In [1]:

```
from tensorflow.keras.layers.experimental.preprocessing import StringLookup
from tensorflow import keras
import matplotlib.pyplot as plt
import tensorflow as tf
import numpy as np
import os
import xml.etree.ElementTree as ET
from tqdm.auto import tqdm
```

In [2]:

```
# def filter_data(data, len_range, max_space):
#     if data["label"] is None:
#         return False
#     if len(data["label"]) < len_range[0] or len(data["label"]) > len_range[1]:
#         return False
#     if data["label"].count(' ') > max_space:
#         return False
#     if data["label"].isascii() == False:
#         return False
#     for char in "\n\r\xad\xa0":
#         if char in data["label"]:
#             return False
#     return True

def filter_only_fonts(data):
    if data["image_path"].startswith("../../datasets/mjsynth/") == True:
        return False
    return True

def load_dataset(data_file_path, len_range, max_space, max_len=-1):
    dataset = []
    lines = open(data_file_path, "r").readlines()
    if max_len != -1:
        lines = lines[:max_len]
    for line in tqdm(lines):
        splitted_line = line.split(' ', 1)
        dataset.append({
            "image_path": splitted_line[0],
            "label": splitted_line[1].split('\n')[0]
        })
    # dataset = list(filter(lambda data: filter_data(data, len_range, max_space), dataset
))
    return dataset

dataset = load_dataset("./data.txt", len_range=(3, 32), max_space=3, max_len=582_103*2)
# dataset = list(filter(filter_only_fonts, tqdm(dataset)))
```

In [3]:

```
print(len(dataset))
# For computer vision deep learning, there is a consensus saying that a dataset of 1000 l
abeled images for each classes is needed
image_paths = list(map(lambda data: data["image_path"], dataset))
labels = list(map(lambda data: data["label"].replace('|',  '\n'), dataset))
np.random.shuffle(dataset)

train_ds = dataset[:int(0.98*len(dataset))] #98% of the whole dataset is train dataset
validation_ds = dataset[int(0.98*len(dataset)):int(0.99*len(dataset))] #1% is  validation
dataset
test_ds = dataset[int(0.99*len(dataset)):] #1% is test dataset


AUTOTUNE = tf.data.AUTOTUNE # Let tf decide the best tunning algos
```

```
characters = sorted(list(set(char for label in labels for char in label)))
max_len = len(max(labels, key=len))
print(max_len)
print(characters)
# Mapping characters to integer -> returns a function
char_to_num = StringLookup(vocabulary=list(characters), mask_token=None)

# Mapping integers back to original characters -> returns a function
num_to_char = StringLookup(vocabulary=char_to_num.get_vocabulary(), mask_token=None, inve
rt=True)

batch_size = 64
padding_token = 99
image_height = 64
image_width = image_height * 4

def distortion_free_resize(image, img_size):
    w, h = img_size
    image = tf.image.resize(image, size=(h, w), preserve_aspect_ratio=True)

    # Check tha amount of padding needed to be done.
    pad_height = h - tf.shape(image)[0]
    pad_width = w - tf.shape(image)[1]

    # Only necessary if you want to do same amount of padding on both sides.
    if pad_height % 2 != 0:
        height = pad_height // 2
        pad_height_top = height + 1
        pad_height_bottom = height
    else:
        pad_height_top = pad_height_bottom = pad_height // 2

    if pad_width % 2 != 0:
        width = pad_width // 2
        pad_width_left = width + 1
        pad_width_right = width
    else:
        pad_width_left = pad_width_right = pad_width // 2

    image = tf.pad(
        image,
        paddings=[
            [pad_height_top, pad_height_bottom],
            [pad_width_left, pad_width_right],
            [0, 0],
        ],
    )

    image = tf.transpose(image, perm=[1, 0, 2])
    image = tf.image.flip_left_right(image)
    return image

def preprocess_image(image_path, img_size=(image_width, image_height)):
    image = tf.io.read_file(image_path) # Open file with tf
    image = tf.image.decode_png(image, channels=1) # transform to matrix of gray scale v
alue
    image = distortion_free_resize(image, img_size) # Distort image
    image = tf.cast(image, tf.float32) / 255.0 # Transform image to data into matrix of
gray scale float32 values in range [0, 1]
    return image

def vectorize_label(label):
    label = char_to_num(tf.strings.unicode_split(label, input_encoding="UTF-8"))
    length = tf.shape(label)[0]
    pad_amount = max_len - length
    label = tf.pad(label, paddings=[[0, pad_amount]], constant_values=padding_token)
    return label

def process_images_labels(image_path, label):
    image = preprocess_image(image_path)
    label = vectorize_label(label)
    return {"image": image, "label": label}
```

```
def prepare_dataset(image_paths, labels):
    return tf.data.Dataset.from_tensor_slices(
        (image_paths, labels)
    ).map(
        process_images_labels, num_parallel_calls=AUTOTUNE
    ).batch(batch_size)
    # return tf.data.Dataset.from_tensor_slices(
    #     (image_paths, labels)
    # ).map(
    #     process_images_labels, num_parallel_calls=AUTOTUNE
    # ).batch(batch_size).cache().prefetch(AUTOTUNE)

train_ds = prepare_dataset(list(map(lambda data: data["image_path"], train_ds)), list(map
(lambda data: data["label"], train_ds)))
validation_ds = prepare_dataset(list(map(lambda data: data["image_path"], validation_ds))
, list(map(lambda data: data["label"], validation_ds)))
test_ds = prepare_dataset(list(map(lambda data: data["image_path"], test_ds)), list(map(
lambda data: data["label"], test_ds)))

class CTCLayer(keras.layers.Layer):
    def __init__(self, name=None):
        super().__init__(name=name)
        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_length = tf.cast(tf.shape(y_pred)[1], dtype="int64")
        label_length = tf.cast(tf.shape(y_true)[1], dtype="int64")

        input_length = input_length * tf.ones(shape=(batch_len, 1), dtype="int64")
        label_length = label_length * tf.ones(shape=(batch_len, 1), dtype="int64")
        loss = self.loss_fn(y_true, y_pred, input_length, label_length)
        self.add_loss(loss)

        # At test time, just return the computed predictions.
        return y_pred


def build_model():
    # Inputs to the model
    input_img = keras.Input(shape=(image_width, image_height, 1), name="image")
    labels = keras.layers.Input(name="label", shape=(None,))

    # First conv block.
    x = keras.layers.Conv2D(
        128,
        (3, 3),
        activation="relu",
        kernel_initializer="he_normal",
        padding="same",
        name="Conv1",
    )(input_img)
    x = keras.layers.MaxPooling2D((2, 2), name="pool1")(x)

    # Second conv block.
    x = keras.layers.Conv2D(
        128,
        (3, 3),
        activation="relu",
        kernel_initializer="he_normal",
        padding="same",
        name="Conv2",
    )(x)
    x = keras.layers.MaxPooling2D((2, 2), name="pool2")(x)

    # We have used two max pool with pool size and strides 2.
    # Hence, downsampled feature maps are 4x smaller. The number of
    # filters in the last layer is 64. Reshape accordingly before
    # passing the output to the RNN part of the model.
    new_shape = ((image_width // 4), (image_height // 4) * 128)
    x = keras.layers.Reshape(target_shape=new_shape, name="reshape")(x)
```

```
    x = keras.layers.Dense(128, activation="relu", name="dense1")(x)
    x = keras.layers.Dropout(0.2)(x)

    # RNNs.
    x = keras.layers.Bidirectional(
        keras.layers.LSTM(128, return_sequences=True, dropout=0.25)
    )(x)
    x = keras.layers.Bidirectional(
        keras.layers.LSTM(128, return_sequences=True, dropout=0.25)
    )(x)

    # +2 is to account for the two special tokens introduced by the CTC loss.
    # The recommendation comes here: https://git.io/J0eXP.
    x = keras.layers.Dense(
        len(char_to_num.get_vocabulary()) + 2, activation="softmax", name="dense2"
    )(x)

    # Add CTC layer for calculating CTC loss at each step.
    output = CTCLayer(name="ctc_loss", )(labels, x)

    # Define the model.
    model = keras.models.Model(
        inputs=[input_img, labels], outputs=output, name="handwriting_recognizer"
    )
    # Optimizer.
    # opt = keras.optimizers.Adam()
    opt = keras.optimizers.Adam()
    # Compile the model and return.
    model.compile(optimizer=opt)
    return model


# Get the model.
model = build_model()
#model.summary()
######## EVALUATION METRICS
validation_images = []
validation_labels = []

for batch in validation_ds:
    validation_images.append(batch["image"])
    validation_labels.append(batch["label"])

def calculate_edit_distance(labels, predictions):
    # Get a single batch and convert its labels to sparse tensors.
    saprse_labels = tf.cast(tf.sparse.from_dense(labels), dtype=tf.int64)

    # Make predictions and convert them to sparse tensors.
    input_len = np.ones(predictions.shape[0]) * predictions.shape[1]
    predictions_decoded = keras.backend.ctc_decode(
        predictions, input_length=input_len, greedy=True
    )[0][0][:, :max_len]
    sparse_predictions = tf.cast(
        tf.sparse.from_dense(predictions_decoded), dtype=tf.int64
    )

    # Compute individual edit distances and average them out.
    edit_distances = tf.edit_distance(
        sparse_predictions, saprse_labels, normalize=False
    )
    return tf.reduce_mean(edit_distances)


class EditDistanceCallback(keras.callbacks.Callback):
    def __init__(self, pred_model):
        super().__init__()
        self.prediction_model = pred_model

    def on_epoch_end(self, epoch, logs=None):
        edit_distances = []

        for i in range(len(validation_images)):
```

```
            labels = validation_labels[i]
            predictions = self.prediction_model.predict(validation_images[i])
            edit_distances.append(calculate_edit_distance(labels, predictions).numpy())

        print(
            f"Mean edit distance for epoch {epoch + 1}: {np.mean(edit_distances):.4f}"
        )

epochs = 10  # To get good results this should be at least 50.
model.summary()
model = build_model()
prediction_model = keras.models.Model(
    model.get_layer(name="image").input, model.get_layer(name="dense2").output
)

edit_distance_callback = EditDistanceCallback(prediction_model)

early_stopping_patience = 10
early_stopping = keras.callbacks.EarlyStopping(monitor="val_loss", patience=early_stoppin
g_patience, restore_best_weights=True)

CP_PATH = "./training/cp-{epoch:04d}.ckpt"
TEMP_CP_PATH = "TRAINING-ONLY-FONTS/cp-{epoch:04d}.ckpt"

# Create checkpoint
cp_callback = tf.keras.callbacks.ModelCheckpoint(
    filepath=CP_PATH,
    save_weights_only=True,
    verbose=1,
    # save_freq=5*batch_size #Only every 5 e^pochs
)

# Train the model.
history = model.fit(
    train_ds,
    validation_data=validation_ds,
    epochs=epochs,
    callbacks=[edit_distance_callback, cp_callback],
)
```

```
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32
[' ', '!', '"', '#', '$', '%', '&', "'", '(', ')', '*', '+', ',', '-', '.', '/', '0', '1'
, '2', '3', '4', '5', '6', '7', '8', '9', ':', ';', '=', '?', '@', 'A', 'B', 'C', 'D', 'E
', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', '
W', 'X', 'Y', 'Z', '[', ']', 'a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l',
'm', 'n', 'o', 'p', 'q', 'r', 's', 't', 'u', 'v', 'w', 'x', 'y', 'z']
Model: "handwriting_recognizer"
_________________________________________________________________________________________
_________
 Layer (type)                Output Shape              Param #     Connected to

==========================================================================================
=========
 image (InputLayer)          [(None, 256, 64, 1)  0           []

                             ]


 Conv1 (Conv2D)              (None, 256, 64, 128  1280        ['image[0][0]']

                             )


 pool1 (MaxPooling2D)        (None, 128, 32, 128  0           ['Conv1[0][0]']

                             )
```

```
 Conv2 (Conv2D)                 (None, 128, 32, 128  147584      ['pool1[0][0]']
                                )

 pool2 (MaxPooling2D)           (None, 64, 16, 128)  0           ['Conv2[0][0]']

 reshape (Reshape)              (None, 64, 2048)     0           ['pool2[0][0]']

 dense1 (Dense)                 (None, 64, 128)      262272      ['reshape[0][0]']

 dropout (Dropout)              (None, 64, 128)      0           ['dense1[0][0]']

 bidirectional (Bidirectional)  (None, 64, 256)      263168      ['dropout[0][0]']

 bidirectional_1 (Bidirectional  (None, 64, 256)     394240      ['bidirectional[0][0]']
 )

 label (InputLayer)             [(None, None)]       0           []

 dense2 (Dense)                 (None, 64, 88)       22616       ['bidirectional_1[0][0]
']

 ctc_loss (CTCLayer)            (None, 64, 88)       0           ['label[0][0]',
                                                                  'dense2[0][0]']


==================================================================================================
Total params: 1,091,160
Trainable params: 1,091,160
Non-trainable params: 0
__________________________________________________________________________________________________
Epoch 1/10
2/2 [==============================] - 2s 17ms/step 0s - loss: 16.64
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2/2 [==============================] - 1s 443ms/step
Mean edit distance for epoch 1: 22.9678

Epoch 1: saving model to ./training\cp-0001.ckpt
15264/15264 [==============================] - 6878s 450ms/step - loss: 16.6444 - val_los
s: 4.3805
Epoch 2/10
```

```
 2605/15264 [====>.....................] - ETA: 1:30:15 - loss: 5.4390

---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
~\AppData\Local\Temp\ipykernel_3172\2885118575.py in <module>
    254
    255 # Train the model.
--> 256 history = model.fit(
    257     train_ds,
    258     validation_data=validation_ds,

c:\Users\madevita\Anaconda3\lib\site-packages\keras\utils\traceback_utils.py in error_han
dler(*args, **kwargs)
     63         filtered_tb = None
     64         try:
---> 65             return fn(*args, **kwargs)
     66         except Exception as e:
     67             filtered_tb = _process_traceback_frames(e.__traceback__)

c:\Users\madevita\Anaconda3\lib\site-packages\keras\engine\training.py in fit(self, x, y,
batch_size, epochs, verbose, callbacks, validation_split, validation_data, shuffle, class
_weight, sample_weight, initial_epoch, steps_per_epoch, validation_steps, validation_batc
h_size, validation_freq, max_queue_size, workers, use_multiprocessing)
   1562                         ):
   1563                             callbacks.on_train_batch_begin(step)
-> 1564                             tmp_logs = self.train_function(iterator)
   1565                             if data_handler.should_sync:
   1566                                 context.async_wait()

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\util\traceback_utils.py i
n error_handler(*args, **kwargs)
    148     filtered_tb = None
    149     try:
--> 150       return fn(*args, **kwargs)
    151     except Exception as e:
    152       filtered_tb = _process_traceback_frames(e.__traceback__)

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py in
__call__(self, *args, **kwds)
    913
    914       with OptionalXlaContext(self._jit_compile):
--> 915         result = self._call(*args, **kwds)
    916
    917       new_tracing_count = self.experimental_get_tracing_count()

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py in
_call(self, *args, **kwds)
    945       # In this case we have created variables on the first call, so we run the
    946       # defunned version which is guaranteed to never create variables.
--> 947       return self._stateless_fn(*args, **kwds)  # pylint: disable=not-callable
    948     elif self._stateful_fn is not None:
    949       # Release the lock early so that multiple threads can perform the call

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\function.py in __ca
ll__(self, *args, **kwargs)
   2494       (graph_function,
   2495        filtered_flat_args) = self._maybe_define_function(args, kwargs)
-> 2496     return graph_function._call_flat(
   2497         filtered_flat_args, captured_inputs=graph_function.captured_inputs)  # py
lint: disable=protected-access
   2498

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\function.py in _cal
l_flat(self, args, captured_inputs, cancellation_manager)
   1860         and executing_eagerly):
   1861       # No tape is watching; skip to running the function.
-> 1862       return self._build_call_outputs(self._inference_function.call(
   1863           ctx, args, cancellation_manager=cancellation_manager))
   1864     forward_backward = self._select_forward_and_backward_functions(

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\function.py in call
(self, ctx, args, cancellation_manager)
```

```
    497       with _interpolateFunctionError(self):
    498         if cancellation_manager is None:
--> 499           outputs = execute.execute(
    500               str(self.signature.name),
    501               num_outputs=self._num_outputs,

c:\Users\madevita\Anaconda3\lib\site-packages\tensorflow\python\eager\execute.py in quick
_execute(op_name, num_outputs, inputs, attrs, ctx, name)
     52   try:
     53     ctx.ensure_initialized()
---> 54     tensors = pywrap_tfe.TFE_Py_Execute(ctx._handle, device_name, op_name,
     55                                         inputs, attrs, num_outputs)
     56   except core._NotOkStatusException as e:

KeyboardInterrupt:
```

In [ ]:

```
### Save complte model after training
model.save('./saved_model/CNN-MODEL-V4')
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled
_convolution_op, lstm_cell_7_layer_call_fn, lstm_cell_7_layer_call_and_return_conditional
_losses, lstm_cell_8_layer_call_fn while saving (showing 5 of 10). These functions will n
ot be directly callable after loading.
```

```
INFO:tensorflow:Assets written to: ./saved_model/CNN-MODEL-V4\assets
```

```
INFO:tensorflow:Assets written to: ./saved_model/CNN-MODEL-V4\assets
```

In [ ]:

```
# A utility function to decode the output of the network.
def decode_batch_predictions(pred):
    input_len = np.ones(pred.shape[0]) * pred.shape[1]
    # Use greedy search. For complex tasks, you can use beam search.
    results = keras.backend.ctc_decode(pred, input_length=input_len, greedy=True)[0][0][
        :, :max_len
    ]
    # Iterate over the results and get back the text.
    output_text = []
    for res in results:
        res = tf.gather(res, tf.where(tf.math.not_equal(res, -1)))
        res = tf.strings.reduce_join(num_to_char(res)).numpy().decode("utf-8")
        output_text.append(res)
    return output_text


#  Let's check results on some test samples.
for batch in test_ds.take(1):
    batch_images = batch["image"]
    batch_label = batch["label"]
    _, ax = plt.subplots(4, 4, figsize=(30, 16))

    preds = prediction_model.predict(batch_images)
    pred_texts = decode_batch_predictions(preds)

    for i in range(16):
        img = batch_images[i]
        img = tf.image.flip_left_right(img)
        img = tf.transpose(img, perm=[1, 0, 2])
        img = (img * 255.0).numpy().clip(0, 255).astype(np.uint8)
        img = img[:, :, 0]

        title = f"Prediction: {pred_texts[i]}"
        ax[i // 4, i % 4].imshow(img, cmap="gray")
        ax[i // 4, i % 4].set_title(title)
        ax[i // 4, i % 4].axis("off")

plt.show()
```

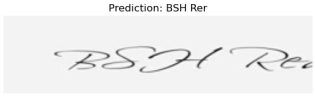
```
2/2 [==============================] - 0s 276ms/step
```

Prediction: Stephan Ehlen

Prediction: Pinha Ribeiro Santo

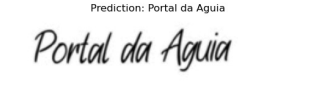
Prediction: Garey Vineyard

Prediction: BSH Rer



Prediction: Stolen Kisses

Prediction: Portal da Aguia

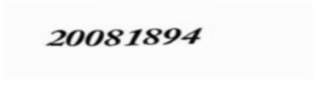


Prediction: Adega de Borba

Prediction: Barde-Haut

Prediction: Il Nonno Estate

Prediction: 20081894



Prediction: Corral Vineyard

Prediction: Lot #7

Prediction: Herb's Block Windrow

Prediction: Gerd Anselmann

Prediction: Barrymore

Prediction: Crete