

Installing necessary packages

This block installs system libraries and Python packages necessary for image processing, document handling, and deep learning tasks.

```
In [4]: # !sudo apt-get install -y libjpeg-dev zlib1g-dev graphviz
# !pip install scikit-image PyMuPDF opencv-python torch torchvision tensorflow
```

Importing required modules

This section imports all the necessary Python libraries for data preprocessing, handling, visualization, and model building.

```
In [5]: # Data Pre-processing
import fitz
import cv2
import csv
import os
from docx import Document
import string
import requests
import pandas as pd
import numpy as np
from PIL import Image, ImageOps
from IPython.display import clear_output as cls

# Data
from glob import glob
from tqdm import tqdm
import tensorflow.data as tfd

# Data Visualization
import matplotlib.pyplot as plt

# Model
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers, callbacks
from tensorflow.keras.utils import plot_model
```

2025-03-15 22:44:38.036778: I tensorflow/core/util/port.cc:153] 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`.

2025-03-15 22:44:38.074170: I tensorflow/core/platform/cpu_feature_guard.cc:210] This TensorFlow binary is optimized to use available CPU instructions in performance-critical operations.

To enable the following instructions: SSE4.1 SSE4.2 AVX AVX2 AVX_VNNI FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.

Downloading the dataset

```
In [6]: # Downloading the Dataset on collab/local notebook

# Virtuosa ( Dataset 1)
!gdown 'http://drive.google.com/uc?id=10NX_UbV2HMBPE02fvKYAIX000ec0g38g' # D

# Perfecto ( Dataset 2)
!gdown 'http://drive.google.com/uc?id=1x6FS3z4WhsHS7s38a2oSH8JnLQ_u_f21' # D

!gdown 'http://drive.google.com/uc?id=1r7TjJ9RjNZHxAzKhd4u0aRWanrQXIqw8' # D
```

```
Downloading...
From: http://drive.google.com/uc?id=10NX_UbV2HMBPE02fvKYAIX000ec0g38g
To: /home/psyduck/GSOC/Padilla - Nobleza virtuosa_testExtract.pdf
100%|████████████████████████████████████████| 2.58M/2.58M [00:00<00:00, 6.39M
B/s]
Downloading...
From: http://drive.google.com/uc?id=1x6FS3z4WhsHS7s38a2oSH8JnLQ_u_f21
To: /home/psyduck/GSOC/Padilla - 2 Noble perfecto_Extract.pdf
100%|████████████████████████████████████████| 3.95M/3.95M [00:00<00:00, 8.45M
B/s]
Downloading...
From (original): http://drive.google.com/uc?id=1r7TjJ9RjNZHxAzKhd4u0aRWanrQXI
qw8
From (redirected): https://drive.google.com/uc?id=1r7TjJ9RjNZHxAzKhd4u0aRWanr
QXIqw8&confirm=t&uuid=8a30f7d3-5954-4067-936d-1798c38df786
To: /home/psyduck/GSOC/utils.py
100%|████████████████████████████████████████| 17.0k/17.0k [00:00<00:00, 20.6M
B/s]
```

```
In [7]: !ls

'Padilla - 2 Noble perfecto_Extract.pdf'      RenAIssence.ipynb
'Padilla - Nobleza virtuosa_testExtract.pdf'  utils.py
```

Pre-processing the dataset

Converting PDF to images

```
In [8]: from utils import pdf_to_images

pdf_path1 = "./Padilla - Nobleza virtuosa_testExtract.pdf" # Path to the PDF
unproc_images_folder_1 = "./preprocessing/imgsUnProcessed1" # Output folder
if not os.path.exists(unproc_images_folder_1):
    os.makedirs(unproc_images_folder_1)
pdf_to_images(pdf_path1, unproc_images_folder_1)

pdf_path2 = "./Padilla - 2 Noble perfecto_Extract.pdf" # Path to the PDF fil
unproc_images_folder_2 = "./preprocessing/imgsUnProcessed2" # Output folder
if not os.path.exists(unproc_images_folder_2):
    os.makedirs(unproc_images_folder_2)
pdf_to_images(pdf_path2, unproc_images_folder_2)
```

Splitting two sided scanned images into individual pages.

```
In [9]: #Segregating 2-sided pages into individual pages
from utils import process_images

unproc_images_folder_1 = "./preprocessing/imgsUnProcessed1"
```

```

proc_images_folder_1 = "./preprocessing/imgsForAllPages1"
if not os.path.exists(proc_images_folder_1):
    os.makedirs(proc_images_folder_1)
process_images(unproc_images_folder_1, proc_images_folder_1)

unproc_images_folder_2 = "./preprocessing/imgsUnProcessed2"
proc_images_folder_2 = "./preprocessing/imgsForAllPages2"
if not os.path.exists(proc_images_folder_2):
    os.makedirs(proc_images_folder_2)
process_images(unproc_images_folder_2, proc_images_folder_2)

print("Image processing complete!")

```

Image processing complete!

Downloading the CRAFT model

```

In [10]: # Check if the folder already exists
if not os.path.exists('CRAFT_Model'):
    # If it doesn't exist, clone the repository
    !git clone 'https://github.com/lochan13/CRAFT.git'
else:
    print("The repository already exists.")

```

Cloning into 'CRAFT'...

remote: Enumerating objects: 38, done.

remote: Total 38 (delta 0), reused 0 (delta 0), pack-reused 38 (from 1)

Receiving objects: 100% (38/38), 73.63 MiB | 8.02 MiB/s, done.

Resolving deltas: 100% (13/13), done.

Text Detection

Extracting words from a scanned text page image we are using the [CRAFT Model](#) for the same.

```

In [11]: !python3 CRAFT/test.py --result_folder='./preprocessing/BoundingBoxApplied1/' --

```

Loading weights from checkpoint (CRAFT/weights/craft_mlt_25k.pth)

elapsed time : 37.68006253242493s/imgsForAllPages1/image_31.png

```

In [12]: !python3 CRAFT/test.py --result_folder='./preprocessing/BoundingBoxApplied2/' --

```

Loading weights from checkpoint (CRAFT/weights/craft_mlt_25k.pth)

elapsed time : 37.26741671562195s/imgsForAllPages2/image_31.png

The output of this model provides coordinates of the polygon enclosing the word. Using these coordinates one can draw a bounding box and crop word images.

```

In [13]: #Sorting the BB based on the Spanish writing style
from utils import sort_bounding_boxes

bound_box_applied1 = './preprocessing/BoundingBoxApplied1/'
bound_box_sorted1 = './preprocessing/BoundingBoxSorted1'
if not os.path.exists(bound_box_sorted1):
    os.makedirs(bound_box_sorted1)
sort_bounding_boxes(bound_box_applied1, bound_box_sorted1)

```

```

bound_box_applied2 = './preprocessing/BoundingBoxApplied2/'
bound_box_sorted2 = './preprocessing/BoundingBoxSorted2'
if not os.path.exists(bound_box_sorted2):
    os.makedirs(bound_box_sorted2)
sort_bounding_boxes(bound_box_applied2, bound_box_sorted2)

```

Generating Test Data

This code is preparing test data by extracting individual words from scanned document pages, using pre-computed bounding box information. The extracted words are saved as separate image files, which can then be used for testing an OCR (Optical Character Recognition) model.

```

In [14]: from utils import count_files_in_folder, extract_bounding_boxes

def apply_extraction_to_folder_for_test(image_folder, bounding_box_folder, ou
    image_count = count_files_in_folder(image_folder, ['.png', '.jpeg', '.jpg

    for image in range(TRAIN_PAGES, image_count):
        image_filename = f'image_{image+1}.png'
        image_base_name = f'image_{image+1}'
        bounding_box_filename = f"res_{image_base_name}_sorted.txt"
        bounding_box_path = os.path.join(bounding_box_folder, bounding_box_fi

        if os.path.exists(bounding_box_path):
            image_path = os.path.join(image_folder, image_filename)
            word = extract_bounding_boxes(image_path, bounding_box_path, outp
            print(image_base_name)
        else:
            print(f'Bounding box file for {image_filename} does not exist.')

    return word

# For testing_data1
proc_images_folder_1 = './preprocessing/imgsForAllPages1'
bound_box_sorted1 = './preprocessing/BoundingBoxSorted1'
testing_data1 = './testing_data1'
word = apply_extraction_to_folder_for_test(proc_images_folder_1, bound_box_so

# For testing_data2
proc_images_folder_2 = './preprocessing/imgsForAllPages2'
bound_box_sorted2 = './preprocessing/BoundingBoxSorted2'
testing_data2 = './testing_data2'
apply_extraction_to_folder_for_test(proc_images_folder_2, bound_box_sorted2,

```

image_26
image_27
image_28
image_29
image_30
image_31
image_1
image_2
image_3
image_4
image_5
image_6
image_7
image_8
image_9
image_10
image_11
image_12
image_13
image_14
image_15
image_16
image_17
image_18
image_19
image_20
image_21
image_22
image_23
image_24
image_25
image_26
image_27
image_28
image_29
image_30
image_31

Out[14]: 5268

In [15]: **from** utils **import** pad_and_resize_images

```
testing_data1 = './testing_data1'  
pad_and_resize_images(testing_data1)
```

```
testing_data2= './testing_data2'  
pad_and_resize_images(testing_data2)
```

[illegible]

[illegible]

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Gathering Training Data

Manually Corrected Training data

```
In [16]: # Training data, corrected manually  
!gdown 'https://drive.google.com/uc?id=1Gd9BWP0aixcSrs_vkDXJewdlSZEir8-m'  
!unzip outputCorrected.zip
```


inflating: outputChanged/output/aquellos.png
extracting: outputChanged/output/Aqui.png
extracting: outputChanged/output/aqu6.png
extracting: outputChanged/output/ar-.png
extracting: outputChanged/output/arduas.png
extracting: outputChanged/output/Aristo-.png
inflating: outputChanged/output/Aristoteles.png
extracting: outputChanged/output/armas.png
extracting: outputChanged/output/Arneses.png
extracting: outputChanged/output/Arre.png
extracting: outputChanged/output/Artifices.png
extracting: outputChanged/output/artilleria.png
extracting: outputChanged/output/Artus-.png
inflating: outputChanged/output/asentado.png
inflating: outputChanged/output/asistencia.png
extracting: outputChanged/output/asistid.png
extracting: outputChanged/output/assi.png
extracting: outputChanged/output/assiento.png
extracting: outputChanged/output/Assistid.png
extracting: outputChanged/output/assistio.png
extracting: outputChanged/output/atencion,y.png
inflating: outputChanged/output/atribuyen.png
extracting: outputChanged/output/Auftria.png
extracting: outputChanged/output/aunque.png
extracting: outputChanged/output/Aurelio.png
inflating: outputChanged/output/aventurada.png
extracting: outputChanged/output/averos.png
extracting: outputChanged/output/aveys.png
extracting: outputChanged/output/avia.png
inflating: outputChanged/output/aviendose.png
extracting: outputChanged/output/ay (2).png
extracting: outputChanged/output/ay.png
extracting: outputChanged/output/aya.png
extracting: outputChanged/output/ayudareys.png
extracting: outputChanged/output/Basilio.png
inflating: outputChanged/output/Bautismo,.png
extracting: outputChanged/output/baxeza.png
extracting: outputChanged/output/beneficio.png
extracting: outputChanged/output/beralidad.png
inflating: outputChanged/output/Bernardo.png
extracting: outputChanged/output/bertad.png
extracting: outputChanged/output/bien (2).png
extracting: outputChanged/output/Bien.png
extracting: outputChanged/output/bienes.png
inflating: outputChanged/output/bisposprocurad.png
extracting: outputChanged/output/bistes.png
extracting: outputChanged/output/bjen.png
extracting: outputChanged/output/ble.png
extracting: outputChanged/output/blen.png
inflating: outputChanged/output/bligados.png
extracting: outputChanged/output/bolver.png
extracting: outputChanged/output/bondad.png
extracting: outputChanged/output/bre.png
extracting: outputChanged/output/brindis.png
extracting: outputChanged/output/Bruno.png
extracting: outputChanged/output/buen.png
extracting: outputChanged/output/buena.png
extracting: outputChanged/output/Buendia.png
extracting: outputChanged/output/buenos.png
extracting: outputChanged/output/Bullon,.png
extracting: outputChanged/output/bus.png
extracting: outputChanged/output/busca,.png

extracting: outputChanged/output/buscando.png
extracting: outputChanged/output/cabezas.png
extracting: outputChanged/output/cacibn,.png
extracting: outputChanged/output/cada.png
extracting: outputChanged/output/cadaver.png
 inflating: outputChanged/output/calamidades.png
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extracting: outputChanged/output/cama.png
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extracting: outputChanged/output/candalo.png
extracting: outputChanged/output/cando.png
extracting: outputChanged/output/cante.png
extracting: outputChanged/output/capaz.png
 inflating: outputChanged/output/Cardinales,y.png
extracting: outputChanged/output/care.png
extracting: outputChanged/output/Carlo.png
extracting: outputChanged/output/casa.png
extracting: outputChanged/output/caso.png
extracting: outputChanged/output/casos.png
extracting: outputChanged/output/Castilla,.png
extracting: outputChanged/output/Castillo.png
extracting: outputChanged/output/Caton,.png
extracting: outputChanged/output/Cavalleros,y.png
extracting: outputChanged/output/cays,.png
extracting: outputChanged/output/celentes.png
extracting: outputChanged/output/cencia,y.png
extracting: outputChanged/output/censuras.png
extracting: outputChanged/output/cente.png
 inflating: outputChanged/output/ceremonias.png
extracting: outputChanged/output/ceron,.png
extracting: outputChanged/output/ces.png
extracting: outputChanged/output/Cesar,Sci-.png
extracting: outputChanged/output/chia.png
extracting: outputChanged/output/chos (2).png
extracting: outputChanged/output/Christiana.png
extracting: outputChanged/output/Ci.png
extracting: outputChanged/output/cia.png
extracting: outputChanged/output/Cicero.png
extracting: outputChanged/output/Ciceron,.png
extracting: outputChanged/output/cidentes.png
extracting: outputChanged/output/cierto.png
extracting: outputChanged/output/cimiento.png
extracting: outputChanged/output/cio.png
extracting: outputChanged/output/cion.png
extracting: outputChanged/output/cionales.png
extracting: outputChanged/output/cipio,.png
extracting: outputChanged/output/civil.png
extracting: outputChanged/output/clemencia.png
extracting: outputChanged/output/Clerigos,.png
extracting: outputChanged/output/co.png
extracting: outputChanged/output/cobreys.png
extracting: outputChanged/output/cochero.png
extracting: outputChanged/output/cofo,y.png
extracting: outputChanged/output/colgar,.png
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 inflating: outputChanged/output/compostura.png
extracting: outputChanged/output/comun.png
 inflating: outputChanged/output/comunicacibn.png
extracting: outputChanged/output/comunion.png
extracting: outputChanged/output/con (1).png

extracting: outputChanged/output/con (2).png
extracting: outputChanged/output/con (3).png
 inflating: outputChanged/output/conciencia.png
extracting: outputChanged/output/conclu.png
extracting: outputChanged/output/concedera.png
extracting: outputChanged/output/Condesa.png
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extracting: outputChanged/output/creacion.png
extracting: outputChanged/output/creed.png
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extracting: outputChanged/output/criado (2).png
extracting: outputChanged/output/criados.png
extracting: outputChanged/output/crian.png
extracting: outputChanged/output/crio.png
 inflating: outputChanged/output/cualquiera.png
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extracting: outputChanged/output/dados.png
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extracting: outputChanged/output/darme.png
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extracting: outputChanged/output/das.png
extracting: outputChanged/output/David.png
extracting: outputChanged/output/de (2).png
extracting: outputChanged/output/de (3).png
extracting: outputChanged/output/de (4).png
extracting: outputChanged/output/de (5).png
extracting: outputChanged/output/de (6).png
extracting: outputChanged/output/de (7).png
extracting: outputChanged/output/De.png
 inflating: outputChanged/output/DEDICATORIA.png
 inflating: outputChanged/output/defcomulgado.png
extracting: outputChanged/output/defde.png
extracting: outputChanged/output/del (2).png
extracting: outputChanged/output/del (3).png
extracting: outputChanged/output/del.png
extracting: outputChanged/output/delan-.png
extracting: outputChanged/output/della.png
extracting: outputChanged/output/dellas.png
extracting: outputChanged/output/dencia,.png
 inflating: outputChanged/output/depravadas.png
extracting: outputChanged/output/dera.png
extracting: outputChanged/output/derillo.png
extracting: outputChanged/output/des-.png
 inflating: outputChanged/output/descubierto.png
extracting: outputChanged/output/descuento.png
 inflating: outputChanged/output/descuydeys.png
extracting: outputChanged/output/desdicha.png
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extracting: outputChanged/output/despuBs.png
extracting: outputChanged/output/desseando.png
extracting: outputChanged/output/dessear.png
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extracting: outputChanged/output/desto.png
extracting: outputChanged/output/destos.png
extracting: outputChanged/output/desuelo.png
extracting: outputChanged/output/desve.png
extracting: outputChanged/output/deuda,y.png
extracting: outputChanged/output/deue.png
extracting: outputChanged/output/deveys.png
extracting: outputChanged/output/devidas.png
extracting: outputChanged/output/devo.png
extracting: outputChanged/output/devotos.png
extracting: outputChanged/output/devria.png
extracting: outputChanged/output/dexaros.png
extracting: outputChanged/output/dexkeys.png
extracting: outputChanged/output/dexo.png
extracting: outputChanged/output/dexb.png
extracting: outputChanged/output/di-.png
extracting: outputChanged/output/dia,.png
extracting: outputChanged/output/dicha.png
extracting: outputChanged/output/dichoso.png
extracting: outputChanged/output/diencia.png
extracting: outputChanged/output/diendose.png
extracting: outputChanged/output/diera.png
extracting: outputChanged/output/dieron.png

inflating: outputChanged/output/diferencias,.png
extracting: outputChanged/output/dificil.png
inflating: outputChanged/output/dignidad.png
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extracting: outputChanged/output/Digo.png
extracting: outputChanged/output/dio.png
extracting: outputChanged/output/Dios.png
extracting: outputChanged/output/discursos.png
extracting: outputChanged/output/dispa.png
inflating: outputChanged/output/distraerlos.png
extracting: outputChanged/output/divina.png
extracting: outputChanged/output/Divino.png
extracting: outputChanged/output/divinos.png
extracting: outputChanged/output/dixo (2).png
extracting: outputChanged/output/dixo.png
extracting: outputChanged/output/dize.png
extracting: outputChanged/output/do.png
extracting: outputChanged/output/doce.png
extracting: outputChanged/output/Doctores.png
extracting: outputChanged/output/Doctos.png
extracting: outputChanged/output/documen.png
extracting: outputChanged/output/dola.png
extracting: outputChanged/output/dole,.png
extracting: outputChanged/output/dolores.png
extracting: outputChanged/output/ dominio.png
extracting: outputChanged/output/Don.png
extracting: outputChanged/output/Dođa.png
extracting: outputChanged/output/donde.png
extracting: outputChanged/output/dos,y.png
extracting: outputChanged/output/dos.png
extracting: outputChanged/output/dres.png
extracting: outputChanged/output/e.png
inflating: outputChanged/output/Eclesiastico.png
extracting: outputChanged/output/educacion.png
extracting: outputChanged/output/educacibn.png
extracting: outputChanged/output/effe.png
extracting: outputChanged/output/efte.png
extracting: outputChanged/output/Eibie.png
extracting: outputChanged/output/el (2).png
extracting: outputChanged/output/el (3).png
extracting: outputChanged/output/Bl,.png
extracting: outputChanged/output/el.png
extracting: outputChanged/output/elegir.png
extracting: outputChanged/output/ella,.png
extracting: outputChanged/output/ellas.png
inflating: outputChanged/output/ello,alumbradle.png
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extracting: outputChanged/output/recatada.png
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extracting: outputChanged/output/recibio,y.png
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extracting: outputChanged/output/rectamente.png
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extracting: outputChanged/output/trabajos.png
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extracting: outputChanged/output/Trajano.png
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extracting: outputChanged/output/vaffallos.png
extracting: outputChanged/output/valde,y.png
extracting: outputChanged/output/valernos.png
extracting: outputChanged/output/valor.png
extracting: outputChanged/output/van.png
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extracting: outputChanged/output/vene-.png
extracting: outputChanged/output/venerad.png
extracting: outputChanged/output/venereys,y.png
extracting: outputChanged/output/venia.png

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extracting: outputChanged/output/Viatico.png
extracting: outputChanged/output/vicios.png
extracting: outputChanged/output/vida (2).png
extracting: outputChanged/output/vida.png
extracting: outputChanged/output/vien-.png
extracting: outputChanged/output/viendolo.png
  inflating: outputChanged/output/vinculada.png
extracting: outputChanged/output/vio.png
extracting: outputChanged/output/Vir-.png
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extracting: outputChanged/output/virtud (2).png
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extracting: outputChanged/output/virtuo-.png
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extracting: outputChanged/output/vivir.png
extracting: outputChanged/output/vna.png
extracting: outputChanged/output/vos,.png
extracting: outputChanged/output/vosotros.png
extracting: outputChanged/output/vueftra (2).png
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extracting: outputChanged/output/vuestros.png
extracting: outputChanged/output/xandro.png
extracting: outputChanged/output/y (2).png
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extracting: outputChanged/output/za (2).png
extracting: outputChanged/output/za.png
extracting: outputChanged/output/zeo.png
extracting: outputChanged/output/zer.png
extracting: outputChanged/output/zidas.png
```

```
In [17]: # Transferring the corrected dataset to the correct location for training
!mv './outputChanged/output' './training_data'
```

Working on Training_data

Padding small sized words for no distortion

```
In [18]: # adding padding to the left and right of small sized words
training_data = './training_data'
pad_and_resize_images(training_data)
```

Processed and replaced: ./training_data/a.png
Processed and replaced: ./training_data/abatio.png
Processed and replaced: ./training_data/abatirse.png
Processed and replaced: ./training_data/aborre.png
Processed and replaced: ./training_data/ac.png
Processed and replaced: ./training_data/acavallo.png
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Processed and replaced: ./training_data/Acudã.png
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Processed and replaced: ./training_data/ador-.png
Processed and replaced: ./training_data/afeminados,.png
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Processed and replaced: ./training_data/za (2).png
Processed and replaced: ./training_data/za.png
Processed and replaced: ./training_data/zelo.png
Processed and replaced: ./training_data/zer.png
Processed and replaced: ./training_data/zidas.png

Image Augmentation by Rotation

```
In [19]: from utils import rotation_aug

training_data = './training_data'
rotation_aug(training_data)
print("Image augmentation by Rotation completed.")
```

Image augmentation by Rotation completed.

Image augmentation by Gaussian Noise

```
In [20]: from utils import gaussian_noise_aug

training_data = './training_data'
gaussian_noise_aug(training_data)
print("Image augmentation by Gaussian Noise completed.")
```

Image augmentation by Gaussian Noise completed.

This part of code creates structured CSV files that can be used to organize and access the image data for future task, particularly for training and testing an OCR (Optical Character Recognition)

model.

```
In [21]: from utils import create_csv_from_folder

# Train data
training_data = './training_data'
train_csv_path = './training_data.csv'
create_csv_from_folder(training_data, train_csv_path)

# Test data
test_data1 = './testing_data1'
test_csv_path1 = './testing_data1.csv'
create_csv_from_folder(test_data1, test_csv_path1)
```

CSV file "./training_data.csv" created successfully.
CSV file "./testing_data1.csv" created successfully.

Splitting train and test dataset

```
In [22]: df = pd.read_csv('training_data.csv')
df.shape
```

Out[22]: (26730, 2)

create a new column IDENTITY that contain the label of the images

```
In [23]: df['IDENTITY'] = df['IDENTITY'].apply(lambda x: x.split('_')[0]).apply(lambda
```

```
In [24]: TRAIN_SIZE = int(df.shape[0]*0.8)
df_train = df.iloc[:TRAIN_SIZE]
df_valid = df.iloc[TRAIN_SIZE+1:]
```

```
In [25]: df_train.to_csv('train.csv', index=False)
df_train.head()
```

Out[25]:

	FILENAME	IDENTITY
--	----------	----------

0	a.png	a
1	abatio.png	abatio
2	abatirse.png	abatirse
3	aborre.png	aborre
4	ac.png	ac

```
In [26]: df_valid.to_csv('valid.csv', index=False)
df_valid.head()
```

Out[26]:

	FILENAME	IDENTITY
21385	meses_rot1_gauss.png	meses
21386	meses_rot2_gauss.png	meses
21387	meses_rot3_gauss.png	meses
21388	meses_rot4_gauss.png	meses
21389	meses_rot5_gauss.png	meses

This code sets up configuration parameters and file paths for training, validating, and testing an OCR model, including image size, batch size, number of epochs, model name, callbacks, learning rate, random seeds, dataset file paths, data sizes, and prefetching settings.

```
In [27]: # Image Size
IMG_WIDTH = 200
IMG_HEIGHT = 50
IMAGE_SIZE = (IMG_WIDTH, IMG_HEIGHT)

# Batch Size
BATCH_SIZE = 16

# EPOCHS
EPOCHS = 100

# Model Name
MODEL_NAME = 'SpanishOCR'

# Callbacks
CALLBACKS = [
    callbacks.EarlyStopping(patience=10, restore_best_weights=True),
    callbacks.ModelCheckpoint(filepath=MODEL_NAME + ".h5", save_best_only=True)
]

# Learning Rate
LEARNING_RATE = 1e-3

# Random Seed
np.random.seed(2569)
tf.random.set_seed(2569)

# File Paths ( replace 1 by 2,3 ... so as to test other folders)
train_csv_path = './train.csv'
valid_csv_path = './valid.csv'
test_csv_path = './testing_data1.csv'

train_image_dir = './training_data'
valid_image_dir = './training_data'
test_image_dir = './testing_data1'

# AUTOTUNE
AUTOTUNE = tfd.AUTOTUNE
```

```
In [28]: # Train CSV
train_csv = pd.read_csv(train_csv_path)
```

```
# Validation CSV
valid_csv = pd.read_csv(valid_csv_path)

# Test CSV
test_csv = pd.read_csv(test_csv_path)
```

```
In [29]: # In order to convert int to string to prevent tf error
test_csv['IDENTITY'] = test_csv['IDENTITY'].apply(lambda x: str(x))
```

```
In [30]: labels = [str(word) for word in df['IDENTITY'].to_numpy()]
labels[:10]
```

```
Out[30]: ['a',
          'abatio',
          'abatirse',
          'aborre',
          'ac',
          'acavallo',
          'acciones',
          'acometer',
          'Acudireys',
          'Acuda']
```

This code extracts unique characters from the dataset labels, calculates the total number of unique characters, and prints both the count and the set of unique characters

```
In [31]: # Unique characters
unique_chars = set(char for word in labels for char in word)
n_classes = len(unique_chars)

# Show
print(f"Total number of unique characters : {n_classes}")
print(f"Unique Characters : \n{unique_chars}")
```

```
Total number of unique characters : 50
Unique Characters :
{'d', 'f', 'j', 'M', 'g', 'R', 'D', 'p', 'L', 'r', 'e', 'A', ',', 'u', '-', 'I', 'T', 'v', 'i', 'z', 'C', 'y', 't', 'B', 'b', 'l', 'B', 'a', 'V', 'x', 'P', 'n', 's', 'o', 'B', 'E', 'G', 'H', 'N', 'a', 'm', 'd', 'F', 'c', 'q', 'ó', 'h', 'S', 'Q', 'O'}
```

```
In [32]: MAX_LABEL_LENGTH = max(map(len, labels))
print(f"Maximum length of a label : {MAX_LABEL_LENGTH}")
```

```
Maximum length of a label : 24
```

This code updates the file paths in the FILENAME columns of the training, validation, and test CSV dataframes by prepending the respective image directory paths to each filename.

```
In [33]: train_csv['FILENAME'] = [train_image_dir + f"/{filename}" for filename in train_csv['FILENAME']]
valid_csv['FILENAME'] = [valid_image_dir + f"/{filename}" for filename in valid_csv['FILENAME']]
test_csv['FILENAME'] = [test_image_dir + f"/{filename}" for filename in test_csv['FILENAME']]
```

```
In [34]: train_csv.head()
```

```
Out[34]:
```

	FILENAME	IDENTITY
0	./training_data/a.png	a
1	./training_data/abatio.png	abatio
2	./training_data/abatirse.png	abatirse
3	./training_data/aborre.png	aborre
4	./training_data/ac.png	ac

```
In [35]: test_csv.head()
```

```
Out[35]:
```

	FILENAME	IDENTITY
0	./testing_data1/0;0.png	0;0
1	./testing_data1/1;0.png	1;0
2	./testing_data1/2;0.png	2;0
3	./testing_data1/3;0.png	3;0
4	./testing_data1/4;0.png	4;0

This code creates two dictionaries: one that maps unique characters to numeric values using `StringLookup`, and another that reverses this mapping, converting numeric values back to characters.

```
In [36]: # Character to numeric value dictionary
char_to_num = layers.StringLookup(
    vocabulary = list(unique_chars),
    mask_token = None
)

# Reverse dictionary
num_to_char = layers.StringLookup(
    vocabulary = char_to_num.get_vocabulary(),
    mask_token = None,
    invert = True
)
```

This function loads an image from a given path, decodes it as a JPEG, converts it to a tensor, resizes and normalizes it, and then returns the processed image as a tensor.

```
In [37]: def load_image(image_path : str):
    ...
    This function loads and preprocesses images. It first receives the image
    decode the image as a JPEG using TensorFlow. Then, it converts the image
    two processing functions: resizing and normalization. The processed image
    the function.

    Argument :
        image_path : The path of the image file to be loaded.

    Return:
```

```

    image : The loaded image as a tensor.
    ...

# Read the Image
image = tf.io.read_file(image_path)

# Decode the image
decoded_image = tf.image.decode_jpeg(contents = image, channels = 1)

# Convert image data type.
cnvt_image = tf.image.convert_image_dtype(image = decoded_image, dtype =

# Resize the image
resized_image = tf.image.resize(images = cnvt_image, size = (IMG_HEIGHT,

# Transpose
image = tf.transpose(resized_image, perm = [1, 0, 2])

# Convert image to a tensor.
image = tf.cast(image, dtype = tf.float32)

# Return loaded image
return image

```

This function loads and preprocesses an image, converts a given label string into a sequence of numeric values, pads the numeric sequence to a fixed length, and returns a dictionary containing the processed image tensor and the label tensor.


```
In [38]: def encode_single_sample(image_path : str, label : str):

    """
    The function takes an image path and label as input and returns a dictionary.
    First, it loads the image using the load_image function, which decodes an
    label string into a sequence of Unicode characters using the unicode_split
    character in the label to a numerical representation. It pads the numeric
    to ensure that all labels have the same length (MAX_LABEL_LENGTH). Finally
    and the label tensor.

    Arguments :
        image_path : The location of the image file.
        label       : The text to present in the image.

    Returns:
        dict : A dictionary containing the processed image and label.
    """

    # Get the image
    image = load_image(image_path)

    # Convert the label into characters
    chars = tf.strings.unicode_split(label, input_encoding='UTF-8')

    # Convert the characters into vectors
    vecs = char_to_num(chars)

    # Pad label
    pad_size = MAX_LABEL_LENGTH - tf.shape(vecs)[0]
    vecs = tf.pad(vecs, paddings = [[0, pad_size]], constant_values=n_classes)

    return {'image':image, 'label':vecs}
```

This code splits the combined dataset into training and validation subsets, shuffles the data, and then creates batched and prefetched TensorFlow datasets for efficient data loading during model training.

```
In [39]: # Further split the training dataset into training and validation subsets
train_size = int(0.8*len(df)) # 80% of the training data for training
val_size = len(df) - train_size # Remaining 20% for validation

# Splitting the training dataset
train_ds = tf.data.Dataset.from_tensor_slices(
    (np.array(df['FILENAME'].to_list()), np.array(df['IDENTITY'].to_list())))
).shuffle(train_size)

# Create training dataset
train_ds = train_ds.take(train_size).batch(BATCH_SIZE).prefetch(AUTOTUNE)

# Create validation dataset
valid_ds = train_ds.skip(train_size).batch(BATCH_SIZE).prefetch(AUTOTUNE)
```

This code creates TensorFlow datasets for training, validation, and testing by loading image paths and labels, shuffling the training data, applying the encode_single_sample function to preprocess the images and labels, batching the data, and using prefetching for optimized data loading.

```
In [40]: # Training Data
train_ds = tf.data.Dataset.from_tensor_slices(
    (np.array(train_csv['FILENAME']).to_list()), np.array(train_csv['IDENTITY']).shuffle(train_size).map(encode_single_sample, num_parallel_calls=AUTOTUNE).

# # Validation data
valid_ds = tf.data.Dataset.from_tensor_slices(
    (np.array(valid_csv['FILENAME']).to_list()), np.array(valid_csv['IDENTITY']).map(encode_single_sample, num_parallel_calls=AUTOTUNE).batch(BATCH_SIZE).pr

# # Testing data.
test_ds = tf.data.Dataset.from_tensor_slices(
    (np.array(test_csv['FILENAME']).to_list()), np.array(test_csv['IDENTITY']).map(encode_single_sample, num_parallel_calls=AUTOTUNE).batch(BATCH_SIZE).pr
```

```
In [41]: print(f"Training Data Size : {tf.data.Dataset.cardinality(train_ds).numpy()}")
print(f"Validation Data Size : {tf.data.Dataset.cardinality(valid_ds).numpy()}")
print(f"Testing Data Size : {tf.data.Dataset.cardinality(test_ds).numpy()}")
```

```
Training Data Size : 21392
Validation Data Size : 5360
Testing Data Size : 864
```

Resizes all images in the input folder to a specified size and saves them as PNG files in the output folder, ensuring the output directory exists.

```
In [42]: # Set the new size in pixels (width, height) according to your choice
def resize_images_in_folder(input_folder, new_size=(200,50)):
    # Loop through all files in the input folder
    for filename in os.listdir(input_folder):
        # Open the image
        with Image.open(os.path.join(input_folder, filename)) as img:
            # Resize the image
            resized_img = img.resize(new_size)
            # Save the resized image to the output folder
            output_filename = os.path.splitext(filename)[0] + '.png' # Ensur
            resized_img.save(os.path.join(input_folder, output_filename))

training_image_dir = "./training_data"
resize_images_in_folder(training_image_dir)

test_image_dir = "./testing_data1"
resize_images_in_folder(test_image_dir)
```

Displays a grid of images with their true labels, and optionally their predicted labels if a model is provided, using Matplotlib for visualization.

```
In [43]: def show_images(data, GRID=[4,4], FIGSIZE=(25, 8), cmap='binary_r', model=None)

    # Plotting configurations
    plt.figure(figsize=FIGSIZE)
    n_rows, n_cols = GRID

    # Loading Data
    data = next(iter(data))
    images, labels = data['image'], data['label']
```

```

# Iterate over the data
for index, (image, label) in enumerate(zip(images, labels)):

    # Label processing
    text_label = num_to_char(label)
    text_label = tf.strings.reduce_join(text_label).numpy().decode('UTF-8')
    text_label = text_label.replace("[UNK]", " ").strip()

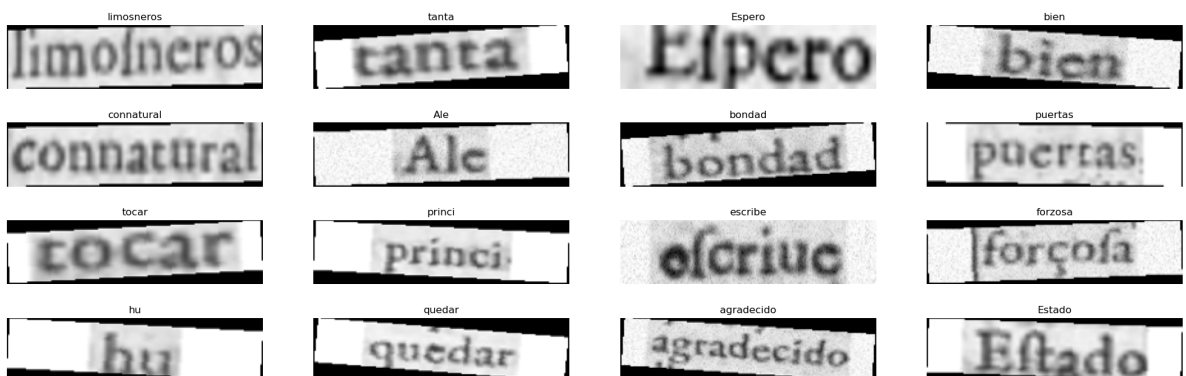
    # Create a sub plot
    plt.subplot(n_rows, n_cols, index+1)
    plt.imshow(tf.transpose(image, perm=[1,0,2]), cmap=cmap)
    plt.axis('off')

    if model is not None and decode_pred is not None:
        # Make prediction
        pred = model.predict(tf.expand_dims(image, axis=0))
        pred = decode_pred(pred)[0]
        title = f"True : {text_label}\nPred : {pred}"
        plt.title(title)
    else:
        # add title
        plt.title(text_label)

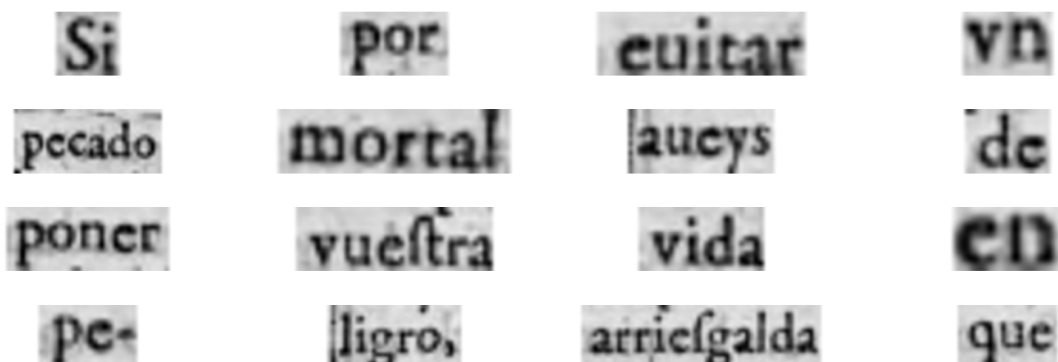
# Show the final plot
cls()
plt.show()

```

In [44]: `show_images(data=train_ds, cmap='gray')`



In [45]: `show_images(data=test_ds, cmap='gray')`



Model Definition

Defines a custom Keras layer that computes and adds the Connectionist Temporal Classification (CTC) loss to the model

for training sequence-to-sequence prediction tasks.

```
In [46]: class CTCLayer(layers.Layer):
def __init__(self, **kwargs) -> None:
    super().__init__(**kwargs)
    self.loss_fn = keras.backend.ctc_batch_cost
def call(self, y_true, y_pred):
    batch_len = tf.cast(tf.shape(y_true)[0], dtype='int64')
    input_len = tf.cast(tf.shape(y_pred)[1], dtype='int64') * tf.ones(shape=(batch_len, 1), dtype='int64')
    label_len = tf.cast(tf.shape(y_true)[1], dtype='int64') * tf.ones(shape=(batch_len, 1), dtype='int64')
    loss = self.loss_fn(y_true, y_pred, input_len, label_len)
    self.add_loss(loss)
    return y_pred
```

Decodes the predicted labels from the OCR model, converting numeric values back to characters and removing unknown tokens to produce the final text output.

```
In [47]: def decode_pred(pred_label):
...
The decode_pred function is used to decode the predicted labels generated
It takes a matrix of predicted labels as input, where each time step represents
for each character. The function uses CTC decoding to decode the numeric
character values. The function also removes any unknown tokens and return
list of strings. The function utilizes the num_to_char function to map numeric
corresponding characters. Overall, the function is an essential step in the
us to obtain the final text output from the model's predictions.

Argument :
    pred_label : These are the model predictions which are needed to be decoded

Return:
    filtered_text : This is the list of all the decoded and processed predictions

...

# Input length
input_len = np.ones(shape=pred_label.shape[0]) * pred_label.shape[1]

# CTC decode
decode = keras.backend.ctc_decode(pred_label, input_length=input_len, greedy=True)

# Converting numerics back to their character values
chars = num_to_char(decode)

# Join all the characters
texts = [tf.strings.reduce_join(inputs=char).numpy().decode('UTF-8') for char in chars]

# Remove the unknown token
filtered_texts = [text.replace('[UNK]', ' ').strip() for text in texts]

return filtered_texts
```

This code defines a deep learning model for optical character recognition (OCR) using a combination of convolutional neural networks (CNNs) for feature extraction and bidirectional long short-term memory (LSTM) networks for sequence learning, concluding with a custom CTC loss layer for training.

```
In [48]: # Input Layer
input_images = layers.Input(shape=(IMG_WIDTH, IMG_HEIGHT, 1), name="image")

# Labels : These are added for the training purpose.
target_labels = layers.Input(shape=(None, ), name="label")

# CNN Network
x = layers.Conv2D(
    filters=32,
    kernel_size=3,
    strides=1,
    padding='same',
    activation='relu',
    kernel_initializer='he_normal'
)(input_images)
x = layers.BatchNormalization()(x)

x = layers.Conv2D(
    filters=32,
    kernel_size=3,
    strides=1,
    padding='same',
    activation='relu',
    kernel_initializer='he_normal'
)(x)
x = layers.BatchNormalization()(x)

x = layers.MaxPool2D(pool_size=(2,2), strides=(2,2))(x)

x = layers.Conv2D(
    filters=64,
    kernel_size=3,
    strides=1,
    padding='same',
    activation='relu',
    kernel_initializer='he_normal'
)(x)
x = layers.BatchNormalization()(x)

x = layers.Conv2D(
    filters=128,
    kernel_size=3,
    strides=1,
    padding='same',
    activation='relu',
    kernel_initializer='he_normal'
)(x)
x = layers.BatchNormalization()(x)

x = layers.MaxPool2D(pool_size=(2,2), strides=(2,2))(x)

# Encoding Space
encoding = layers.Reshape(target_shape=((IMG_WIDTH//4), (IMG_HEIGHT//4)*128))
encoding = layers.Dense(128, activation='relu', kernel_initializer='he_normal')
```

```

encoding = layers.Dropout(0.5)(encoding)

# RNN Network
x = layers.Bidirectional(layers.LSTM(256, return_sequences=True, dropout=0.5))
x = layers.Bidirectional(layers.LSTM(128, return_sequences=True, dropout=0.5))

# Output Layer
output = layers.Dense(len(char_to_num.get_vocabulary())+1, activation='softmax')

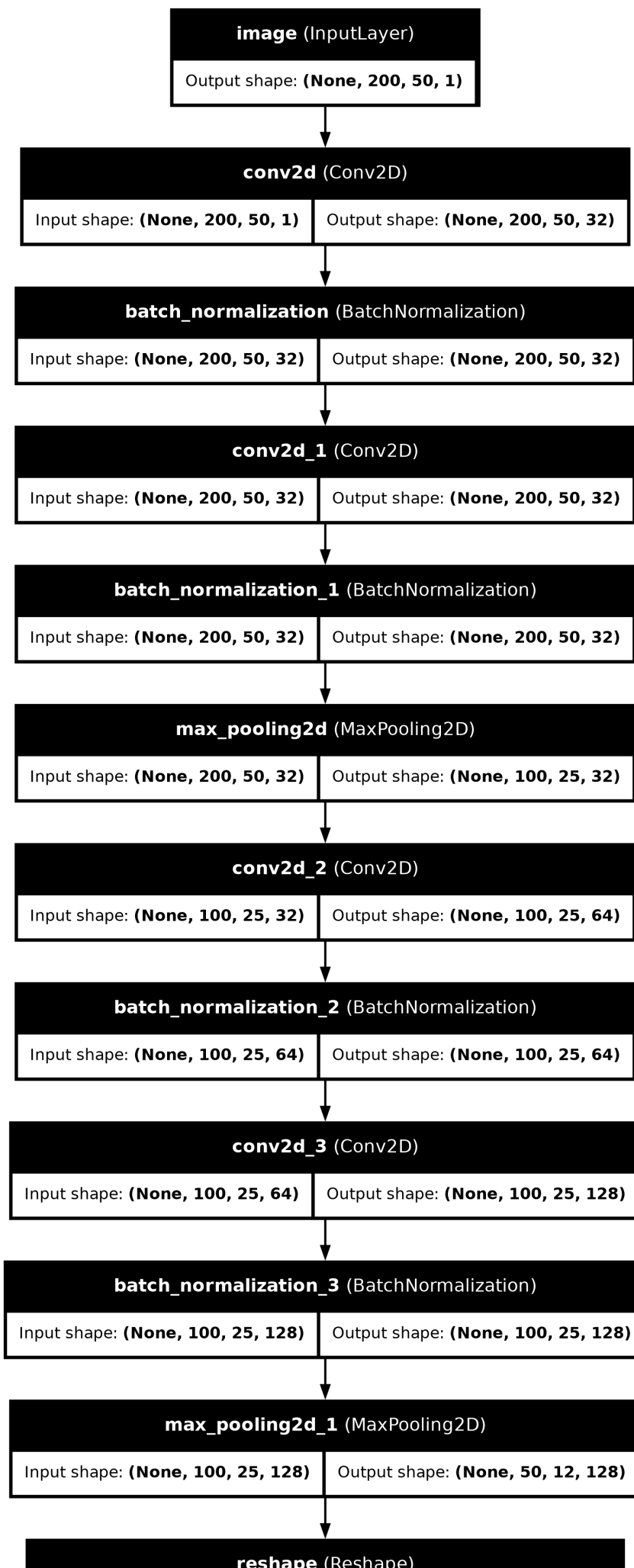
# CTC Layer
ctc_layer = CTCLayer()(target_labels, output)

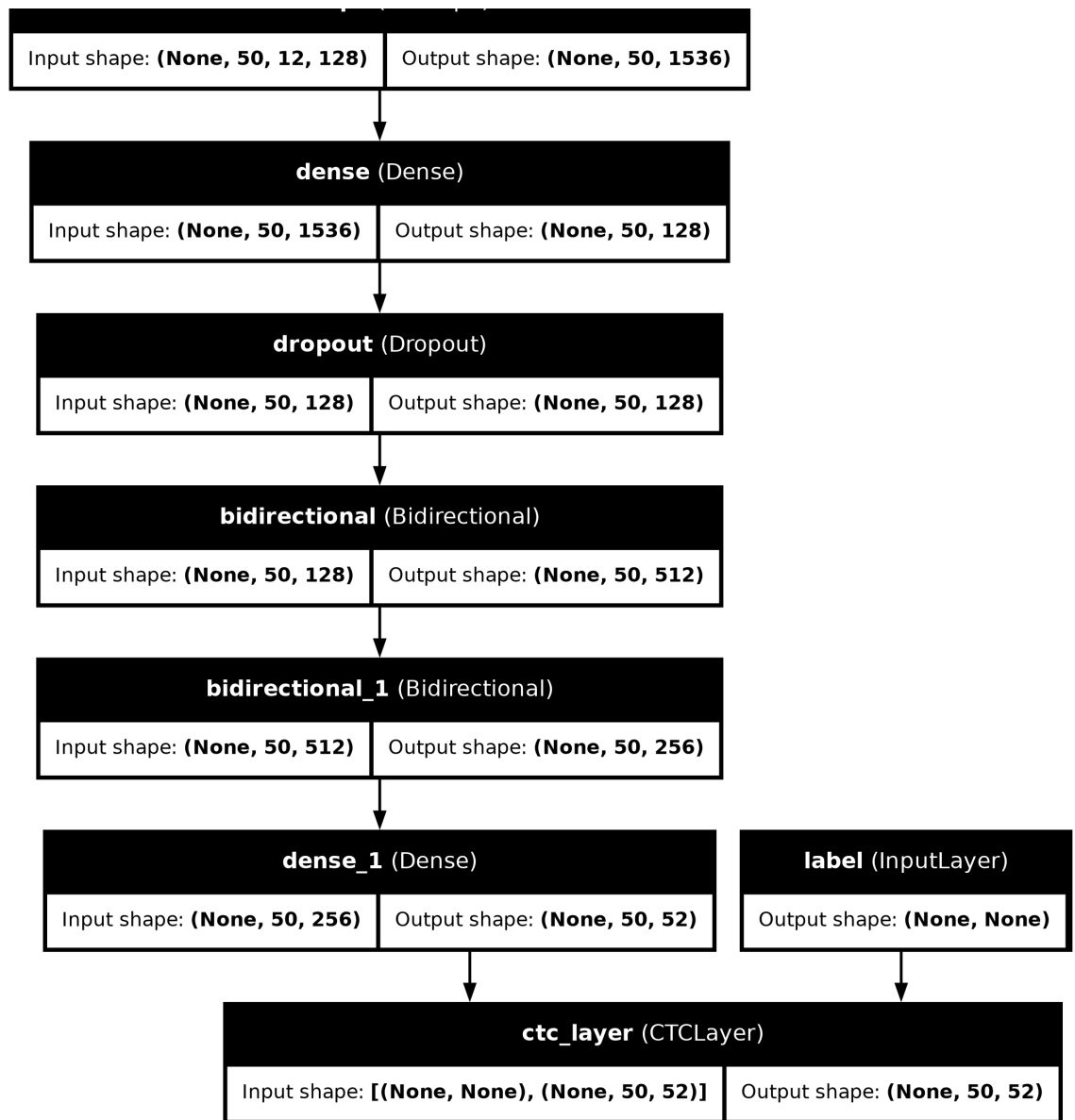
# Model
ocr_model = keras.Model(
    inputs=[input_images, target_labels],
    outputs=[ctc_layer]
)

```

```
In [49]: plot_model(ocr_model, show_shapes=True, show_layer_names=True)
```

Out[49]:





Compiles the OCR model with the Adam optimizer and trains it on the training dataset with validation, using early stopping and model checkpoint callbacks.

```
In [50]: # Compile
ocr_model.compile(optimizer=keras.optimizers.Adam(learning_rate=1e-3))

# Learning Rate Scheduler
lr_scheduler = callbacks.ReduceLROnPlateau(
    monitor='val_loss',
    factor=0.5,
    patience=3,
    verbose=1,
    min_lr=1e-6
)

# Train
history = ocr_model.fit(
    train_ds,
    validation_data=valid_ds,
    epochs=EPOCHS,
    callbacks=[
        callbacks.EarlyStopping(patience=5, restore_best_weights=True),
        lr_scheduler
    ]
)
```












































```
    ]  
)  
  
# Learning Curve  
pd.DataFrame(history.history).plot(figsize=(8,5))  
plt.legend(fontsize=15)  
plt.xlabel("Epochs")  
plt.ylabel("CTC Loss Score")  
plt.title("Learning Curve", fontsize=15)  
plt.grid()  
plt.show()
```

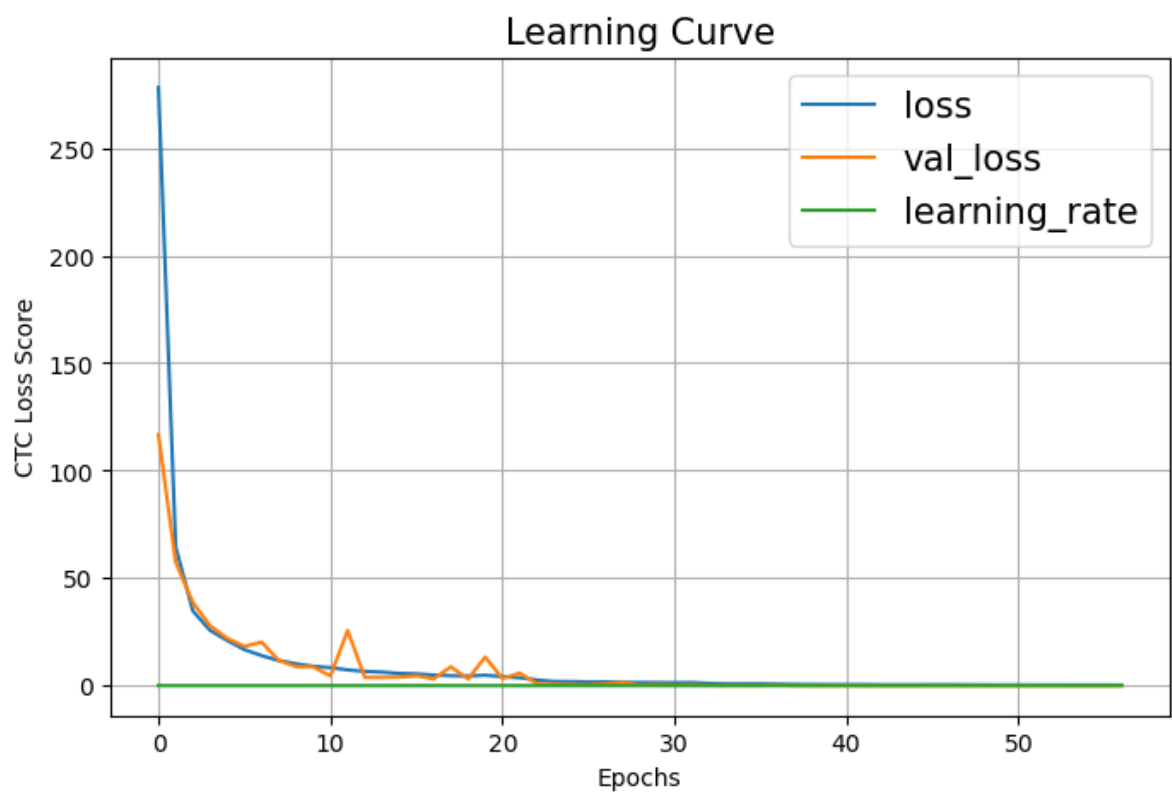
Epoch 1/100

2025-03-15 22:47:44.643775: E tensorflow/core/util/util.cc:131] oneDNN supports DT_INT32 only on platforms with AVX-512. Falling back to the default Eigen-based implementation if present.

1337/1337 ————— 308s 227ms/step - loss: 344.6297 - val_loss: 16.7242 - learning_rate: 0.0010
Epoch 2/100
1337/1337 ————— 301s 225ms/step - loss: 83.5386 - val_loss: 57.3998 - learning_rate: 0.0010
Epoch 3/100
1337/1337 ————— 294s 220ms/step - loss: 37.9092 - val_loss: 38.6986 - learning_rate: 0.0010
Epoch 4/100
1337/1337 ————— 294s 220ms/step - loss: 27.3159 - val_loss: 27.8769 - learning_rate: 0.0010
Epoch 5/100
1337/1337 ————— 294s 220ms/step - loss: 21.9082 - val_loss: 21.9582 - learning_rate: 0.0010
Epoch 6/100
1337/1337 ————— 294s 220ms/step - loss: 17.1996 - val_loss: 18.2914 - learning_rate: 0.0010
Epoch 7/100
1337/1337 ————— 294s 220ms/step - loss: 14.5014 - val_loss: 20.2447 - learning_rate: 0.0010
Epoch 8/100
1337/1337 ————— 294s 220ms/step - loss: 12.0294 - val_loss: 11.6461 - learning_rate: 0.0010
Epoch 9/100
1337/1337 ————— 312s 233ms/step - loss: 10.4881 - val_loss: 8.8982 - learning_rate: 0.0010
Epoch 10/100
1337/1337 ————— 310s 232ms/step - loss: 9.5858 - val_loss: 8.7013 - learning_rate: 0.0010
Epoch 11/100
1337/1337 ————— 315s 235ms/step - loss: 8.5631 - val_loss: 4.4733 - learning_rate: 0.0010
Epoch 12/100
1337/1337 ————— 314s 234ms/step - loss: 6.9937 - val_loss: 25.6349 - learning_rate: 0.0010
Epoch 13/100
1337/1337 ————— 313s 234ms/step - loss: 6.6876 - val_loss: 3.8694 - learning_rate: 0.0010
Epoch 14/100
1337/1337 ————— 312s 234ms/step - loss: 5.9999 - val_loss: 3.8176 - learning_rate: 0.0010
Epoch 15/100
1337/1337 ————— 310s 232ms/step - loss: 5.7217 - val_loss: 3.9791 - learning_rate: 0.0010
Epoch 16/100
1337/1337 ————— 311s 233ms/step - loss: 5.2359 - val_loss: 4.6057 - learning_rate: 0.0010
Epoch 17/100
1337/1337 ————— 311s 232ms/step - loss: 5.1155 - val_loss: 3.1414 - learning_rate: 0.0010
Epoch 18/100
1337/1337 ————— 311s 232ms/step - loss: 4.5947 - val_loss: 8.7482 - learning_rate: 0.0010
Epoch 19/100
1337/1337 ————— 311s 232ms/step - loss: 4.5069 - val_loss: 3.0934 - learning_rate: 0.0010
Epoch 20/100
1337/1337 ————— 318s 238ms/step - loss: 4.7770 - val_loss: 13.2827 - learning_rate: 0.0010
Epoch 21/100
1337/1337 ————— 308s 230ms/step - loss: 4.6653 - val_loss: 3.3211 - learning_rate: 0.0010

Epoch 22/100
1337/1337  **0s** 215ms/step - loss: 3.7438
Epoch 22: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.
1337/1337  **308s** 230ms/step - loss: 3.7437 - val_loss: 5.8
337 - learning_rate: 0.0010
Epoch 23/100
1337/1337  **308s** 230ms/step - loss: 2.9427 - val_loss: 0.9
109 - learning_rate: 5.0000e-04
Epoch 24/100
1337/1337  **310s** 232ms/step - loss: 1.9647 - val_loss: 0.5
902 - learning_rate: 5.0000e-04
Epoch 25/100
1337/1337  **313s** 234ms/step - loss: 1.9077 - val_loss: 0.4
942 - learning_rate: 5.0000e-04
Epoch 26/100
1337/1337  **310s** 232ms/step - loss: 1.6779 - val_loss: 0.3
955 - learning_rate: 5.0000e-04
Epoch 27/100
1337/1337  **310s** 232ms/step - loss: 1.6783 - val_loss: 0.8
029 - learning_rate: 5.0000e-04
Epoch 28/100
1337/1337  **314s** 235ms/step - loss: 1.4969 - val_loss: 1.4
302 - learning_rate: 5.0000e-04
Epoch 29/100
1337/1337  **310s** 232ms/step - loss: 1.4681 - val_loss: 0.2
352 - learning_rate: 5.0000e-04
Epoch 30/100
1337/1337  **310s** 232ms/step - loss: 1.4752 - val_loss: 0.5
724 - learning_rate: 5.0000e-04
Epoch 31/100
1337/1337  **309s** 231ms/step - loss: 1.2929 - val_loss: 0.2
432 - learning_rate: 5.0000e-04
Epoch 32/100
1337/1337  **0s** 217ms/step - loss: 1.4099
Epoch 32: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.
1337/1337  **311s** 232ms/step - loss: 1.4100 - val_loss: 0.4
548 - learning_rate: 5.0000e-04
Epoch 33/100
1337/1337  **309s** 231ms/step - loss: 0.9900 - val_loss: 0.1
493 - learning_rate: 2.5000e-04
Epoch 34/100
1337/1337  **310s** 232ms/step - loss: 0.8494 - val_loss: 0.0
876 - learning_rate: 2.5000e-04
Epoch 35/100
1337/1337  **309s** 231ms/step - loss: 0.7734 - val_loss: 0.1
031 - learning_rate: 2.5000e-04
Epoch 36/100
1337/1337  **309s** 231ms/step - loss: 0.8068 - val_loss: 0.0
898 - learning_rate: 2.5000e-04
Epoch 37/100
1337/1337  **0s** 216ms/step - loss: 0.7384
Epoch 37: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.
1337/1337  **309s** 231ms/step - loss: 0.7384 - val_loss: 0.3
407 - learning_rate: 2.5000e-04
Epoch 38/100
1337/1337  **309s** 231ms/step - loss: 0.5499 - val_loss: 0.0
755 - learning_rate: 1.2500e-04
Epoch 39/100
1337/1337  **309s** 231ms/step - loss: 0.5192 - val_loss: 0.0
585 - learning_rate: 1.2500e-04
Epoch 40/100
1337/1337  **309s** 231ms/step - loss: 0.5005 - val_loss: 0.0

509 - learning_rate: 1.2500e-04
Epoch 41/100
1337/1337  **309s** 231ms/step - loss: 0.5020 - val_loss: 0.0
582 - learning_rate: 1.2500e-04
Epoch 42/100
1337/1337  **309s** 231ms/step - loss: 0.4783 - val_loss: 0.0
468 - learning_rate: 1.2500e-04
Epoch 43/100
1337/1337  **309s** 231ms/step - loss: 0.4049 - val_loss: 0.0
440 - learning_rate: 1.2500e-04
Epoch 44/100
1337/1337  **308s** 231ms/step - loss: 0.4563 - val_loss: 0.0
444 - learning_rate: 1.2500e-04
Epoch 45/100
1337/1337  **308s** 231ms/step - loss: 0.3918 - val_loss: 0.0
456 - learning_rate: 1.2500e-04
Epoch 46/100
1337/1337  **0s** 216ms/step - loss: 0.4717
Epoch 46: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.
1337/1337  **309s** 231ms/step - loss: 0.4717 - val_loss: 0.0
478 - learning_rate: 1.2500e-04
Epoch 47/100
1337/1337  **308s** 231ms/step - loss: 0.4283 - val_loss: 0.0
356 - learning_rate: 6.2500e-05
Epoch 48/100
1337/1337  **309s** 231ms/step - loss: 0.3911 - val_loss: 0.0
381 - learning_rate: 6.2500e-05
Epoch 49/100
1337/1337  **309s** 231ms/step - loss: 0.3156 - val_loss: 0.0
401 - learning_rate: 6.2500e-05
Epoch 50/100
1337/1337  **309s** 231ms/step - loss: 0.3051 - val_loss: 0.0
340 - learning_rate: 6.2500e-05
Epoch 51/100
1337/1337  **309s** 231ms/step - loss: 0.3377 - val_loss: 0.0
343 - learning_rate: 6.2500e-05
Epoch 52/100
1337/1337  **309s** 231ms/step - loss: 0.3083 - val_loss: 0.0
322 - learning_rate: 6.2500e-05
Epoch 53/100
1337/1337  **309s** 231ms/step - loss: 0.2663 - val_loss: 0.0
333 - learning_rate: 6.2500e-05
Epoch 54/100
1337/1337  **309s** 231ms/step - loss: 0.2813 - val_loss: 0.0
346 - learning_rate: 6.2500e-05
Epoch 55/100
1337/1337  **0s** 216ms/step - loss: 0.2923
Epoch 55: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.
1337/1337  **309s** 231ms/step - loss: 0.2923 - val_loss: 0.0
366 - learning_rate: 6.2500e-05
Epoch 56/100
1337/1337  **309s** 231ms/step - loss: 0.2928 - val_loss: 0.0
349 - learning_rate: 3.1250e-05
Epoch 57/100
1337/1337  **309s** 231ms/step - loss: 0.2579 - val_loss: 0.0
364 - learning_rate: 3.1250e-05



```
In [51]: # Model Summary  
ocr_model.summary()
```

Model: "functional"

Layer (type)	Output Shape	Param #	Connected to
image (InputLayer)	(None, 200, 50, 1)	0	-
conv2d (Conv2D)	(None, 200, 50, 32)	320	image[0][0]
batch_normalization (BatchNormalizatio...	(None, 200, 50, 32)	128	conv2d[0][0]
conv2d_1 (Conv2D)	(None, 200, 50, 32)	9,248	batch_normaliz
batch_normalizatio... (BatchNormalizatio...	(None, 200, 50, 32)	128	conv2d_1[0][0]
max_pooling2d (MaxPooling2D)	(None, 100, 25, 32)	0	batch_normaliz
conv2d_2 (Conv2D)	(None, 100, 25, 64)	18,496	max_pooling2d[
batch_normalizatio... (BatchNormalizatio...	(None, 100, 25, 64)	256	conv2d_2[0][0]
conv2d_3 (Conv2D)	(None, 100, 25, 128)	73,856	batch_normaliz
batch_normalizatio... (BatchNormalizatio...	(None, 100, 25, 128)	512	conv2d_3[0][0]
max_pooling2d_1 (MaxPooling2D)	(None, 50, 12, 128)	0	batch_normaliz
reshape (Reshape)	(None, 50, 1536)	0	max_pooling2d_
dense (Dense)	(None, 50, 128)	196,736	reshape[0][0]
dropout (Dropout)	(None, 50, 128)	0	dense[0][0]
bidirectional (Bidirectional)	(None, 50, 512)	788,480	dropout[0][0]
bidirectional_1 (Bidirectional)	(None, 50, 256)	656,384	bidirectional[
label (InputLayer)	(None, None)	0	-
dense_1 (Dense)	(None, 50, 52)	13,364	bidirectional_
ctc_layer (CTCLayer)	(None, 50, 52)	0	label[0][0], dense_1[0][0]

Total params: 5,272,702 (20.11 MB)

Trainable params: 1,757,396 (6.70 MB)

Non-trainable params: 512 (2.00 KB)

Optimizer params: 3,514,794 (13.41 MB)

Creates an inference model from the trained OCR model for

making predictions and prints the model summary.

```
In [52]: inference_model = keras.Model(  
        inputs=ocr_model.input[0], # Use only the first input if multiple  
        outputs=ocr_model.get_layer(name="dense_1").output # Adjust output layer  
        )
```

```
In [53]: print(decode_pred(inference_model.predict(test_ds))[:10]) #convert to test_
```

/home/psyduck/anaconda3/envs/renaissance/lib/python3.9/site-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the expected structure.
Expected: image

Received: inputs=['Tensor(shape=(16, 200, 50, 1))']
warnings.warn(msg)

53/54 ————— 0s 58ms/step

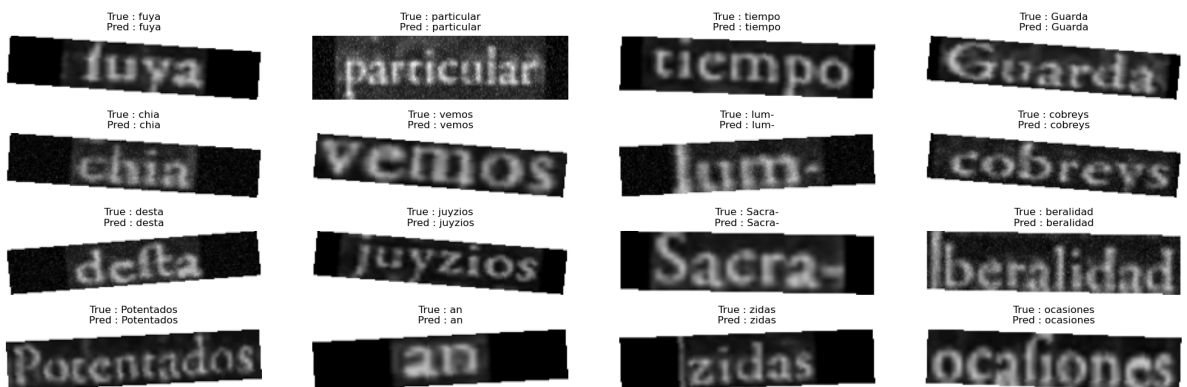
/home/psyduck/anaconda3/envs/renaissance/lib/python3.9/site-packages/keras/src/models/functional.py:237: UserWarning: The structure of `inputs` doesn't match the expected structure.
Expected: image

Received: inputs=['Tensor(shape=(None, 200, 50, 1))']
warnings.warn(msg)

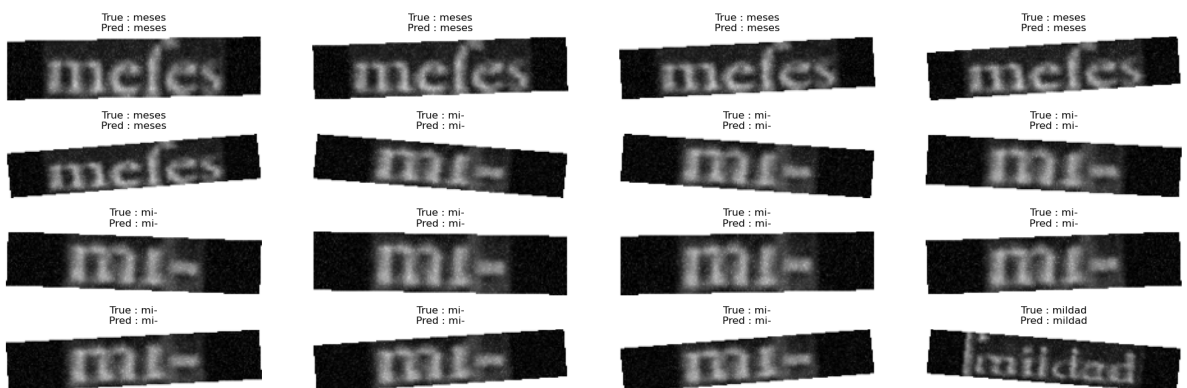
54/54 ————— 4s 65ms/step

['Si', 'por', 'evitar', 'un', 'pecado', 'mortal', 'aveys', 'de', 'poner', 'vueftra']

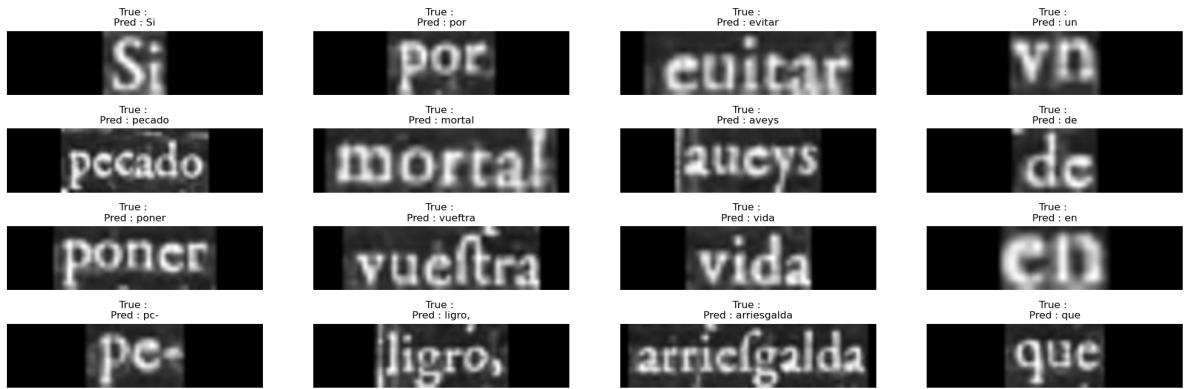
```
In [54]: show_images(data=train_ds, model=inference_model, decode_pred=decode_pred, cm
```



```
In [55]: show_images(data=valid_ds, model=inference_model, decode_pred=decode_pred, cm
```



```
In [56]: show_images(data=test_ds, model=inference_model, decode_pred=decode_pred, cma
```



Saving the model

```
In [57]: # Saving the model
ocr_model.save('ocr_model.keras')
```

Generates and decodes predictions from the inference model on the test dataset, printing the results as it is written in the book.

```
In [58]: test_csv.head()
```

```
Out[58]:
```

	FILENAME	IDENTITY
0	./testing_data1/0;0.png	0;0
1	./testing_data1/1;0.png	1;0
2	./testing_data1/2;0.png	2;0
3	./testing_data1/3;0.png	3;0
4	./testing_data1/4;0.png	4;0

```
In [59]: df_infer = test_csv

# Step 1: Sort the dataframe based on values before ';'
df_infer['before_semicolon'] = df_infer['IDENTITY'].apply(lambda x: int(x.split(';')[0]))
df_infer['after_semicolon'] = df_infer['IDENTITY'].apply(lambda x: int(x.split(';')[1]))
sorted_df = df_infer.sort_values(['before_semicolon']).reset_index(drop=True)
sorted_df.drop(columns=['before_semicolon', 'after_semicolon'], inplace=True)
```

```
In [60]: sorted_df.shape
```

```
Out[60]: (855, 2)
```

```
In [61]: sorted_df.head()
```


Out[61]:

	FILENAME	IDENTITY
0	./testing_data1/0;0.png	0;0
1	./testing_data1/1;0.png	1;0
2	./testing_data1/2;0.png	2;0
3	./testing_data1/3;0.png	3;0
4	./testing_data1/4;0.png	4;0

```
In [62]: sorted_df['IDENTITY'] = sorted_df['IDENTITY'].astype(str)

sorted_dfs = tf.data.Dataset.from_tensor_slices(
    (np.array(sorted_df['FILENAME']).to_list()), np.array(sorted_df['IDENTITY']
).map(encode_single_sample, num_parallel_calls=AUTOTUNE).batch(BATCH_SIZE).pr

decoded_predictions = decode_pred(inference_model.predict(sorted_dfs))
```

54/54 ————— 3s 55ms/step

```
In [63]: sorted_df.head()
```

Out[63]:

	FILENAME	IDENTITY
0	./testing_data1/0;0.png	0;0
1	./testing_data1/1;0.png	1;0
2	./testing_data1/2;0.png	2;0
3	./testing_data1/3;0.png	3;0
4	./testing_data1/4;0.png	4;0

```
In [64]: pred = sorted_df['IDENTITY'].tolist()

# Print decoded predictions with a new line when there's a change in the numb
current_group = None
i=0
for prediction in pred:
    before, after = map(int, prediction.split(';'))

    if current_group is None:
        current_group = after

    if after != current_group:
        print() # Start a new line for the new group
        current_group = after

    print(decoded_predictions[i], end=' ')
    i+=1
print()
```

Si por evitar un pecado mortal
 aveys de poner vueftra vida en pc-
 ligro, arriesgaldá que es el mevor
 empleo que della podeys hazer
 de vueftra hazienda para efte fin en
 redemir cautivos sacar mugeres
 de pecado, dotandolas liberalmen-
 te- dixo hagás el bjen
 Caton nunca
 sleyo titrye Templm, Obe fe sepa dad pues voy fin
 put qualquiera obra con que
 huyreye labipocresia, pero tam-
 poco escondays las que han de ser
 de buen exsmpto pues es obliga-
 cion de personas tales el darlo y lol
 contrario tentacien en algunos So
 ha gays profession de santero pe-
 ro de buen Christiano no apro-
 veymas tampoco reproveys santi-
 dades dudosas fino estimad las cier-
 tas, y aprobadas y a esto toca el no
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 imitad patroci aquella esperan-
 za en Dios f tan gloriea probada del
 gran Patriarcha Abraham y hazed Ca-
 como dezia el Santo Padre Francif-
 co de Poria todas las posibles dili-
 gencias en los negocios como sino
 huviera Dios Dero no fiando en nin-
 guna sino solo en el No comuni-
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 confusion mil tro-
 piezos en fu ciencia mas dado caso
 que fuera segura fi anuncian algun
 bien, y ha de venir, es tormento
 esperarle, y se estima en menos qua-
 do llega fi no fale cierto lo es la
 pena de tal engado pues fi mal pata
 que se ha de anticipar el sentimien-
 to del, aviendo de Teor fino por
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 sera
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 dispuesto a dar por fu Fe, honra la
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 pes, a quien illustro incomparable-
 mente
 mente mas el derramar feanEms, e0ie estacav-
 fa fu sangre que el heredado
 tan generosa, vivid determinado
 de no perder ocasion en servirle
 cumplir fu voluntad
 q vuestro Consessorlo- escogc
 reys espiritual docto yot hombrei realce
 gran talento tened mirad respeto
 dadle autoridad para que os diga
 lbremente quantas verdades a vue-
 ftra alma lmporten en las cosas to-
 cantes a ella obedecedle entera-

mente con todo rendimiento y tal
 que no admitays razon para lo que
 os ord enare en esfas, materias por
 no perder el merito dela Fe,y obe-
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 le con las partes dichas no avra peli
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 injusto fque es propiedad ree igno
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 mas
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 a negociacion de las cosas pias,
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 el qual siendo a proposito no muda-
 reys, fino ojos mas no poder y aquí Reli- os
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 giones Tempaenma,e el amor que ehta di
 cho en materia no os ateys
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 suieto,se ha de buscar para esto,y no
 todala Religion ser cadal
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 otra ocupacibn, y no useys de almo-
 hada en estas ocasiones rezasedes
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 ro
 rio cada dia, cuya devocion seleslu
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 jovi Ten cos lly Vll y a otros muchos Los
 y- Lunes Oficio de disuntos Los Vier
 nes los Psalmos Penirenciales, Of
 cio dela Crvz,y un rato de oracion,
 procurad no perderle pensando en
 clsin para que fuystes criado y
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 portante Cada q
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 examen de vuestra concien
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 en el otro mundo como sucedio
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 mo ftrad con particularidad que
 soys Christiano celebrando con
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que
que proceda de vivo sentimlento
interior la Passion de Christo e y se
ria bien retiraros a un Convento
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vandos despuBs los pies besan
los clos, costumbte loable de todoss
los Reyes Christianos,
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aya ocupacion que os lo estorve
que son insinitas las ganancias des-
to como dizen San Cirilo, y San Ci- Peosi-
prianoero sea en la Iglesia q no en sita
calalaundu en ella aveys de tener caro
oratorio muy brien adornado, y de- co ur
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mente vueftra vexas ge Dero vos
le tend reys, de que Capellanes
sean virtuosos no hagays esperar
al que os ha de dezir la Missa renes
tido, que c grande indecencia ni
seays de los que reprehende S ojo gu ai
tin porque buscan Missas breves
Cuydad mirad de escogerlos Sa
cerdotes

Saving predictions as .txt file

```
In [65]: formatted_output = []

current_group = None
i = 0
for prediction in pred:
    before, after = map(int, prediction.split(';'))

    if current_group is None:
        current_group = after

    if after != current_group:
        formatted_output.append('\n') # Start a new line for the new group
        current_group = after

    formatted_output.append(decoded_predictions[i] + ' ')
    i += 1

formatted_output.append('\n') # Final new line

with open('formatted_predictions.txt', 'w') as file:
    file.writelines(formatted_output)
```

```
In [66]: predictions = decode_pred(inference_model.predict(valid_ds))
true = df_valid['IDENTITY'].tolist()
```

335/335 ————— 20s 60ms/step

```
In [67]: import numpy as np
from difflib import SequenceMatcher

def calculate_cer(predicted, ground_truth):
    # Calculate the Levenshtein distance between the predicted and ground tru
```

```

matcher = SequenceMatcher(None, ground_truth, predicted)
num_edits = sum(triple[-1] for triple in matcher.get_opcodes() if triple[0] != triple[1])

# CER is the number of edits divided by the total number of characters in ground_truth
return num_edits / len(ground_truth) if len(ground_truth) > 0 else 1.0

def calculate_accuracy(true_list, predictions_list):
    correct_count = sum([pred == gt for pred, gt in zip(predictions_list, true_list)])
    return correct_count / len(true_list)

# Calculate CER for each word and the overall Accuracy
cer_list = [calculate_cer(pred, gt) for pred, gt in zip(predictions, true)]
cer = np.mean(cer_list)

accuracy = calculate_accuracy(true, predictions)

print(f"Character Error Rate (CER): {cer}")
print(f"Accuracy: {accuracy}")

```

Character Error Rate (CER): 0.0
Accuracy: 1.0

In [68]:

```

sorted_df = tf.data.Dataset.from_tensor_slices(
    (np.array(sorted_df['FILENAME']).to_list(), np.array(sorted_df['IDENTITY']
).map(encode_single_sample, num_parallel_calls=AUTOTUNE).batch(BATCH_SIZE).pr
show_images(data=sorted_df, model=inference_model, decode_pred=decode_pred, c

```

