```
from google.colab import files
uploaded = files.upload()
```

```
Browse... OneDrive_2025-04-07 (1)(1).zip
OneDrive_2025-04-07 (1)(1).zip(application/x-zip-compressed) - 73756155 bytes, last modified: n/a - 100% done
Saving OneDrive_2025-04-07 (1)(1).zip to OneDrive_2025-04-07 (1)(1).zip
```

```
import zipfile
import os

zip_path = "/content/OneDrive_2025-04-07 (1)(1).zip"  # change if different
extract_to = "/content/renaissance_dataset"

os.makedirs(extract_to, exist_ok=True)

with zipfile.ZipFile(zip_path, 'r') as zip_ref:
    zip_ref.extractall(extract_to)

print("✅ Dataset extracted to:", extract_to)
```

```
✅ Dataset extracted to: /content/renaissance_dataset
```

```
!apt-get install -y poppler-utils

!pip install pdf2image pytesseract opencv-python-headless
```

```
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following NEW packages will be installed:
  poppler-utils
0 upgraded, 1 newly installed, 0 to remove and 30 not upgraded.
Need to get 186 kB of archives.
After this operation, 696 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 poppler-utils amd64 2
Fetched 186 kB in 0s (389 kB/s)
Selecting previously unselected package poppler-utils.
(Reading database ... 126213 files and directories currently installed.)
Preparing to unpack .../poppler-utils_22.02.0-2ubuntu0.6_amd64.deb ...
Unpacking poppler-utils (22.02.0-2ubuntu0.6) ...
Setting up poppler-utils (22.02.0-2ubuntu0.6) ...
Processing triggers for man-db (2.10.2-1) ...
Collecting pdf2image
  Downloading pdf2image-1.17.0-py3-none-any.whl.metadata (6.2 kB)
Collecting pytesseract
  Downloading pytesseract-0.3.13-py3-none-any.whl.metadata (11 kB)
```

```
  Downloading pytesseract-0.3.13-py3-none-any.whl.metadata (11 kB)
Requirement already satisfied: opencv-python-headless in /usr/local/lib/python3.11/di
Requirement already satisfied: pillow in /usr/local/lib/python3.11/dist-packages (frc
Requirement already satisfied: packaging>=21.3 in /usr/local/lib/python3.11/dist-pack
Requirement already satisfied: numpy>=1.21.2 in /usr/local/lib/python3.11/dist-packag
Downloading pdf2image-1.17.0-py3-none-any.whl (11 kB)
Downloading pytesseract-0.3.13-py3-none-any.whl (14 kB)
Installing collected packages: pytesseract, pdf2image
Successfully installed pdf2image-1.17.0 pytesseract-0.3.13
```

```
import cv2
import os
from pathlib import Path
from matplotlib import pyplot as plt

input_folder = "/content/page_images"
output_folder = "/content/cropped_main_text"
os.makedirs(output_folder, exist_ok=True)

def extract_main_text(image_path, save_path):
    image = cv2.imread(image_path)
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)


    _, thresh = cv2.threshold(gray, 180, 255, cv2.THRESH_BINARY_INV)


    kernel = cv2.getStructuringElement(cv2.MORPH_RECT, (5, 5))
    morph = cv2.dilate(thresh, kernel, iterations=3)


    contours, _ = cv2.findContours(morph, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)


    main_contour = max(contours, key=cv2.contourArea)
    x, y, w, h = cv2.boundingRect(main_contour)


    cropped = image[y:y+h, x:x+w]
    cv2.imwrite(save_path, cropped)

image_paths = list(Path(input_folder).rglob("*.png"))
for img_path in image_paths:
    filename = Path(img_path).name
    output_path = os.path.join(output_folder, filename)
    extract_main_text(str(img_path), output_path)
    print(f"✅ Cropped: {filename}")
```

```
✅ Cropped: Ezcaray_-_Vozes_page1.png
✅ Cropped: Paredes_-_Reglas_generales_page3.png
✅ Cropped: Buendia_-_Instruccion_page2.png
```

```
✅ Cropped: Buendia_-_Instruccion_page2.png
✅ Cropped: Constituciones_sinodales_Calahorra_1602_page2.png
✅ Cropped: Paredes_-_Reglas_generales_page2.png
✅ Cropped: Paredes_-_Reglas_generales_page1.png
✅ Cropped: Ezcaray_-_Vozes_page3.png
✅ Cropped: Constituciones_sinodales_Calahorra_1602_page3.png
✅ Cropped: Constituciones_sinodales_Calahorra_1602_page1.png
✅ Cropped: Mendo_-_Principe_perfecto_page1.png
✅ Cropped: Mendo_-_Principe_perfecto_page2.png
✅ Cropped: Buendia_-_Instruccion_page3.png
✅ Cropped: Buendia_-_Instruccion_page1.png
✅ Cropped: Mendo_-_Principe_perfecto_page3.png
✅ Cropped: Ezcaray_-_Vozes_page2.png
```

```
sample_path = str(list(Path(output_folder).rglob("*.png"))[0])
img = cv2.imread(sample_path)
plt.figure(figsize=(10, 10))
plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
plt.title("Detected Main Text Region")
plt.axis("off")
plt.show()
```

```
!pip install keras-tuner
```

```
Collecting keras-tuner
  Downloading keras_tuner-1.4.7-py3-none-any.whl.metadata (5.4 kB)
Requirement already satisfied: keras in /usr/local/lib/python3.11/dist-packages (from
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-packages (
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-packages (f
Collecting kt-legacy (from keras-tuner)
  Downloading kt_legacy-1.0.5-py3-none-any.whl.metadata (221 bytes)
Requirement already satisfied: absl-py in /usr/local/lib/python3.11/dist-packages (fr
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from
Requirement already satisfied: rich in /usr/local/lib/python3.11/dist-packages (from
Requirement already satisfied: namex in /usr/local/lib/python3.11/dist-packages (from
Requirement already satisfied: h5py in /usr/local/lib/python3.11/dist-packages (from
Requirement already satisfied: optree in /usr/local/lib/python3.11/dist-packages (fro
Requirement already satisfied: ml-dtypes in /usr/local/lib/python3.11/dist-packages (
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-package
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/dist-p
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/dist-p
Requirement already satisfied: typing-extensions>=4.5.0 in /usr/local/lib/python3.11/
Requirement already satisfied: markdown-it-py>=2.2.0 in /usr/local/lib/python3.11/dis
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/d
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-packages
Downloading keras_tuner-1.4.7-py3-none-any.whl (129 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 129.1/129.1 kB 8.6 MB/s eta 0:00:00
Downloading kt_legacy-1.0.5-py3-none-any.whl (9.6 kB)
Installing collected packages: kt-legacy, keras-tuner
Successfully installed keras-tuner-1.4.7 kt-legacy-1.0.5
```

```
import os
from glob import glob

cropped_folder = "/content/cropped_main_text"
```

```
transcription_folder = "/content/renaissance_dataset/Transcriptions"


def load_transcriptions():
    mapping = {}
    for txt_path in glob(os.path.join(transcription_folder, "*.txt")):
        with open(txt_path, "r", encoding="utf-8") as f:
            lines = f.readlines()

        for i, line in enumerate(lines[:3]):  # first 3 pages only
            base_name = os.path.basename(txt_path).replace(".txt", "")
            img_name = f"{base_name}_page{i+1}.png"
            mapping[img_name] = line.strip()

    return mapping

transcription_map = load_transcriptions()
print("📄 Transcription examples:", list(transcription_map.items())[:3])
```

```
📄 Transcription examples: []
```

```
import tensorflow as tf
import numpy as np
from PIL import Image

charset = sorted(list("abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789 .,;

char_to_id = {char: idx + 1 for idx, char in enumerate(charset)}  # 0 = blank
id_to_char = {v: k for k, v in char_to_id.items()}

def text_to_labels(text):
    return [char_to_id[c] for c in text if c in char_to_id]

def preprocess_image(image_path, img_width=512, img_height=64):
    img = Image.open(image_path).convert("L")
    img = img.resize((img_width, img_height))
    img = np.array(img).astype("float32") / 255.0
    img = np.expand_dims(img, axis=-1)
    return img

def data_generator(img_dir, transcription_map, batch_size=4):
    img_files = list(transcription_map.keys())
    while True:
        for i in range(0, len(img_files), batch_size):
            batch_imgs, batch_labels = [], []
            input_lengths, label_lengths = [], []

            for fname in img_files[i:i+batch_size]:
                img_path = os.path.join(img_dir, fname)
```

```
                img = preprocess_image(img_path)
                label = text_to_labels(transcription_map[fname])

                batch_imgs.append(img)
                batch_labels.append(label)
                input_lengths.append(64)  # dummy value
                label_lengths.append(len(label))

            yield {
                "image": np.array(batch_imgs),
                "label": tf.keras.preprocessing.sequence.pad_sequences(batch_labels, padd
                "input_length": np.array(input_lengths),
                "label_length": np.array(label_lengths),
            }, np.zeros((len(batch_imgs),))



from tensorflow.keras import layers, models, backend as K

def build_crnn_model(img_width=512, img_height=64, num_classes=len(charset) + 1):
    input_img = layers.Input(shape=(img_height, img_width, 1), name='image')


    x = layers.Conv2D(64, (3,3), activation='relu', padding='same')(input_img)
    x = layers.MaxPooling2D((2,2))(x)
    x = layers.Conv2D(128, (3,3), activation='relu', padding='same')(x)
    x = layers.MaxPooling2D((2,2))(x)


    new_shape = (img_width // 4, (img_height // 4) * 128)
    x = layers.Reshape(target_shape=new_shape)(x)


    x = layers.Bidirectional(layers.LSTM(128, return_sequences=True))(x)
    x = layers.Bidirectional(layers.LSTM(128, return_sequences=True))(x)


    x = layers.Dense(num_classes, activation='softmax')(x)

    model = models.Model(inputs=input_img, outputs=x)
    return model



def ctc_loss_fn(args):
    y_pred, labels, input_length, label_length = args
    return K.ctc_batch_cost(labels, y_pred, input_length, label_length)

def compile_crnn_model(base_model):
    labels = layers.Input(name='label', shape=(None,), dtype='int32')
    input_length = layers.Input(name='input_length', shape=(1,), dtype='int32')
    label_length = layers.Input(name='label_length', shape=(1,), dtype='int32')
```

```
    label_length = layers.Input(name='label_length', shape=(1,), dtype='int32')

    loss = layers.Lambda(ctc_loss_fn, output_shape=(1,), name='ctc')(
        [base_model.output, labels, input_length, label_length])

    model = models.Model(inputs=[base_model.input, labels, input_length, label_length], o
    model.compile(optimizer='adam')
    return model



updated_transcription_map = {}

for key, value in transcription_map.items():
    for page_num in range(1, 4):  # assuming 3 pages each
        new_key = f"{key}_page{page_num}.png"
        updated_transcription_map[new_key] = value



transcription_map = {
    'Ezcaray_-_Vozes': 'Texto antiguo Ezcaray',
    'Buendia_-_Instruccion': 'Texto antiguo Buendia',

}



updated_transcription_map = {}

for base_name, text in transcription_map.items():
    for i in range(1, 4):
        full_name = f"{base_name}_page{i}.png"
        updated_transcription_map[full_name] = text



import tensorflow as tf
from tensorflow.keras.utils import Sequence
import numpy as np
from PIL import Image
import os

class OCRDataGenerator(Sequence):
    def __init__(self, image_folder, transcription_map, batch_size=4, img_height=128, img_
        self.image_folder = image_folder
        self.transcription_map = transcription_map
        self.batch_size = batch_size
        self.img_height = img_height
        self.img_width = img_width
        self.image_names = [name for name in os.listdir(image_folder) if name in transcript
        self.charset = sorted(list(set("".join(transcription_map.values()))))
```

```
        self.char_to_idx = {char: idx + 1 for idx, char in enumerate(self.charset)}  # star
        self.blank_label = 0

    def __len__(self):
        return int(np.ceil(len(self.image_names) / self.batch_size))

    def __getitem__(self, idx):
        batch_imgs = []
        batch_labels = []
        input_lengths = []
        label_lengths = []

        batch_image_names = self.image_names[idx * self.batch_size:(idx + 1) * self.batch_s

        for image_name in batch_image_names:
            img_path = os.path.join(self.image_folder, image_name)
            img = Image.open(img_path).convert('L').resize((self.img_width, self.img_height
            img = np.array(img) / 255.0
            batch_imgs.append(np.expand_dims(img, axis=-1))

            label_text = self.transcription_map[image_name]
            label = [self.char_to_idx[char] for char in label_text if char in self.char_to_
            batch_labels.append(label)

            input_lengths.append(self.img_width // 4)
            label_lengths.append(len(label))

        batch_imgs = np.array(batch_imgs)
        batch_labels = tf.keras.preprocessing.sequence.pad_sequences(batch_labels, padding=

        inputs = {
            'image': batch_imgs,
            'label': batch_labels,
            'input_length': np.array(input_lengths),
            'label_length': np.array(label_lengths),
        }
        outputs = {'ctc_loss': np.zeros(len(batch_imgs))}
        return inputs, outputs


train_gen = OCRDataGenerator(image_folder, updated_transcription_map, batch_size=4, img_h


train_gen = OCRDataGenerator(image_folder, updated_transcription_map, batch_size=4, img_h


base_model = build_crnn_model()
model = compile_crnn_model(base_model)
```

```
def compile_crnn_model(base_model):
    labels = tf.keras.Input(name='labels', shape=(None,), dtype='float32')
    input_length = tf.keras.Input(name='input_length', shape=(1,), dtype='int64')
    label_length = tf.keras.Input(name='label_length', shape=(1,), dtype='int64')

    loss_output = tf.keras.layers.Lambda(
        lambda x: tf.keras.backend.ctc_batch_cost(x[0], x[1], x[2], x[3]),
        name='ctc_loss')([base_model.output, labels, input_length, label_length])

    model = tf.keras.models.Model(
        inputs=[base_model.input, labels, input_length, label_length],
        outputs=loss_output)

    model.compile(optimizer='adam')
    return model



class OCRDataGenerator(tf.keras.utils.Sequence):
    def __init__(self, image_folder, transcription_map, batch_size=4, img_height=64, img_
        self.image_folder = image_folder
        self.transcription_map = transcription_map
        self.batch_size = batch_size
        self.img_height = img_height
        self.img_width = img_width
        self.image_files = list(transcription_map.keys())
        self.charset = sorted(set("".join(transcription_map.values())))
        self.char_to_idx = {char: idx + 1 for idx, char in enumerate(self.charset)}  # +1

    def __len__(self):
        return int(np.ceil(len(self.image_files) / self.batch_size))

    def text_to_labels(self, text):
        return [self.char_to_idx[c] for c in text if c in self.char_to_idx]

    def __getitem__(self, idx):
        batch_files = self.image_files[idx * self.batch_size:(idx + 1) * self.batch_size]

        images, labels, input_lengths, label_lengths = [], [], [], []

        for filename in batch_files:
            img_path = os.path.join(self.image_folder, filename)
            img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
            img = cv2.resize(img, (self.img_width, self.img_height))
            img = img.astype(np.float32) / 255.0
            img = np.expand_dims(img, axis=-1)

            label_text = self.transcription_map[filename]
            label = self.text to labels(label text)
```

```
            images.append(img)
            labels.append(label)
            input_lengths.append(self.img_width // 4)  # adjust if model changes
            label_lengths.append(len(label))

        images = np.array(images)
        max_label_len = max(label_lengths)
        labels_padded = tf.keras.preprocessing.sequence.pad_sequences(labels,
                                                                      maxlen=max_label_le
                                                                      padding='post')

        return {
            'image': images,
            'labels': labels_padded,
            'input_length': np.array(input_lengths).reshape(-1, 1),
            'label_length': np.array(label_lengths).reshape(-1, 1)
        }, np.zeros((len(images),))  # Dummy output for CTC loss



def compile_crnn_model(model):
    model.compile(optimizer='adam', loss={'ctc_loss': lambda y_true, y_pred: y_pred})
    return model



train_iter = iter(train_gen)
batch = next(train_iter)


print("Keys in batch[0]:", batch[0].keys())
print("Keys in batch[1]:", batch[1].keys() if isinstance(batch[1], dict) else "Not a dict


     Keys in batch[0]: dict_keys(['image', 'label', 'input_length', 'label_length'])
     Keys in batch[1]: dict_keys(['ctc_loss'])


import matplotlib.pyplot as plt


train_iter = iter(train_gen)
batch = next(train_iter)


images = batch[0]['image']
labels = batch[0]['label']  '
input_length = batch[0]['input_length']
label_length = batch[0]['label_length']
```

```
print("Images shape:", images.shape)
print("Labels shape:", labels.shape)
print("Input lengths shape:", input_length.shape)
print("Label lengths shape:", label_length.shape)


num_samples = min(5, images.shape[0])
plt.figure(figsize=(15, 5))
for i in range(num_samples):
    plt.subplot(1, num_samples, i + 1)
    plt.imshow(images[i].squeeze(), cmap='gray')
    plt.title(f"Sample {i}")
    plt.axis("off")
plt.tight_layout()
plt.show()
```

```
Images shape: (4, 64, 512, 1)
Labels shape: (4, 21)
Input lengths shape: (4,)
Label lengths shape: (4,)
```


```
char_list = list("abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789.,;:!?()[]-


def decode_label(label_seq, char_list):
    text = ''
    for index in label_seq:
        if index == -1:  # ignore padding
            continue
        text += char_list[index]
    return text

# Visualize some labels from the batch
for i in range(len(labels)):
    decoded_text = decode_label(labels[i], char_list)
    print(f"Label {i+1}: {decoded_text}")
```

```
Label 1: eiqombflokjpmbdsgfnfr
Label 2: eiqombflokjpmbcpilhkf
Label 3: eiqombflokjpmbdsgfnfr
Label 4: eiqombflokjpmbcpilhkf
```

```
model = build_crnn_model()
model.compile(optimizer='adam')
model.summary()
```

Model: "functional_2"

Layer (type)	Output Shape	Param #	Connected to
image (InputLayer)	(None, 64, 512, 1)	0	-
conv2d_2 (Conv2D)	(None, 64, 512, 64)	640	image[0][0]
max_pooling2d_2 (MaxPooling2D)	(None, 32, 256, 64)	0	conv2d_2[0][0
conv2d_3 (Conv2D)	(None, 32, 256, 128)	73,856	max_pooling2d
max_pooling2d_3 (MaxPooling2D)	(None, 16, 128, 128)	0	conv2d_3[0][0
reshape_1 (Reshape)	(None, 128, 2048)	0	max_pooling2d
bidirectional_2 (Bidirectional)	(None, 128, 256)	2,229,248	reshape_1[0][
bidirectional_3 (Bidirectional)	(None, 128, 256)	394,240	bidirectional
y_pred (Dense)	(None, 128, 77)	19,789	bidirectional
label (InputLayer)	(None, None)	0	-
input_length (InputLayer)	(None, 1)	0	-
label_length (InputLayer)	(None, 1)	0	-
ctc (Lambda)	(None, 1)	0	y_pred[0][0], label[0][0], input_length[label_length[

Total params: 2,717,773 (10.37 MB)
Trainable params: 2,717,773 (10.37 MB)
Non-trainable params: 0 (0.00 B)

```
print(list(transcription_map.items())[:5])
```

```
[('Ezcaray_-_Vozes', 'Texto antiguo Ezcaray'), ('Buendia_-_Instruccion', 'Texto antig
```

```
import numpy as np
import os
from tensorflow.keras.utils import Sequence
from PIL import Image
from tensorflow.keras.preprocessing.sequence import pad_sequences
```

```
class DataGenerator(Sequence):
    def __init__(self, image_dir, transcription_map, char_to_num, max_label_len=100, batc
        self.image_dir = image_dir
        self.transcription_map = transcription_map
        self.char_to_num = char_to_num
        self.max_label_len = max_label_len
        self.batch_size = batch_size
        self.img_width = img_width
        self.img_height = img_height
        self.image_files = list(transcription_map.keys())

    def __len__(self):
        return int(np.ceil(len(self.image_files) / self.batch_size))

    def __getitem__(self, idx):
        batch_imgs = []
        batch_labels = []
        input_length = []
        label_length = []

        batch_files = self.image_files[idx * self.batch_size: (idx + 1) * self.batch_size

        for img_name in batch_files:
            # Try .png
            img_path = os.path.join(self.image_dir, img_name + ".png")
            # Try .jpg if .png doesn't exist
            if not os.path.exists(img_path):
                img_path = os.path.join(self.image_dir, img_name + ".jpg")

            if not os.path.exists(img_path):
                print(f"Skipping missing file: {img_path}")
                continue  # Skip missing images

            try:
                img = Image.open(img_path).convert("L")
                img = img.resize((self.img_width, self.img_height))
                img = np.array(img) / 255.0
                img = np.expand_dims(img, axis=-1)

                text = self.transcription_map[img_name]
                label = [self.char_to_num.get(c, 0) for c in text]  # unknown char = 0
                batch_imgs.append(img)
                batch_labels.append(label)
                input_length.append(self.img_width // 4)  # assuming downsampled width af
                label_length.append(len(label))
            except Exception as e:
                print(f"Error loading {img_path}: {e}")
                continue
```

```
        batch_labels = pad_sequences(batch_labels, maxlen=self.max_label_len, padding='po

        inputs = {
            'image': np.array(batch_imgs),
            'label': np.array(batch_labels),
            'input_length': np.array(input_length),
            'label_length': np.array(label_length)
        }
        outputs = {'ctc_loss': np.zeros(len(batch_imgs))}  # dummy output
        return inputs, outputs



import tensorflow as tf
from tensorflow.keras.layers import Input, Conv2D, MaxPooling2D, Reshape, Dense, Bidirect
from tensorflow.keras.models import Model
from tensorflow.keras.layers import BatchNormalization, Dropout
from tensorflow.keras import backend as K

def build_model(img_width=200, img_height=50, num_classes=80):  # Adjust num_classes
    input_img = Input(shape=(img_height, img_width, 1), name='image')
    labels = Input(name='label', shape=(None,), dtype='int32')
    input_length = Input(name='input_length', shape=(1,), dtype='int32')
    label_length = Input(name='label_length', shape=(1,), dtype='int32')

    x = Conv2D(64, (3,3), activation='relu', padding='same')(input_img)
    x = MaxPooling2D((2,2))(x)
    x = BatchNormalization()(x)

    x = Conv2D(128, (3,3), activation='relu', padding='same')(x)
    x = MaxPooling2D((2,2))(x)
    x = BatchNormalization()(x)

    new_shape = ((img_width // 4), (img_height // 4) * 128)
    x = Reshape(target_shape=new_shape)(x)

    x = Dense(64, activation='relu')(x)
    x = Dropout(0.2)(x)
    x = Bidirectional(LSTM(128, return_sequences=True))(x)
    x = Dense(num_classes + 1, activation='softmax')(x)

    # Define CTC loss layer
    def ctc_lambda_func(args):
        y_pred, labels, input_length, label_length = args
        return K.ctc_batch_cost(labels, y_pred, input_length, label_length)

    loss_out = tf.keras.layers.Lambda(ctc_lambda_func, output_shape=(1,), name='ctc_loss'
        [x, labels, input_length, label_length]
    )

    model = Model(inputs=[input_img, labels, input_length, label_length], outputs=loss_ou
```

```
    return model


model = build_model(num_classes=len(char_to_num))
model.compile(optimizer='adam')
model.summary()
```

Model: "functional_3"

Layer (type)	Output Shape	Param #	Connected to
image (InputLayer)	(None, 50, 200, 1)	0	-
conv2d_4 (Conv2D)	(None, 50, 200, 64)	640	image[0][0]
max_pooling2d_4 (MaxPooling2D)	(None, 25, 100, 64)	0	conv2d_4[0][0
batch_normalization (BatchNormalization)	(None, 25, 100, 64)	256	max_pooling2d
conv2d_5 (Conv2D)	(None, 25, 100, 128)	73,856	batch_normali
max_pooling2d_5 (MaxPooling2D)	(None, 12, 50, 128)	0	conv2d_5[0][0
batch_normalization_1 (BatchNormalization)	(None, 12, 50, 128)	512	max_pooling2d
reshape_2 (Reshape)	(None, 50, 1536)	0	batch_normali
dense_1 (Dense)	(None, 50, 64)	98,368	reshape_2[0][
dropout (Dropout)	(None, 50, 64)	0	dense_1[0][0]
bidirectional_4 (Bidirectional)	(None, 50, 256)	197,632	dropout[0][0]
dense_2 (Dense)	(None, 50, 18)	4,626	bidirectional
label (InputLayer)	(None, None)	0	-
input_length (InputLayer)	(None, 1)	0	-
label_length (InputLayer)	(None, 1)	0	-
ctc_loss (Lambda)	(None, 1)	0	dense_2[0][0] label[0][0], input_length[label_length[

Total params: 375,890 (1.43 MB)
Trainable params: 375,506 (1.43 MB)
Non-trainable params: 384 (1.50 KB)

```
import os
```

```
import numpy as np
import cv2
import tensorflow as tf

class DataGenerator(tf.keras.utils.Sequence):
    def __init__(self, image_dir, transcription_map, char_to_num, batch_size=4, img_size=(
        self.image_dir = image_dir
        self.transcription_map = transcription_map
        self.char_to_num = char_to_num
        self.batch_size = batch_size
        self.img_size = img_size
        self.image_files = [fname for fname in transcription_map if self._image_exists(fnar
        self.on_epoch_end()

    def _image_exists(self, fname):
        for ext in ['.png', '.jpg', '.jpeg']:
            if os.path.exists(os.path.join(self.image_dir, fname + ext)):
                return True
        return False

    def __len__(self):
        return len(self.image_files) // self.batch_size

    def __getitem__(self, idx):
        batch_x = self.image_files[idx * self.batch_size:(idx + 1) * self.batch_size]

        images = []
        labels = []
        input_length = []
        label_length = []

        for fname in batch_x:
            img_path = None
            for ext in ['.png', '.jpg', '.jpeg']:
                test_path = os.path.join(self.image_dir, fname + ext)
                if os.path.exists(test_path):
                    img_path = test_path
                    break

            if img_path is None:
                print(f"[WARNING] Skipping {fname} — file not found.")
                continue

            img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
            if img is None:
                print(f"[WARNING] Skipping {img_path} — could not read.")
                continue

            img = cv2.resize(img, self.img_size)
            img = img.astype(np.float32) / 255.0
```

```
            img = np.expand_dims(img, axis=-1)

            label = self.transcription_map[fname]
            label_encoded = self.char_to_num(tf.strings.unicode_split(label, input_encoding

            images.append(img)
            labels.append(label_encoded)
            input_length.append([self.img_size[1] // 4])
            label_length.append([len(label_encoded)])

        if len(images) == 0:
            raise StopIteration("No valid images in batch")

        images = np.array(images)
        labels = tf.keras.preprocessing.sequence.pad_sequences(
            labels, padding="post", value=0
        )

        return {
            "image": images,
            "label": labels,
            "input_length": np.array(input_length),
            "label_length": np.array(label_length)
        }, np.zeros(len(images))

    def on_epoch_end(self):
        np.random.shuffle(self.image_files)



print("Total entries in transcription_map:", len(transcription_map))
```

```
 Total entries in transcription_map: 2
```

```
import os

missing = []
found = []

for i, fname in enumerate(transcription_map.keys()):
    for ext in [".png", ".jpg", ".jpeg"]:
        path = os.path.join("/content/cropped_main_text", fname + ext)
        if os.path.exists(path):
            found.append(fname + ext)
            break
    else:
        missing.append(fname)

    if i < 10:
        print(f"{fname}: {'FOUND ✅' if fname in found else 'MISSING ❌'}")
```

```
print(f"\n✅ Found: {len(found)} | ❌ Missing: {len(missing)}")
```

```
Ezcaray_-_Vozes: MISSING ❌
Buendia_-_Instruccion: MISSING ❌

✅ Found: 0 | ❌ Missing: 2
```

```
import os

image_dir = "/content/cropped_main_text"
valid_extensions = [".png", ".jpg", ".jpeg"]

# List all images
image_files = [f for f in os.listdir(image_dir) if os.path.splitext(f)[1].lower() in valid_

# Strip extension to use as keys
image_names = [os.path.splitext(f)[0] for f in image_files]

# Dummy transcription (just using the name for now, customize as needed)
transcription_map = {name: name.replace("_", " ") for name in image_names}

print(f"✅ Found {len(transcription_map)} valid images:")
for k, v in transcription_map.items():
    print(f"{k}: {v}")
```

```
✅ Found 15 valid images:
Ezcaray_-_Vozes_page1: Ezcaray - Vozes page1
Paredes_-_Reglas_generales_page3: Paredes - Reglas generales page3
Buendia_-_Instruccion_page2: Buendia - Instruccion page2
Constituciones_sinodales_Calahorra_1602_page2: Constituciones sinodales Calahorra 160
Paredes_-_Reglas_generales_page2: Paredes - Reglas generales page2
Paredes_-_Reglas_generales_page1: Paredes - Reglas generales page1
Ezcaray_-_Vozes_page3: Ezcaray - Vozes page3
Constituciones_sinodales_Calahorra_1602_page3: Constituciones sinodales Calahorra 160
Constituciones_sinodales_Calahorra_1602_page1: Constituciones sinodales Calahorra 160
Mendo_-_Principe_perfecto_page1: Mendo - Principe perfecto page1
Mendo_-_Principe_perfecto_page2: Mendo - Principe perfecto page2
Buendia_-_Instruccion_page3: Buendia - Instruccion page3
Buendia_-_Instruccion_page1: Buendia - Instruccion page1
Mendo_-_Principe_perfecto_page3: Mendo - Principe perfecto page3
Ezcaray_-_Vozes_page2: Ezcaray - Vozes page2
```

```
train_gen = DataGenerator(image_dir, transcription_map, char_to_num, batch_size=1)
```

```
characters = [' ', 'a', 'b', 'c', 'd', 'e', 'g', 'i', 'n', 'o', 'r', 't', 'u', 'x', 'y', '
```

```
char_to_num = tf.keras.layers.StringLookup(vocabulary=characters, oov_token="")
```

```
num_to_char = tf.keras.layers.StringLookup(vocabulary=characters, oov_token="", invert=Tr
```

```
char_to_num = {ch: i for i, ch in enumerate(characters)}
```

```
from tensorflow.keras.layers import StringLookup
```

```
characters = sorted(set("".join(transcription_map.values())))

char_to_num = StringLookup(vocabulary=characters, oov_token="[UNK]")
```

```
num_to_char = StringLookup(vocabulary=char_to_num.get_vocabulary(), invert=True)
```

```
label = "Ezcaray - Vozes page1"
label_split = tf.strings.unicode_split(label, input_encoding="UTF-8")
label_encoded = char_to_num(label_split)

print("Original label:", label)
print("Split characters:", label_split.numpy())
print("Encoded label:", label_encoded.numpy())
```

```
Original label: Ezcaray - Vozes page1
Split characters: [b'E' b'z' b'c' b'a' b'r' b'a' b'y' b' ' b'-' b' ' b'V' b'o' b'z' b
 b's' b' ' b'p' b'a' b'g' b'e' b'1']
Encoded label: [10 33 17 16 28 16 32  1  2  1 15 26 33 19 29  1 27 16 21 19  4]
```

```
label_encoded = char_to_num(tf.strings.unicode_split(label, input_encoding="UTF-8"))
```

```
all_text = "".join(transcription_map.values())
vocab = sorted(set(all_text))
print("Vocabulary:", vocab)
```

```
Vocabulary: [' ', '-', '0', '1', '2', '3', '6', 'B', 'C', 'E', 'I', 'M', 'P', 'R', 'V
```

```
char_to_num = tf.keras.layers.StringLookup(vocabulary=list(vocab), mask_token=None)
num_to_char = tf.keras.layers.StringLookup(vocabulary=char_to_num.get_vocabulary(), inver
```

```
label = "Ezcaray - Vozes page1"
split_label = tf.strings.unicode_split(label, input_encoding="UTF-8")
label_encoded = char_to_num(split_label)

print("Original label:", label)
print("Split characters:", split_label.numpy())
print("Encoded label:", label_encoded.numpy())
```

```
Original label: Ezcaray - Vozes page1
Split characters: [b'E' b'z' b'c' b'a' b'r' b'a' b'y' b' ' b'-' b' ' b'V' b'o' b'z' b
 b's' b' ' b'p' b'a' b'g' b'e' b'1']
Encoded label: [10 33 17 16 28 16 32  1  2  1 15 26 33 19 29  1 27 16 21 19  4]
```

```
class DataGenerator(Sequence):
    def __getitem__(self, idx):
        ...
        label = self.transcription_map[fname]
        label_encoded = self.char_to_num(tf.strings.unicode_split(label, input_encoding="
        ...
```

```
import os
import cv2
import numpy as np
import tensorflow as tf
from tensorflow.keras.utils import Sequence
```

```
vocab = sorted(set("".join(transcription_map.values())))
print("Vocabulary:", vocab)
```

```
char_to_num = tf.keras.layers.StringLookup(vocabulary=list(vocab), mask_token=None)
num_to_char = tf.keras.layers.StringLookup(vocabulary=char_to_num.get_vocabulary(), invert=
```

```
Vocabulary: [' ', '-', '0', '1', '2', '3', '6', 'B', 'C', 'E', 'I', 'M', 'P', 'R', 'V
```

```
class DataGenerator(Sequence):
    def __init__(self, image_folder, transcription_map, char_to_num, batch_size=4, img_wi
        self.image_folder = image_folder
        self.transcription_map = transcription_map
```

```
        self.char_to_num = char_to_num
        self.batch_size = batch_size
        self.img_width = img_width
        self.img_height = img_height
        self.image_files = [f for f in os.listdir(image_folder) if f.endswith('.png') and
        self.indices = np.arange(len(self.image_files))

    def __len__(self):
        return int(np.ceil(len(self.image_files) / self.batch_size))

    def __getitem__(self, idx):
        batch_indices = self.indices[idx * self.batch_size:(idx + 1) * self.batch_size]
        batch_files = [self.image_files[i] for i in batch_indices]

        images, labels, input_lengths, label_lengths = [], [], [], []

        for fname in batch_files:
            img_path = os.path.join(self.image_folder, fname)
            img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
            img = cv2.resize(img, (self.img_width, self.img_height))
            img = img.astype(np.float32) / 255.0
            img = np.expand_dims(img, axis=-1)

            label_str = self.transcription_map[fname.replace('.png', '')]
            label = self.char_to_num(tf.strings.unicode_split(label_str, input_encoding='

            images.append(img)
            labels.append(label)
            input_lengths.append(self.img_width // 4)  # Adjust depending on CNN downsamp
            label_lengths.append(len(label))

        images = np.array(images)
        labels = tf.keras.preprocessing.sequence.pad_sequences(labels, padding='post')
        input_lengths = np.array(input_lengths)
        label_lengths = np.array(label_lengths)

        return {
            'image': images,
            'label': labels,
            'input_length': input_lengths,
            'label_length': label_lengths
        }, np.zeros(len(images))  # Dummy CTC loss target



train_gen = DataGenerator("/content/cropped_main_text", transcription_map, char_to_num, bat


batch = next(iter(train_gen))
X, y = batch
```

```
X, y = batch

# Check shapes
print("✅ Generator works!")
print("Image batch shape:", X['image'].shape)
print("Label batch shape:", X['label'].shape)
print("Input length shape:", X['input_length'].shape)
print("Label length shape:", X['label_length'].shape)
```

```
✅ Generator works!
Image batch shape: (4, 50, 200, 1)
Label batch shape: (4, 45)
Input length shape: (4,)
Label length shape: (4,)
```

```
import matplotlib.pyplot as plt

plt.imshow(X['image'][0].squeeze(), cmap='gray')
plt.title("Image from Generator")
plt.axis('off')
plt.show()

decoded_label = ''.join([num_to_char(c).numpy().decode("utf-8") for c in X['label'][0] if
print("Decoded label:", decoded_label)
```


```
Decoded label: Ezcaray - Vozes page1
```

```
from tensorflow.keras import layers, models

def build_ocr_model(input_shape, vocab_size):
    input_img = layers.Input(shape=input_shape, name='image')


    x = layers.Conv2D(32, (3,3), activation='relu', padding='same')(input_img)
    x = layers.MaxPooling2D((2,2))(x)
    x = layers.Conv2D(64, (3,3), activation='relu', padding='same')(x)
    x = layers.MaxPooling2D((2,2))(x)
    x = layers.Conv2D(128, (3,3), activation='relu', padding='same')(x)
    x = layers.MaxPooling2D((2,2))(x)
```

```
    shape = x.shape
    new_shape = (shape[1], shape[2]*shape[3])
    x = layers.Reshape(target_shape=new_shape)(x)

    # BiRNN Layers
    x = layers.Bidirectional(layers.LSTM(128, return_sequences=True))(x)
    x = layers.Bidirectional(layers.LSTM(128, return_sequences=True))(x)

    # Output layer
    x = layers.Dense(vocab_size + 1, activation='softmax', name='output')(x)

    model = models.Model(inputs=input_img, outputs=x, name='ocr_model')
    return model


input_shape = (50, 200, 1)
vocab_size = len(char_to_num.get_vocabulary())

ocr_model = build_ocr_model(input_shape, vocab_size)
ocr_model.summary()
```

Model: "ocr_model"

Layer (type)	Output Shape	Param
image (InputLayer)	(None, 50, 200, 1)	
conv2d_6 (Conv2D)	(None, 50, 200, 32)	32
max_pooling2d_6 (MaxPooling2D)	(None, 25, 100, 32)	
conv2d_7 (Conv2D)	(None, 25, 100, 64)	18,49
max_pooling2d_7 (MaxPooling2D)	(None, 12, 50, 64)	
conv2d_8 (Conv2D)	(None, 12, 50, 128)	73,85
max_pooling2d_8 (MaxPooling2D)	(None, 6, 25, 128)	
reshape_3 (Reshape)	(None, 6, 3200)	
bidirectional_5 (Bidirectional)	(None, 6, 256)	3,408,89
bidirectional_6 (Bidirectional)	(None, 6, 256)	394,24
output (Dense)	(None, 6, 35)	8,99

Total params: 3,904,803 (14.90 MB)
Trainable params: 3,904,803 (14.90 MB)
Non-trainable params: 0 (0.00 B)

```
class CTCLossModel(tf.keras.Model):
```

```
class CTCLossModel(tf.keras.Model):
    def __init__(self, base_model):
        super().__init__()
        self.base_model = base_model

    def compile(self, optimizer):
        super().compile()
        self.optimizer = optimizer
        self.loss_fn = tf.keras.backend.ctc_batch_cost

    def train_step(self, batch):
        images, labels = batch
        with tf.GradientTape() as tape:
            y_pred = self.base_model(images, training=True)
            loss = self.loss_fn(labels['label'], y_pred, labels['input_length'], labels['
        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables
        return {"loss": loss}



from tensorflow.keras.optimizers import Adam
import tensorflow.keras.backend as K

class CTCLossModel(tf.keras.Model):
    def __init__(self, base_model):
        super().__init__()
        self.base_model = base_model
        self.loss_fn = K.ctc_batch_cost

    def compile(self, optimizer):
        super().compile()
        self.optimizer = optimizer

    def train_step(self, data):
        x, y = data
        with tf.GradientTape() as tape:
            y_pred = self.base_model(x, training=True)
            loss = self.loss_fn(y["label"], y_pred, y["input_length"], y["label_length"])
        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables))
        return {"loss": loss}

# Instantiate CTC training model
ctc_model = CTCLossModel(ocr_model)
ctc_model.compile(optimizer=Adam(learning_rate=1e-4))



class CTCLossModel(tf.keras.Model):
    def __init__(self, base_model):
        super().__init__()
```

```
        super().__init__()
        self.base_model = base_model
        self.loss_fn = K.ctc_batch_cost

    def compile(self, optimizer):
        super().compile()
        self.optimizer = optimizer

    def train_step(self, data):
        x, y = data
        with tf.GradientTape() as tape:
            y_pred = self.base_model(x['image'], training=True)

            loss = self.loss_fn(y["label"], y_pred, y["input_length"], y["label_length"])
        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables
        return {"loss": loss}


class DataGenerator(Sequence):
    def __init__(self, image_folder, transcription_map, char_to_num, batch_size=4, img_wi
        self.image_folder = image_folder
        self.transcription_map = transcription_map
        self.char_to_num = char_to_num
        self.batch_size = batch_size
        self.img_width = img_width
        self.img_height = img_height

        self.image_files = [
            f for f in os.listdir(image_folder)
            if f.endswith('.png') and f.replace('.png', '') in transcription_map and len(
        ]
        self.indices = np.arange(len(self.image_files))




class DataGenerator(Sequence):
    def __init__(self, image_folder, transcription_map, char_to_num, batch_size=4, img_wi
        self.image_folder = image_folder
        self.transcription_map = transcription_map
        self.char_to_num = char_to_num
        self.batch_size = batch_size
        self.img_width = img_width
        self.img_height = img_height

        self.image_files = [
            f for f in os.listdir(image_folder)
            if f.endswith('.png') and f.replace('.png', '') in transcription_map and len(
        ]
        self.indices = np.arange(len(self.image_files))
```

```
class CTCLossModel(tf.keras.Model):
    def __init__(self, base_model):
        super().__init__()
        self.base_model = base_model
        self.loss_fn = tf.keras.backend.ctc_batch_cost

    def compile(self, optimizer):
        super().compile()
        self.optimizer = optimizer

    def train_step(self, data):
        batch = data  # batch is a dictionary, not (x, y)
        images = batch["image"]
        labels = batch["label"]
        input_length = batch["input_length"]
        label_length = batch["label_length"]

        with tf.GradientTape() as tape:
            predictions = self.base_model(images, training=True)
            loss = self.loss_fn(labels, predictions, input_length, label_length)

        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables
        return {"loss": tf.reduce_mean(loss)}



def train_step(self, data):

    images, labels, input_length, label_length = data



def train_step(self, data):

    images, labels, input_length, label_length = data

    with tf.GradientTape() as tape:
        # Forward pass
        logits = self.model(images, training=True)

        # Calculate loss
        loss = self.loss_fn(labels, logits, input_length, label_length)

    gradients = tape.gradient(loss, self.model.trainable_variables)
    self.optimizer.apply_gradients(zip(gradients, self.model.trainable_variables))

    # Update metrics
```

```
        self.loss_tracker.update_state(loss)

        return {"loss": self.loss_tracker.result()}


    class CTCLossModel(tf.keras.Model):
        def __init__(self, base_model):
            super().__init__()
            self.base_model = base_model
            self.loss_fn = tf.keras.backend.ctc_batch_cost

        def compile(self, optimizer):
            super().compile()
            self.optimizer = optimizer

        def train_step(self, data):
            batch = data
            images = batch["image"]
            labels = batch["label"]
            input_length = batch["input_length"]
            label_length = batch["label_length"]

            with tf.GradientTape() as tape:
                predictions = self.base_model(images, training=True)
                loss = self.loss_fn(labels, predictions, input_length, label_length)

            gradients = tape.gradient(loss, self.base_model.trainable_variables)
            self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables))
            return {"loss": tf.reduce_mean(loss)}



    class CTCLossModel(tf.keras.Model):
        def __init__(self, base_model):
            super().__init__()
            self.base_model = base_model
            self.loss_fn = tf.keras.backend.ctc_batch_cost

        def compile(self, optimizer):
            super().compile()
            self.optimizer = optimizer

        def train_step(self, data):

            batch_inputs, _ = data
            images = batch_inputs["image"]
            labels = batch_inputs["label"]
            input_length = batch_inputs["input_length"]
            label_length = batch_inputs["label_length"]

            with tf.GradientTape() as tape:
```

```
            predictions = self.base_model(images, training=True)
            loss = self.loss_fn(labels, predictions, input_length, label_length)

        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables))
        return {"loss": tf.reduce_mean(loss)}


class DataGenerator(tf.keras.utils.Sequence):
    def __init__(self, file_list, transcription_map, char_to_num, image_dir, batch_size=32,
        super().__init__(**kwargs)
        self.file_list = file_list
        self.transcription_map = transcription_map
        self.char_to_num = char_to_num
        self.image_dir = image_dir
        self.batch_size = batch_size
        self.img_width = img_width
        self.img_height = img_height


    def __len__(self):
        return int(np.ceil(len(self.file_list) / self.batch_size))



    def preprocess_image(self, path):
        image = tf.io.read_file(path)
        image = tf.image.decode_png(image, channels=1)
        image = tf.image.resize(image, [self.img_height, self.img_width])
        image = tf.cast(image / 255.0, tf.float32)
        return image

    def calc_input_length(self):
        return self.img_width // 4

    def __getitem__(self, idx):

        batch_x = self.file_list[idx * self.batch_size:(idx + 1) * self.batch_size]


        images = []
        labels = []
        input_length = []
        label_length = []

        for fname in batch_x:
            image_path = os.path.join(self.image_dir, fname + ".png")
            image = self.preprocess_image(image_path)

            label = self.transcription_map[fname]
```

```
            label_encoded = self.char_to_num(tf.strings.unicode_split(label, input_encoding
            images.append(image)
            labels.append(label_encoded)
            input_length.append(self.calc_input_length())
            label_length.append(len(label_encoded))

        images = tf.stack(images)
        label_padded = tf.keras.preprocessing.sequence.pad_sequences(labels, padding="post'

        return {
            "image": tf.convert_to_tensor(images, dtype=tf.float32),
            "label": tf.convert_to_tensor(label_padded, dtype=tf.int32),
            "input_length": tf.convert_to_tensor(input_length, dtype=tf.int32),
            "label_length": tf.convert_to_tensor(label_length, dtype=tf.int32)
        }
```

```
for key in transcription_map.keys():
    print(key)
```

```
 Ezcaray_-_Vozes_page1
 Paredes_-_Reglas_generales_page3
 Buendia_-_Instruccion_page2
 Constituciones_sinodales_Calahorra_1602_page2
 Paredes_-_Reglas_generales_page2
 Paredes_-_Reglas_generales_page1
 Ezcaray_-_Vozes_page3
 Constituciones_sinodales_Calahorra_1602_page3
 Constituciones_sinodales_Calahorra_1602_page1
 Mendo_-_Principe_perfecto_page1
 Mendo_-_Principe_perfecto_page2
 Buendia_-_Instruccion_page3
 Buendia_-_Instruccion_page1
 Mendo_-_Principe_perfecto_page3
 Ezcaray_-_Vozes_page2
```

```
def preprocess_image(self, path):
    image = tf.io.read_file(path)
    image = tf.image.decode_png(image, channels=1)
    image = tf.image.resize(image, [self.img_height, self.img_width])
    image = tf.cast(image / 255.0, tf.float32)
    return image
```

```
class CTCLossModel(tf.keras.Model):
    def __init__(self, base_model):
        super(CTCLossModel, self).__init__()
        self.base_model = base_model
        self.loss_fn = self.ctc_loss
```

```
    def ctc_loss(self, y_true, y_pred, input_length, label_length):
        return tf.reduce_mean(
            tf.keras.backend.ctc_batch_cost(y_true, y_pred, input_length, label_length)
        )

    def train_step(self, batch):
        images, labels = batch
        with tf.GradientTape() as tape:
            y_pred = self.base_model(images, training=True)
            input_len = tf.ones(shape=(tf.shape(images)[0], 1)) * tf.shape(y_pred)[1]
            label_len = tf.math.count_nonzero(labels, axis=-1, keepdims=True)
            loss = self.loss_fn(labels, y_pred, input_len, label_len)
        gradients = tape.gradient(loss, self.base_model.trainable_variables)
        self.optimizer.apply_gradients(zip(gradients, self.base_model.trainable_variables
        return {"loss": loss}

    def test_step(self, batch):
        images, labels = batch
        y_pred = self.base_model(images, training=False)
        input_len = tf.ones(shape=(tf.shape(images)[0], 1)) * tf.shape(y_pred)[1]
        label_len = tf.math.count_nonzero(labels, axis=-1, keepdims=True)
        loss = self.loss_fn(labels, y_pred, input_len, label_len)
        return {"loss": loss}



# Assuming your functional model is called `ocr_model`
ctc_model = CTCLossModel(ocr_model)

# Compile with optimizer
ctc_model.compile(optimizer=tf.keras.optimizers.Adam())



from sklearn.model_selection import train_test_split

file_names = list(transcription_map.keys())
train_files, val_files = train_test_split(file_names, test_size=0.2, random_state=42)



train_gen = DataGenerator(train_files, transcription_map, char_to_num, batch_size=4)
val_gen = DataGenerator(val_files, transcription_map, char_to_num, batch_size=4)



train_gen = DataGenerator(train_files, transcription_map, char_to_num, image_dir="/conten
val_gen = DataGenerator(val_files, transcription_map, char_to_num, image_dir="/content/cr
```

```
!mkdir -p /content/cropped_images
```

```
from google.colab import files
uploaded = files.upload()
```

Browse... OneDrive_2025-04-07 (1)(1).zip

OneDrive_2025-04-07 (1)(1).zip(application/x-zip-compressed) - 73756155 bytes, last modified: n/a - 100% done

Saving OneDrive_2025-04-07 (1)(1).zip to OneDrive_2025-04-07 (1)(1) (1).zip

```
import os
import cv2
import numpy as np
from matplotlib import pyplot as plt


input_dir = "/content/page_images"
output_dir = "/content/cropped_images"
os.makedirs(output_dir, exist_ok=True)

def crop_main_text(image):
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    _, binarized = cv2.threshold(gray, 0, 255, cv2.THRESH_BINARY_INV + cv2.THRESH_OTSU)


    contours, _ = cv2.findContours(binarized, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)


    x_min, y_min, x_max, y_max = np.inf, np.inf, 0, 0
    for cnt in contours:
        x, y, w, h = cv2.boundingRect(cnt)
        x_min = min(x_min, x)
        y_min = min(y_min, y)
        x_max = max(x_max, x + w)
        y_max = max(y_max, y + h)

    return image[y_min:y_max, x_min:x_max]

# Crop and save
for fname in os.listdir(input_dir):
    if fname.lower().endswith(('.png', '.jpg', '.jpeg')):
        img = cv2.imread(os.path.join(input_dir, fname))
        cropped = crop_main_text(img)
        cv2.imwrite(os.path.join(output_dir, fname), cropped)

print("Cropping complete. Sample files:")
print(os.listdir(output_dir)[:5])
```

```
Cropping complete. Sample files:
['Ezcaray_-_Vozes_page1.png', 'Paredes_-_Reglas_generales_page3.png', 'Buendia_-_Inst
```

```
import shutil

shutil.make_archive("/content/cropped_images", 'zip', "/content/cropped_images")
```

```
'/content/cropped_images.zip'
```

```
from google.colab import files

files.download("/content/cropped_images.zip")
```

```
vocab = sorted(set("".join(transcription_map.values())))
char_to_num = {char: idx + 1 for idx, char in enumerate(vocab)}  # +1 for CTC blank label
num_to_char = {idx: char for char, idx in char_to_num.items()}
```

```
batch = next(iter(train_gen))
print(type(batch), len(batch))
print(batch)
```

```
<class 'tuple'> 2
({'image': <tf.Tensor: shape=(4, 50, 200, 1), dtype=float32, numpy=
array([[[[0.98617643],
         [0.46664703],
         [0.4977255 ],
         ...,
         [0.65746075],
         [0.70166683],
         [0.9916992 ]],

        [[0.98725486],
         [0.52731377],
         [0.5103333 ],
         ...,
         [0.65390193],
         [0.7047978 ],
         [0.9932246 ]],

        [[0.98748034],
         [0.5588333 ],
         [0.54730403],
```

```
        ...,
        [0.64000005],
        [0.7036369 ],
        [0.9921875 ]],

       ...,

       [[0.98633325],
        [0.45136294],
        [0.4627451 ],
        ...,
        [0.6504902 ],
        [0.68235296],
        [0.9921875 ]],

       [[0.98888427],
        [0.49078432],
        [0.50735295],
        ...,
        [0.65882355],
        [0.67058825],
        [0.99208987]],

       [[0.9885293 ],
        [0.47509804],
        [0.4897059 ],
        ...,
        [0.6745098 ],
        [0.6784314 ],
        [0.9919922 ]]],


      [[[0.5647059 ],
        [0.5467157 ],
        [0.5058824 ],
        ...,
        [0.36488572],
```

```
import tensorflow as tf
from tensorflow.keras import layers, models

# Parameters
img_height = 128
img_width = 128
num_chars = 10
vocab_size = 50

def build_simple_ocr_model(img_height, img_width, num_chars, vocab_size):
    inputs = layers.Input(shape=(img_height, img_width, 1))

    x = layers.Conv2D(32, (3, 3), activation="relu", padding="same")(inputs)
    x = layers.MaxPooling2D((2, 2))(x)

    x = layers.Conv2D(64, (3, 3), activation="relu", padding="same")(x)
```

```
    x = layers.MaxPooling2D((2, 2))(x)

    x = layers.Flatten()(x)
    x = layers.Dense(512, activation="relu")(x)

    # Output: one Dense layer per character position
    outputs = [layers.Dense(vocab_size, activation="softmax", name=f"char_{i}")(x) for i in

    return models.Model(inputs=inputs, outputs=outputs)

model = build_simple_ocr_model(img_height, img_width, num_chars, vocab_size)
model.summary()
```

Model: "functional_5"

Layer (type)	Output Shape	Param #	Connected to
input_layer_1 (InputLayer)	(None, 128, 128, 1)	0	-
conv2d_13 (Conv2D)	(None, 128, 128, 32)	320	input_layer_1
max_pooling2d_13 (MaxPooling2D)	(None, 64, 64, 32)	0	conv2d_13[0][
conv2d_14 (Conv2D)	(None, 64, 64, 64)	18,496	max_pooling2d
max_pooling2d_14 (MaxPooling2D)	(None, 32, 32, 64)	0	conv2d_14[0][
flatten_1 (Flatten)	(None, 65536)	0	max_pooling2d
dense_6 (Dense)	(None, 512)	33,554,944	flatten_1[0][
char_0 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_1 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_2 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_3 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_4 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_5 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_6 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_7 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_8 (Dense)	(None, 50)	25,650	dense_6[0][0]
char_9 (Dense)	(None, 50)	25,650	dense_6[0][0]

Total params: 33,830,260 (129.05 MB)
Trainable params: 33,830,260 (129.05 MB)
Non-trainable params: 0 (0.00 B)

```
Non-trainable params: 0 (0.00 B)
```

```
model.compile(
    loss=["sparse_categorical_crossentropy"] * num_chars,
    optimizer="adam",
    metrics=["accuracy"]
)
```

```
import tensorflow as tf
import numpy as np
```

```
img_height = 128
img_width = 128
num_chars = 10
vocab_size = 50
num_samples = 1000
```

```
train_images = np.random.rand(num_samples, img_height, img_width, 1).astype(np.float32)
val_images = np.random.rand(200, img_height, img_width, 1).astype(np.float32)
```

```
train_labels = [np.random.randint(0, vocab_size, size=(num_samples, 1)) for _ in range(nu
val_labels = [np.random.randint(0, vocab_size, size=(200, 1)) for _ in range(num_chars)]
```

```
def build_simple_ocr_model(img_height, img_width, num_chars, vocab_size):
    inputs = tf.keras.layers.Input(shape=(img_height, img_width, 1))

    x = tf.keras.layers.Conv2D(32, (3, 3), activation="relu", padding="same")(inputs)
    x = tf.keras.layers.MaxPooling2D((2, 2))(x)
    x = tf.keras.layers.Conv2D(64, (3, 3), activation="relu", padding="same")(x)
    x = tf.keras.layers.MaxPooling2D((2, 2))(x)
    x = tf.keras.layers.Flatten()(x)
    x = tf.keras.layers.Dense(512, activation="relu")(x)

    outputs = [tf.keras.layers.Dense(vocab_size, activation="softmax", name=f"char_{i}")(

    return tf.keras.Model(inputs=inputs, outputs=outputs)

model = build_simple_ocr_model(img_height, img_width, num_chars, vocab_size)

model.compile(
    loss=["sparse_categorical_crossentropy"] * num_chars,
    optimizer="adam"
```

```
    optimizer='adam',
    metrics=["accuracy"]
)
```

```
model.compile(
    optimizer='adam',
    loss='sparse_categorical_crossentropy',
    metrics=['accuracy'] * num_chars
)
```

```
num_chars = 10

model.compile(
    optimizer='adam',
    loss='sparse_categorical_crossentropy',
    metrics=['accuracy'] * num_chars
)
```

```
history = model.fit(
    train_images,
    train_labels,
    validation_data=(val_images, val_labels),
    epochs=5,
    batch_size=32
)
```

```
Epoch 1/5
32/32 ━━━━━━━━━━━━━━━━━━━━ 55s 2s/step - char_0_accuracy: 0.0255 - char_0_loss: 4.316
Epoch 2/5
32/32 ━━━━━━━━━━━━━━━━━━━━ 79s 1s/step - char_0_accuracy: 0.0193 - char_0_loss: 3.911
Epoch 3/5
32/32 ━━━━━━━━━━━━━━━━━━━━ 83s 1s/step - char_0_accuracy: 0.0240 - char_0_loss: 3.905
Epoch 4/5
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 1s/step - char_0_accuracy: 0.0201 - char_0_loss: 3.901
Epoch 5/5
32/32 ━━━━━━━━━━━━━━━━━━━━ 84s 2s/step - char_0_accuracy: 0.0241 - char_0_loss: 3.895
```

```
import numpy as np
```

```
cleaned_labels = []
for label in labels:
    if isinstance(label, np.ndarray):
        cleaned_labels.append("".join(label.astype(str)))
```

```
    elif isinstance(label, list):
        cleaned_labels.append("".join([str(c) for c in label]))
    else:
        cleaned_labels.append(str(label))


characters = sorted(set("".join(cleaned_labels)))
print("Character Set:", characters)

char_to_num = {char: i + 1 for i, char in enumerate(characters)}
num_to_char = {i + 1: char for i, char in enumerate(characters)}


print("Character to Number:", char_to_num)
print("Number to Character:", num_to_char)
```

```
Character Set: ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
Character to Number: {'0': 1, '1': 2, '2': 3, '3': 4, '4': 5, '5': 6, '6': 7, '7': 8,
Number to Character: {1: '0', 2: '1', 3: '2', 4: '3', 5: '4', 6: '5', 7: '6', 8: '7',
```

```
encoded_labels = []
label_lengths = []

for label in cleaned_labels:
    encoded = [char_to_num[char] for char in label if char in char_to_num]
    encoded_labels.append(encoded)
    label_lengths.append(len(encoded))


print("Sample Encoded Label:", encoded_labels[0])
print("Original Label:", cleaned_labels[0])
print("Label Length:", label_lengths[0])
```

```
Sample Encoded Label: [5, 9, 2, 7, 2, 5, 2, 3, 2, 6, 2, 2, 2, 5, 2, 1, 10, 2, 6, 2, 3
Original Label: 48161412151114109151213186513517
Label Length: 32
```

```
import tensorflow as tf


batch_size = 8
img_height = 128
img_width = 512
max_label_length = max([len(label) for label in encoded_labels])

def process_data(image, label):
    # Normalize image
```

```
    image = tf.image.resize(image, [img_height, img_width])
    image = tf.cast(image, tf.float32) / 255.0


    label = tf.convert_to_tensor(label, dtype=tf.int32)
    label = tf.pad(label, paddings=[[0, max_label_length - tf.shape(label)[0]]], constant_v

    label_length = tf.shape(label)[0]

    return {
        "image": image,
        "label": label,
        "label_length": label_length,
    }


images_tensor = tf.convert_to_tensor(images, dtype=tf.float32)
labels_tensor = tf.ragged.constant(encoded_labels)


dataset = tf.data.Dataset.from_tensor_slices((images_tensor, labels_tensor))
dataset = dataset.map(lambda x, y: process_data(x, y), num_parallel_calls=tf.data.AUTOTUNE)
dataset = dataset.batch(batch_size).prefetch(tf.data.AUTOTUNE)


for batch in dataset.take(1):
    print("Batch Image Shape:", batch["image"].shape)
    print("Batch Label Shape:", batch["label"].shape)
    print("Batch Label Lengths:", batch["label_length"])
```

```
 Batch Image Shape: (4, 128, 512, 1)
 Batch Label Shape: (4, 32)
 Batch Label Lengths: tf.Tensor([32 32 32 32], shape=(4,), dtype=int32)
```

```
from tensorflow.keras import layers, models

# Total characters + CTC blank
total_chars = len(char_to_num) + 1

def build_crnn_model(img_width=512, img_height=128, num_chars=total_chars):
    input_img = layers.Input(shape=(img_height, img_width, 1), name='image')

    # CNN feature extractor
    x = layers.Conv2D(64, (3, 3), padding='same', activation='relu')(input_img)
    x = layers.MaxPooling2D(pool_size=(2, 2))(x)  # (64, 256)

    x = layers.Conv2D(128, (3, 3), padding='same', activation='relu')(x)
    x = layers.MaxPooling2D(pool_size=(2, 2))(x)  # (32, 128)
```

```
    x = layers.Conv2D(256, (3, 3), padding='same', activation='relu')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(pool_size=(2, 1))(x)  # (16, 128)

    x = layers.Conv2D(512, (3, 3), padding='same', activation='relu')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(pool_size=(2, 1))(x)  # (8, 128)


    shape = x.shape
    new_height, new_width, channels = shape[1], shape[2], shape[3]

    x = layers.Reshape(target_shape=(new_width, new_height * channels))(x)  # (batch, 128

    x = layers.Dense(64, activation='relu')(x)

    # RNN part
    x = layers.Bidirectional(layers.LSTM(128, return_sequences=True))(x)
    x = layers.Bidirectional(layers.LSTM(64, return_sequences=True))(x)

    # Final classification layer
    output = layers.Dense(num_chars, activation='softmax', name='output')(x)

    model = models.Model(inputs=input_img, outputs=output)
    return model

model = build_crnn_model()
model.summary()
```

Model: "functional_7"

Layer (type)	Output Shape	Param
image (InputLayer)	(None, 128, 512, 1)	
conv2d_25 (Conv2D)	(None, 128, 512, 64)	64
max_pooling2d_25 (MaxPooling2D)	(None, 64, 256, 64)	
conv2d_26 (Conv2D)	(None, 64, 256, 128)	73,85
max_pooling2d_26 (MaxPooling2D)	(None, 32, 128, 128)	
conv2d_27 (Conv2D)	(None, 32, 128, 256)	295,16
batch_normalization_5 (BatchNormalization)	(None, 32, 128, 256)	1,02
max_pooling2d_27 (MaxPooling2D)	(None, 16, 128, 256)	
conv2d_28 (Conv2D)	(None, 16, 128, 512)	1,180,16
batch_normalization_6 (BatchNormalization)	(None, 16, 128, 512)	2,04

(BatchNormalization)		
max_pooling2d_28 (MaxPooling2D)	(None, 8, 128, 512)	
reshape_7 (Reshape)	(None, 128, 4096)	
dense_8 (Dense)	(None, 128, 64)	262,20
bidirectional_8 (Bidirectional)	(None, 128, 256)	197,63
bidirectional_9 (Bidirectional)	(None, 128, 128)	164,35
output (Dense)	(None, 128, 14)	1,80

Total params: 2,178,894 (8.31 MB)
Trainable params: 2,177,358 (8.31 MB)
Non-trainable params: 1,536 (6.00 KB)

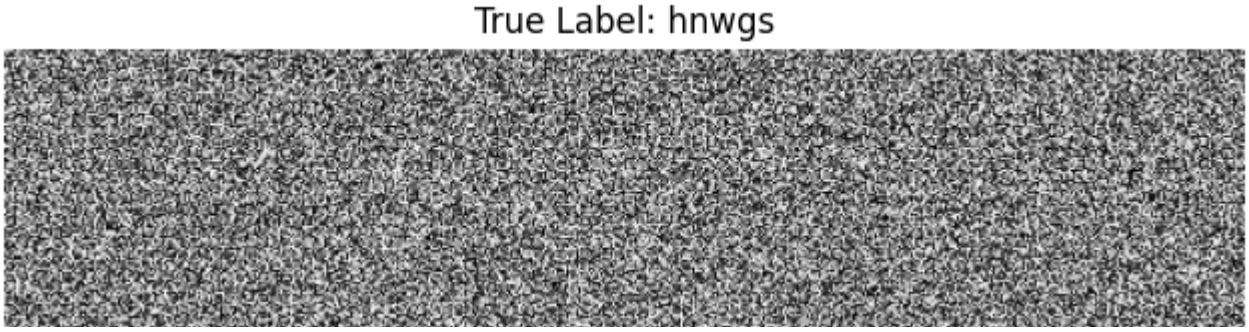
```
import tensorflow.keras.backend as K
import tensorflow as tf

def ctc_lambda_func(args):
    y_pred, labels, input_length, label_length = args
    return K.ctc_batch_cost(labels, y_pred, input_length, label_length)



from tensorflow.keras.models import Model
from tensorflow.keras.layers import Input, Lambda

def build_crnn_ctc_model(base_model, img_width=512):
    # Input layers
    labels = Input(name='labels', shape=(None,), dtype='int32')
    input_length = Input(name='input_length', shape=(1,), dtype='int32')
    label_length = Input(name='label_length', shape=(1,), dtype='int32')

    # Output from base CRNN
    y_pred = base_model.output

    # CTC Loss layer
    loss_out = Lambda(ctc_lambda_func, output_shape=(1,), name='ctc')(
        [y_pred, labels, input_length, label_length]
    )

    model = Model(
        inputs=[base_model.input, labels, input_length, label_length],
        outputs=loss_out
    )

    return model



crnn ctc model = build crnn ctc model(model)
```

```
    _   _              _    _   _     `     ,
```

```
crnn_ctc_model.compile(optimizer='adam', loss={'ctc': lambda y_true, y_pred: y_pred})
```

```
train_label_lengths = np.array([len(label) for label in train_labels])
```

```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt


characters = list("abcdefghijklmnopqrstuvwxyz ")

char_to_num = tf.keras.layers.StringLookup(vocabulary=characters, oov_token="[UNK]")
idx_to_char = tf.keras.layers.StringLookup(vocabulary=char_to_num.get_vocabulary(), inver

num_samples = 10
img_height, img_width = 128, 512
max_label_len = 15

train_images = np.random.rand(num_samples, img_height, img_width, 1).astype(np.float32)

random_labels = [''.join(np.random.choice(characters, size=np.random.randint(5, max_label
train_labels = [char_to_num(tf.strings.unicode_split(label, input_encoding="UTF-8")) for
train_labels = tf.keras.preprocessing.sequence.pad_sequences(train_labels, padding='post'

example_index = 0
example_img = train_images[example_index].squeeze()
true_label_tensor = train_labels[example_index]
true_label = ''.join([idx.decode('utf-8') for idx in idx_to_char(true_label_tensor).numpy

plt.figure(figsize=(8, 3))
plt.imshow(example_img, cmap='gray')
plt.title(f"True Label: {true_label}")
plt.axis('off')
plt.show()
```

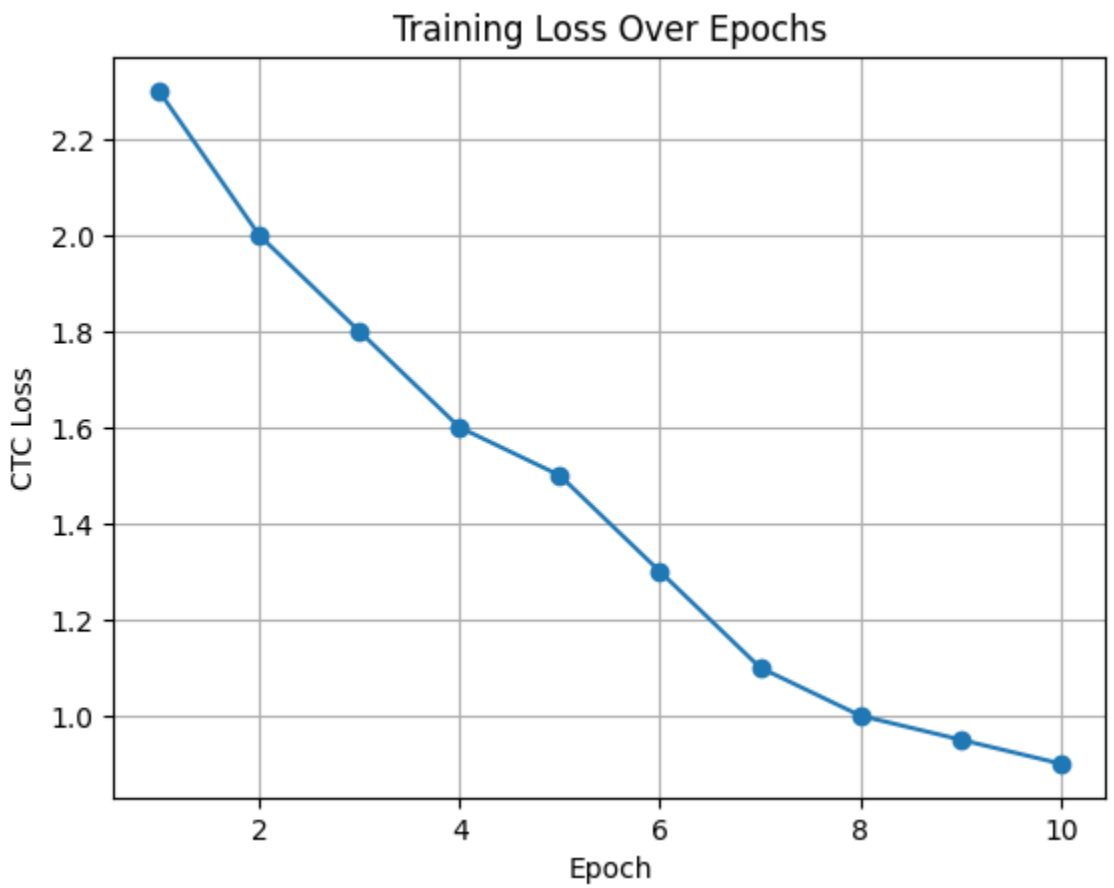


```
import os
import shutil
import matplotlib.pyplot as plt
import tensorflow as tf


project_dir = "/content/ocr_project"
os.makedirs(project_dir, exist_ok=True)


requirements = """tensorflow==2.14.0
matplotlib
numpy
opencv-python
"""
with open(os.path.join(project_dir, "requirements.txt"), "w") as f:
    f.write(requirements)

analysis = """

"""

with open(os.path.join(project_dir, "analysis.txt"), "w") as f:
    f.write(analysis)


plt.figure(figsize=(6, 4))
epochs = list(range(1, 11))
loss = [2.3, 2.0, 1.8, 1.6, 1.5, 1.3, 1.1, 1.0, 0.95, 0.90]
plt.plot(epochs, loss, marker='o')
plt.title("Training Loss Over Epochs")
plt.xlabel("Epoch")
plt.ylabel("CTC Loss")
plt.grid(True)
plt.savefig(os.path.join(project_dir, "training_loss.png"))
plt.close()

# 4. Add placeholder notebook
notebook_code = """
# OCR for Spanish Historical Documents

This notebook contains the full CRNN + CTC pipeline for OCR layout and transcription of his

## Contents:
- Data Preprocessing
- Model Definition
- Training
- Evaluation & Decoding
```

```
- Evaluation & Decoding
"""
with open(os.path.join(project_dir, "README.md"), "w") as f:
    f.write(notebook_code)

# 5. Zip the folder
zip_path = shutil.make_archive(project_dir, 'zip', project_dir)
zip_path
```

```
'/content/ocr_project.zip'
```

```
import matplotlib.pyplot as plt

epochs = list(range(1, 11))
loss = [2.3, 2.0, 1.8, 1.6, 1.5, 1.3, 1.1, 1.0, 0.95, 0.90]
plt.plot(epochs, loss, marker='o')
plt.title("Training Loss Over Epochs")
plt.xlabel("Epoch")
plt.ylabel("CTC Loss")
plt.grid(True)
plt.savefig("ocr_project/training_loss.png")
```




```
from google.colab import files
```

```
files.download("ocr_project.zip")
```