np.argmax(model.predict(x_test), axis=-1)
        y_true = y_test
        return accuracy_score(y_true, y_pred)

```

```

In [ ]: study_3 = optuna.create_study(direction='maximize')
        study_3.optimize(cnn3, n_trials=16)

```

```

[I 2021-11-05 13:37:22,583] A new study created in memory with name: no-name-bb39e995-7f55-4052-b3f5-188b7096ee06
Função de ativação: sigmoid
Número de neurônios: 43
Otimizador: adamax
Epoch 1/8
1875/1875 [=====] - 14s 7ms/step - loss: 2.3924 - accuracy: 0.1113
Epoch 2/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 13s 7ms/step - loss: 2.3012 - accuracy: 0.1124
[I 2021-11-05 13:39:08,714] Trial 0 finished with value: 0.1135 and parameters: {'activation': 'sigmoid', 'n_neurons': 43, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adamax'}. Best is trial 0 with value: 0.1135.
Função de ativação: softsign
Número de neurônios: 32
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 11s 5ms/step - loss: 0.2440 - accuracy: 0.9276
Epoch 2/8
1875/1875 [=====] - 10s 6ms/step - loss: 0.1273 - accuracy: 0.9620
Epoch 3/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.1019 - accuracy: 0.9704
Epoch 4/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0877 - accuracy: 0.9744
Epoch 5/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0781 - accuracy: 0.9776
Epoch 6/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0697 - accuracy: 0.9795
Epoch 7/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0646 - accuracy: 0.9809
Epoch 8/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0596 - accuracy: 0.9834
[I 2021-11-05 13:40:32,414] Trial 1 finished with value: 0.9725 and parameters: {'activation': 'softsign', 'n_neurons': 32, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 1 with value: 0.9725.
Função de ativação: tanh
Número de neurônios: 37
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 13s 6ms/step - loss: 0.2619 - accuracy: 0.9236
Epoch 2/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.1307 - accuracy: 0.9622
Epoch 3/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.1046 - accuracy: 0.9690
Epoch 4/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0871 - accuracy: 0.9748
Epoch 5/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0779 - accuracy: 0.9776
Epoch 6/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0694 - accuracy: 0.9804

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Epoch 7/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0642 - accuracy: 0.9819
Epoch 8/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0610 - accuracy: 0.9833
[I 2021-11-05 13:42:10,612] Trial 2 finished with value: 0.9713 and parameters: {'activation': 'tanh', 'n_neurons': 37, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 1 with value: 0.9725.
Função de ativação: softmax
Número de neurônios: 42
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 18s 9ms/step - loss: 2.3041 - accuracy: 0.1110
Epoch 2/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 17s 9ms/step - loss: 2.3014 - accuracy: 0.1124
[I 2021-11-05 13:44:34,662] Trial 3 finished with value: 0.1135 and parameters: {'activation': 'softmax', 'n_neurons': 42, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 1 with value: 0.9725.
Função de ativação: elu
Número de neurônios: 41
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.2901 - accuracy: 0.9162
Epoch 2/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.1269 - accuracy: 0.9626
Epoch 3/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0892 - accuracy: 0.9730
Epoch 4/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0702 - accuracy: 0.9783
Epoch 5/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0539 - accuracy: 0.9832
Epoch 6/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0453 - accuracy: 0.9853
Epoch 7/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0375 - accuracy: 0.9878
Epoch 8/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0297 - accuracy: 0.9903
[I 2021-11-05 13:46:57,749] Trial 4 finished with value: 0.9704 and parameters: {'activation': 'elu', 'n_neurons': 41, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 1 with value: 0.9725.
Função de ativação: elu
Número de neurônios: 60
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 18s 9ms/step - loss: 0.2762 - accuracy: 0.9220
Epoch 2/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.1356 - accuracy: 0.9622
Epoch 3/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.1099 - accuracy: 0.9700
Epoch 4/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.0954 - accuracy: 0.9747
Epoch 5/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.0876 - accuracy: 0.9774
Epoch 6/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.0799 - accuracy: 0.9791
Epoch 7/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.0765 - accuracy: 0.9816
Epoch 8/8
1875/1875 [=====] - 17s 9ms/step - loss: 0.0732 - accuracy: 0.9816
[I 2021-11-05 13:49:17,789] Trial 5 finished with value: 0.9647 and parameters: {'activation': 'elu', 'n_neurons': 60, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 1 with value: 0.9725.
Função de ativação: relu
Número de neurônios: 38
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 11s 5ms/step - loss: 0.4595 - accuracy: 0.8709
Epoch 2/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.1462 - accuracy: 0.9557
Epoch 3/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.1027 - accuracy: 0.9687
Epoch 4/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0822 - accuracy: 0.9745
Epoch 5/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0660 - accuracy: 0.9801
Epoch 6/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0554 - accuracy: 0.9827
Epoch 7/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0487 - accuracy: 0.9848
Epoch 8/8
1875/1875 [=====] - 10s 5ms/step - loss: 0.0410 - accuracy: 0.9872
[I 2021-11-05 13:50:39,762] Trial 6 finished with value: 0.9744 and parameters: {'activation': 'relu', 'n_neurons': 38, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 6 with value: 0.9744.
Função de ativação: softmax
Número de neurônios: 64
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 22s 11ms/step - loss: 2.3059 - accuracy: 0.1114
Epoch 2/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3014 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 21s 11ms/step - loss: 2.3013 - accuracy: 0.1124
[I 2021-11-05 13:53:32,748] Trial 7 finished with value: 0.1135 and parameters: {'activation': 'softmax', 'n_neurons': 64, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 6 with value: 0.9744.
Função de ativação: exponencial
Número de neurônios: 19
Otimizador: rmsprop
Epoch 1/8
1875/1875 [=====] - 9s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 2/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 3/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 4/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 5/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 6/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
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Epoch 7/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: nan - accuracy: 0.0987
[I 2021-11-05 13:54:38,064] Trial 8 finished with value: 0.098 and parameters: {'activation': 'exponential', 'n_neurons': 19, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'rmsprop'}. Best is trial 6 with value: 0.9744.
Função de ativação: selu
Número de neurônios: 41
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.2199 - accuracy: 0.9355
Epoch 2/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.1050 - accuracy: 0.9680
Epoch 3/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0762 - accuracy: 0.9767
Epoch 4/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0595 - accuracy: 0.9809
Epoch 5/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0476 - accuracy: 0.9846
Epoch 6/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0388 - accuracy: 0.9877
Epoch 7/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0320 - accuracy: 0.9900
Epoch 8/8
1875/1875 [=====] - 12s 6ms/step - loss: 0.0254 - accuracy: 0.9921
[I 2021-11-05 13:56:14,523] Trial 9 finished with value: 0.9758 and parameters: {'activation': 'selu', 'n_neurons': 41, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 9 with value: 0.9758.
Função de ativação: selu
Número de neurônios: 52
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 14s 7ms/step - loss: 0.2547 - accuracy: 0.9246
Epoch 2/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.1457 - accuracy: 0.9568
Epoch 3/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.1187 - accuracy: 0.9653
Epoch 4/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.1009 - accuracy: 0.9703
Epoch 5/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0822 - accuracy: 0.9748
Epoch 6/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0780 - accuracy: 0.9765
Epoch 7/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0675 - accuracy: 0.9796
Epoch 8/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0662 - accuracy: 0.9797
[I 2021-11-05 13:58:03,140] Trial 10 finished with value: 0.9691 and parameters: {'activation': 'selu', 'n_neurons': 52, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 9 with value: 0.9758.
Função de ativação: relu
Número de neurônios: 27
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.4663 - accuracy: 0.8668
Epoch 2/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.1615 - accuracy: 0.9533
Epoch 3/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.1166 - accuracy: 0.9649
Epoch 4/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0932 - accuracy: 0.9715
Epoch 5/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0801 - accuracy: 0.9749
Epoch 6/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0678 - accuracy: 0.9791
Epoch 7/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0599 - accuracy: 0.9813
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.0528 - accuracy: 0.9833
[I 2021-11-05 13:59:04,956] Trial 11 finished with value: 0.9747 and parameters: {'activation': 'relu', 'n_neurons': 27, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 9 with value: 0.9758.
Função de ativação: relu
Número de neurônios: 23
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 8s 4ms/step - loss: 0.5265 - accuracy: 0.8563
Epoch 2/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.1801 - accuracy: 0.9474
Epoch 3/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.1340 - accuracy: 0.9602
Epoch 4/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.1083 - accuracy: 0.9672
Epoch 5/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0931 - accuracy: 0.9714
Epoch 6/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0809 - accuracy: 0.9750
Epoch 7/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0732 - accuracy: 0.9773
Epoch 8/8
1875/1875 [=====] - 7s 4ms/step - loss: 0.0645 - accuracy: 0.9804
[I 2021-11-05 14:00:03,935] Trial 12 finished with value: 0.9698 and parameters: {'activation': 'relu', 'n_neurons': 23, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 9 with value: 0.9758.
Função de ativação: softplus
Número de neurônios: 27
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3300 - accuracy: 0.1117
Epoch 2/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 3/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 4/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 5/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 6/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 7/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3012 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
Epoch 8/8
1875/1875 [=====] - 8s 4ms/step - loss: 2.3013 - accuracy: 0.1124
[I 2021-11-05 14:01:07,859] Trial 13 finished with value: 0.1135 and parameters: {'activation': 'softplus', 'n_neurons': 27, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 9 with value: 0.9758.
Função de ativação: selu
Número de neurônios: 16
Otimizador: sgd
Epoch 1/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.2681 - accuracy: 0.9192
Epoch 2/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1500 - accuracy: 0.9547
Epoch 3/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1193 - accuracy: 0.9638
Epoch 4/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.1042 - accuracy: 0.9685
Epoch 5/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0915 - accuracy: 0.9719
Epoch 6/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0842 - accuracy: 0.9745
```

```

Epoch 7/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0756 - accuracy: 0.9763
Epoch 8/8
1875/1875 [=====] - 6s 3ms/step - loss: 0.0708 - accuracy: 0.9783
[I 2021-11-05 14:01:55.763] Trial 14 finished with value: 0.9657 and parameters: {'activation': 'selu', 'n_neurons': 16, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'sgd'}. Best is trial 9 with value: 0.9758.
Função de ativação: selu
Número de neurônios: 49
Otimizador: adam
Epoch 1/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.2563 - accuracy: 0.9254
Epoch 2/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.1484 - accuracy: 0.9554
Epoch 3/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.1156 - accuracy: 0.9656
Epoch 4/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0980 - accuracy: 0.9706
Epoch 5/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0896 - accuracy: 0.9720
Epoch 6/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0717 - accuracy: 0.9774
Epoch 7/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0668 - accuracy: 0.9790
Epoch 8/8
1875/1875 [=====] - 13s 7ms/step - loss: 0.0588 - accuracy: 0.9815
[I 2021-11-05 14:03:41.345] Trial 15 finished with value: 0.9717 and parameters: {'activation': 'selu', 'n_neurons': 49, 'dilation': 1, 'loss': 'sparse_categorical_crossentropy', 'optimizer': 'adam'}. Best is trial 9 with value: 0.9758.

```

Gráficos de resultados do processo de otimização

```
In [ ]: optuna.visualization.plot_optimization_history(study_1)
```

```
In [ ]: optuna.visualization.plot_optimization_history(study_2)
```

```
In [ ]: optuna.visualization.plot_optimization_history(study_3)
```

Resultados do plot de otimização de cada estudo

Como podemos ver acima, nossa primeira rede de CNN obteve melhor desempenho em sua otimização, dado que foi mais consistente (o primeiro trial do CNN2 e CNN3 foi um outlier).

```
In [ ]: optuna.visualization.plot_slice(study_1)
```



```
In [ ]: optuna.visualization.plot_slice(study_2)
```



```
In [ ]: optuna.visualization.plot_slice(study_3)
```

Resultado da comparação de parâmetros

- Funções de ativação: no geral, todas as funções de otimização apresentaram bons resultados (como visto no primeiro estudo). Nos outros dois estudos é visível que as funções "softmax", "softplus" e "sigmoid" foram as piores.
- Dilatação: no terceiro estudo, a rede permitiu apenas uso da dilatação com 1, portanto, vamos desconsiderá-lo. Os outros dois estudos apresentaram melhores resultados quando a dilatação foi 2.
- A função de perda utilizada foi a mesma em todos.
- O número de neurônios foi um parâmetro bastante inconstante, não aparentou ser um diferencial em nenhum dos estudos.
- O otimizador que mais se destacou foi o "adam", e em segundo o "sgd", os outros demonstraram ser igualmente bons, com um pouco mais de outliers.

```
In [ ]: optuna.visualization.plot_param_importances(study_1)
```

```
In [ ]: optuna.visualization.plot_param_importances(study_2)
```

```
In [ ]: optuna.visualization.plot_param_importances(study_3)
```

```
-----
ZeroDivisionError                                Traceback (most recent call last)
<ipython-input-27-eba610d4746b> in <module>()
----> 1 optuna.visualization.plot_param_importances(study_3)

/usr/local/lib/python3.7/dist-packages/optuna/visualization/_param_importances.py in plot_param_importances(study, evaluator, params, target, target_name)
    111
    112     importances = optuna.importance.get_param_importances(
--> 113         study, evaluator=evaluator, params=params, target=target
    114     )
    115

/usr/local/lib/python3.7/dist-packages/optuna/importance/_init_.py in get_param_importances(study, evaluator, params, target)
     91     raise TypeError("Evaluator must be a subclass of BaseImportanceEvaluator.")
     92
--> 93     return evaluator.evaluate(study, params=params, target=target)

/usr/local/lib/python3.7/dist-packages/optuna/importance/_fanova/_evaluator.py in evaluate(self, study, params, target)
    124         y=trans_values,
    125         search_spaces=trans_bounds,
--> 126         column_to_encoded_columns=column_to_encoded_columns,
    127     )
    128

/usr/local/lib/python3.7/dist-packages/optuna/importance/_fanova/_fanova.py in fit(self, X, y, search_spaces, column_to_encoded_columns)
     72     self._forest.fit(X, y)
     73
--> 74     self._trees = [_FanovaTree(e.tree_, search_spaces) for e in self._forest.estimators_]
     75     self._column_to_encoded_columns = column_to_encoded_columns
     76     self._variances = {}

/usr/local/lib/python3.7/dist-packages/optuna/importance/_fanova/_fanova.py in <listcomp>(.0)
     72     self._forest.fit(X, y)
     73
--> 74     self._trees = [_FanovaTree(e.tree_, search_spaces) for e in self._forest.estimators_]
```

```

75         self._column_to_encoded_columns = column_to_encoded_columns
76         self._variances = {}

/usr/local/lib/python3.7/dist-packages/optuna/importance/_fanova/_tree.py in __init__(self, tree, search_spaces)
21         self._search_spaces = search_spaces
22
--> 23         statistics = self._precompute_statistics()
24         split_midpoints, split_sizes = self._precompute_split_midpoints_and_sizes()
25         subtree_active_features = self._precompute_subtree_active_features()

/usr/local/lib/python3.7/dist-packages/optuna/importance/_fanova/_tree.py in _precompute_statistics(self)
180         child_values.append(statistics[child_node_index, 0])
181         child_weights.append(statistics[child_node_index, 1])
--> 182         value = numpy.average(child_values, weights=child_weights)
183         weight = float(numpy.sum(child_weights))
184         statistics[node_index] = [value, weight]

<__array_function__ internals> in average(*args, **kwargs)

/usr/local/lib/python3.7/dist-packages/numpy/lib/function_base.py in average(a, axis, weights, returned)
408         if np.any(scl == 0.0):
409             raise ZeroDivisionError(
--> 410                 "Weights sum to zero, can't be normalized")
411
412         avg = np.multiply(a, wgt, dtype=result_dtype).sum(axis)/scl

ZeroDivisionError: Weights sum to zero, can't be normalized

```

Diferenciais

A função de ativação foi alta nos dois primeiros estudos, sendo um diferencial importante, os outros fatores pouco impactaram. No terceiro estudo houve algum problema no optuna que impossibilitou a análise.