Denoising Dirty Documents

Team 7

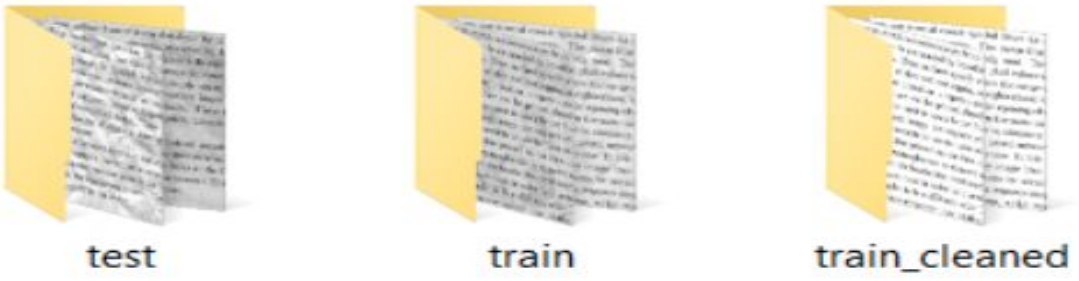
- Febronia Ashraf (fourth year)
- Mennatullah Osman (fourth year)
- Kadija Assem (third year)

Problem statement

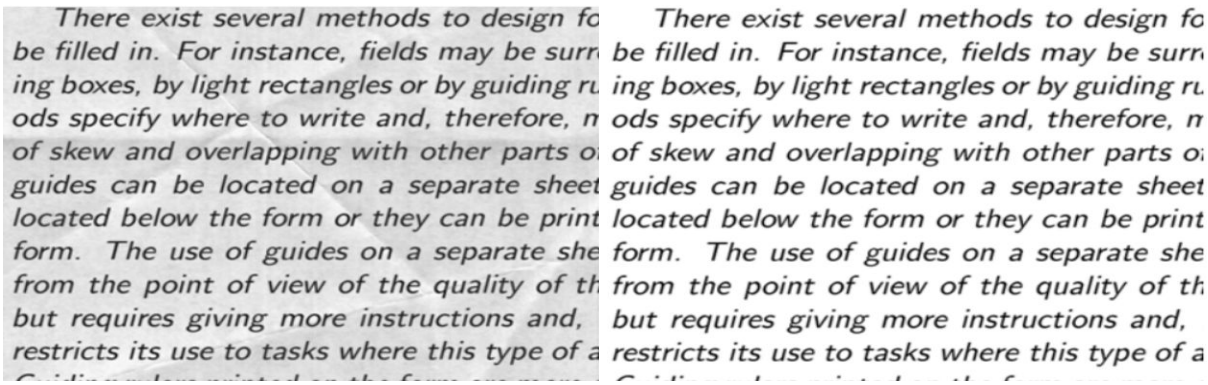
This problem challenges us to remove noise from the given scanned documents**.** Lots of documents eager for digitalization are being held back. Coffee stains, faded sun spots, dog-eared pages and lots of wrinkles are keeping some printed documents offline and in the past. This competition challenges us to remove the noise from the images, improving the ease of document enhancement.

Dataset

The dataset used to develop our models is obtained from the Denoising Dirty Documents challenge on Kaggle. It contains three unzipped folders with images of text in various fonts.



- ‘train’ folder has noisy documents data.
  (144 images of the shape of (420,540,1))
- ‘train_cleaned’ folder has cleaned document data
  (144 images of the shape of (420,540,1))
- ‘test’ folder has dirty documents that will be used as input for prediction
  (72 images some of the shape of (280,540,1) and (420,540,1))



Noisy Document Clean Document

Models

Simple Autoencoder :

We defined encoder and decoder blocks.

- In the encoder block, we have a convolution layer followed by a maxPooling layer.
- In the decoder block, we have a convolution layer followed by an upsampling layer.
- followed by a convolution layer.

We are trying to minimize mean squared error between the input data and output data.

```
tf.keras.backend.clear_session()

input_layer = tf.keras.Input(shape=(420, 540, 1))

# Encoder

x = Conv2D(32, (3, 3), activation='relu', padding='same')(input_layer)
x = MaxPooling2D((2, 2), padding='same')(x)

# Decoder

x = Conv2D(32, (3, 3), activation='relu', padding='same')(x)
x = UpSampling2D((2, 2))(x)
output_layer = Conv2D(1, (3, 3), activation='sigmoid', padding='same')(x)

AutoEncoder = tf.keras.Model(input_layer, output_layer)

AutoEncoder.compile(optimizer = 'adam', loss='mse' ,metrics='accuracy')
```

Deeper Autoencoder :

We defined encoder and decoder blocks.

- In the encoder block, we have two convolution layers each followed by a maxPooling layer.
- In the decoder block, we have two convolution layers each followed by an upsampling layer.
- followed by a convolution layer.

We are trying to minimize mean squared error between the input data and output data.

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x = Conv2D(32, (3, 3), activation='relu', padding='same')(x)
x = MaxPooling2D((2, 2), padding='same')(x)

# Decoder
x = Conv2D(32, (3, 3), activation='relu', padding='same')(x)
x = UpSampling2D((2, 2))(x)
x = Conv2D(32, (3, 3), activation='relu', padding='same')(x)
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Overview Of Our Work

1) Read the problem statement

First, we read the problem and tried to figure out how we could apply the course we learnt to solve the problem. The first problem for us was the output because we didn't have classes or text as a label but the output was images!. We begin to think that the output will be compared pixel by pixel with the input.

2) Read discussion & notebooks of the problem in kaggle

As we needed to get more into the problem, we tried to see what others did to deal with the problem. One of the notebooks that we saw, tried simple CNN and without data augmentation, started to train the model with adam optimizer.After finishing training he recommended for optimization, not to use adam because it's aggressive for that kind of problem and also recommended to use deeper CNN.So we began doing like what he said, as a start for our code.

3) view images and make some preprocessing on them

We loaded images and saw their size and scale. There were 216 grayscale images, divided into 144 for train and 72 for test. Most of them have the shape of (420,540,1) except some test images which have the shape of (280, 540,1) and those images need to be resized. As the dataset was very small we begin to think that we will need data augmentation to avoid overfitting.so, we made 4 different techniques :

- Horizontal Flip
- Vertical Flip
- Rotation
- Scale

We make them nested as we apply the first technique and then take the result added to the original images then take the result applying another technique then add the result with the previous result. So, we had 1600 images after data augmentation.

Before applying data augmentation we split the train images where train to validation is 70% to 30%

4) Try a simple Model

1. We began with a simple model with one layer as encoder and one layer as decoder and SGD optimizer with 0.01 learning rate.After training our first model, the result of the model wasn't good at all.
2. We tried the same model and the same optimizer but now on an augmented dataset but the result had very small improvement.
3. We thought of tring Adam for an augmented dataset and see what would happen!. The result improved rapidly and significantly.
4. So finally we tried an augmented dataset with Adam optimizer on the Model and it has a slight impact for improving the result.

5) Try Deeper Neural Network

1. We then tried to make more optimization by using the Deep Neural Network. We tried two layers as encoder and two as decoder and it has also some improvement on the Model
2. Finally, we use Model with three layers in both encoder and decoder and it made a noticeable improvement

6) Compare result and submit on kaggle

The last thing that we did, is comparing the output from each step and choose the Model with the cleaner output and made submission on kaggle

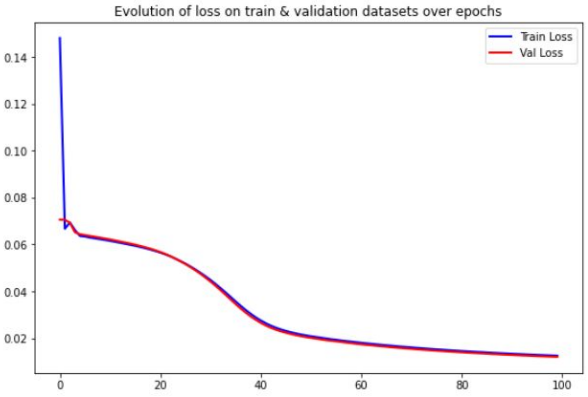
Result

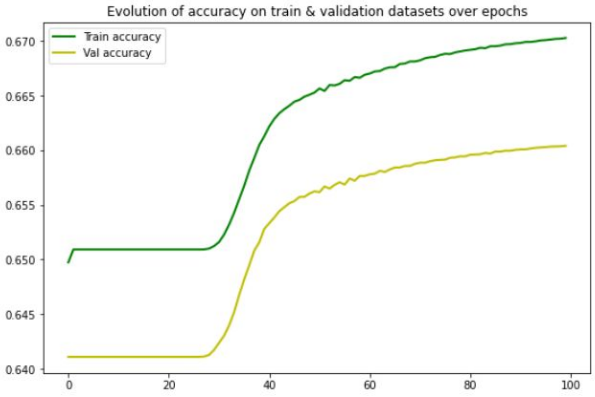
1) SGD(1e - 2 ,momentum = 0.9 , decay = 1e - 2/epochs)

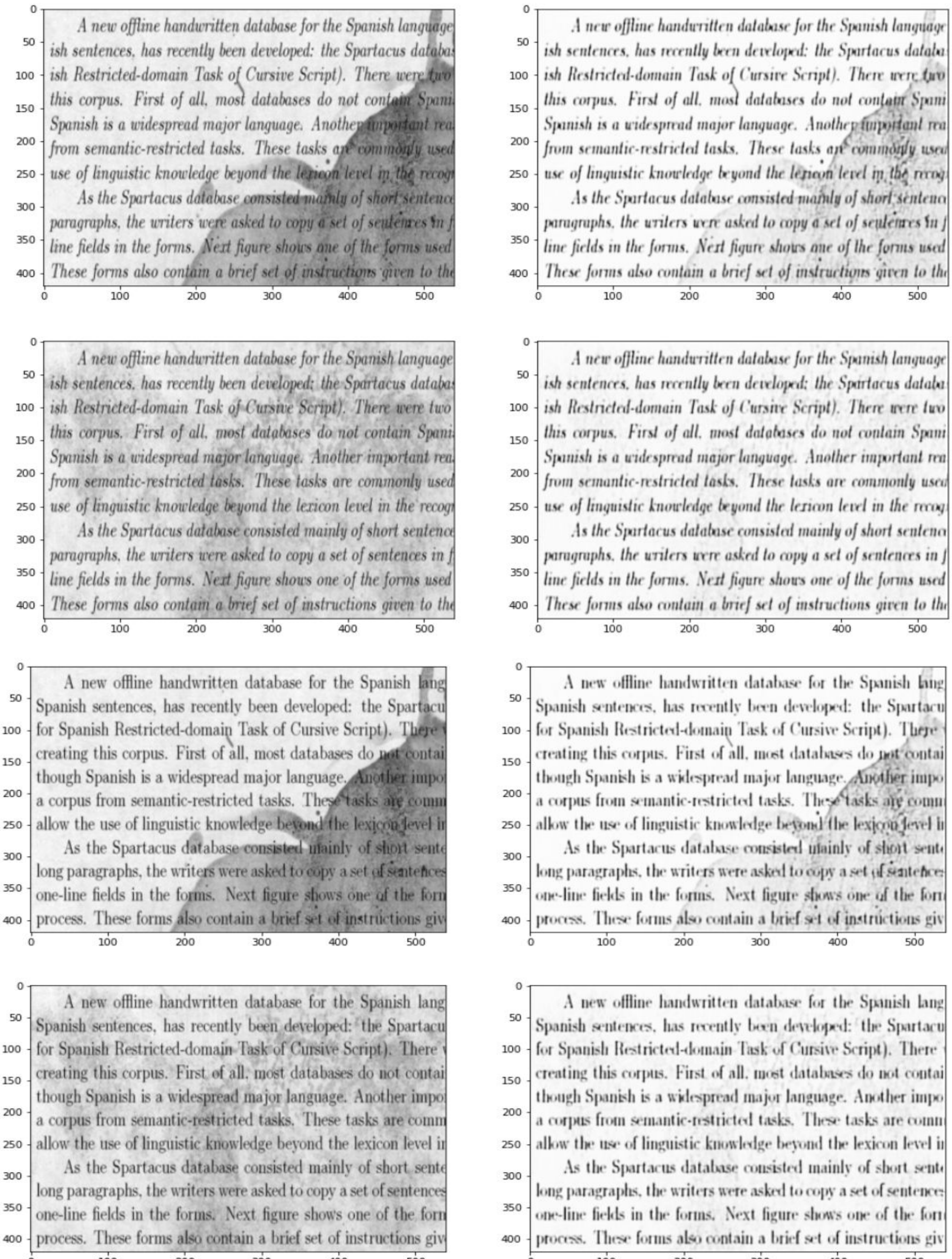
- Without Data Augmentation

```
Epoch 1/100
13/13 [==============================] - 1s 97ms/step - loss: 0.1480 - accuracy: 0.6497 - val_loss: 0.0706 - val_accuracy: 0.6411
Epoch 2/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0667 - accuracy: 0.6509 - val_loss: 0.0705 - val_accuracy: 0.6411
Epoch 3/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0694 - accuracy: 0.6509 - val_loss: 0.0692 - val_accuracy: 0.6411
Epoch 4/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0662 - accuracy: 0.6509 - val_loss: 0.0652 - val_accuracy: 0.6411
Epoch 5/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0636 - accuracy: 0.6509 - val_loss: 0.0644 - val_accuracy: 0.6411
Epoch 6/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0634 - accuracy: 0.6509 - val_loss: 0.0640 - val_accuracy: 0.6411
Epoch 7/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0629 - accuracy: 0.6509 - val_loss: 0.0636 - val_accuracy: 0.6411
Epoch 8/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0626 - accuracy: 0.6509 - val_loss: 0.0633 - val_accuracy: 0.6411
Epoch 9/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0622 - accuracy: 0.6509 - val_loss: 0.0629 - val_accuracy: 0.6411
Epoch 10/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0619 - accuracy: 0.6509 - val_loss: 0.0625 - val_accuracy: 0.6411

Epoch 90/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0135 - accuracy: 0.6698 - val_loss: 0.0130 - val_accuracy: 0.6600
Epoch 91/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0134 - accuracy: 0.6698 - val_loss: 0.0129 - val_accuracy: 0.6601
Epoch 92/100
13/13 [==============================] - 1s 70ms/step - loss: 0.0133 - accuracy: 0.6699 - val_loss: 0.0128 - val_accuracy: 0.6601
Epoch 93/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0132 - accuracy: 0.6699 - val_loss: 0.0127 - val_accuracy: 0.6601
Epoch 94/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0131 - accuracy: 0.6700 - val_loss: 0.0126 - val_accuracy: 0.6602
Epoch 95/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0130 - accuracy: 0.6700 - val_loss: 0.0125 - val_accuracy: 0.6602
Epoch 96/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0129 - accuracy: 0.6701 - val_loss: 0.0124 - val_accuracy: 0.6603
Epoch 97/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0128 - accuracy: 0.6701 - val_loss: 0.0123 - val_accuracy: 0.6603
Epoch 98/100
13/13 [==============================] - 1s 70ms/step - loss: 0.0128 - accuracy: 0.6702 - val_loss: 0.0123 - val_accuracy: 0.6603
Epoch 99/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0127 - accuracy: 0.6702 - val_loss: 0.0122 - val_accuracy: 0.6604
Epoch 100/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0126 - accuracy: 0.6703 - val_loss: 0.0121 - val_accuracy: 0.6604
```



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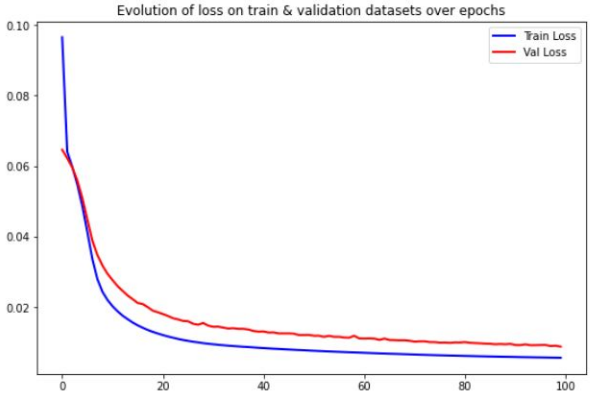
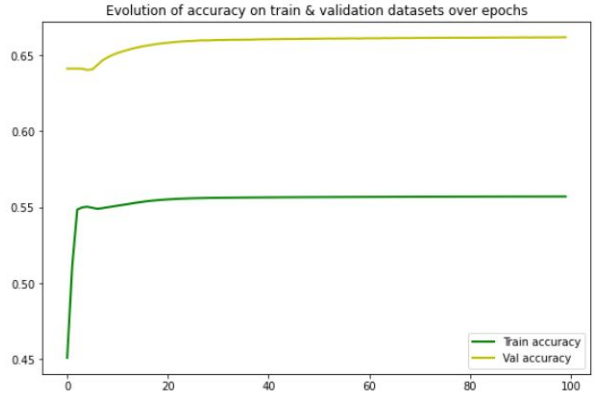
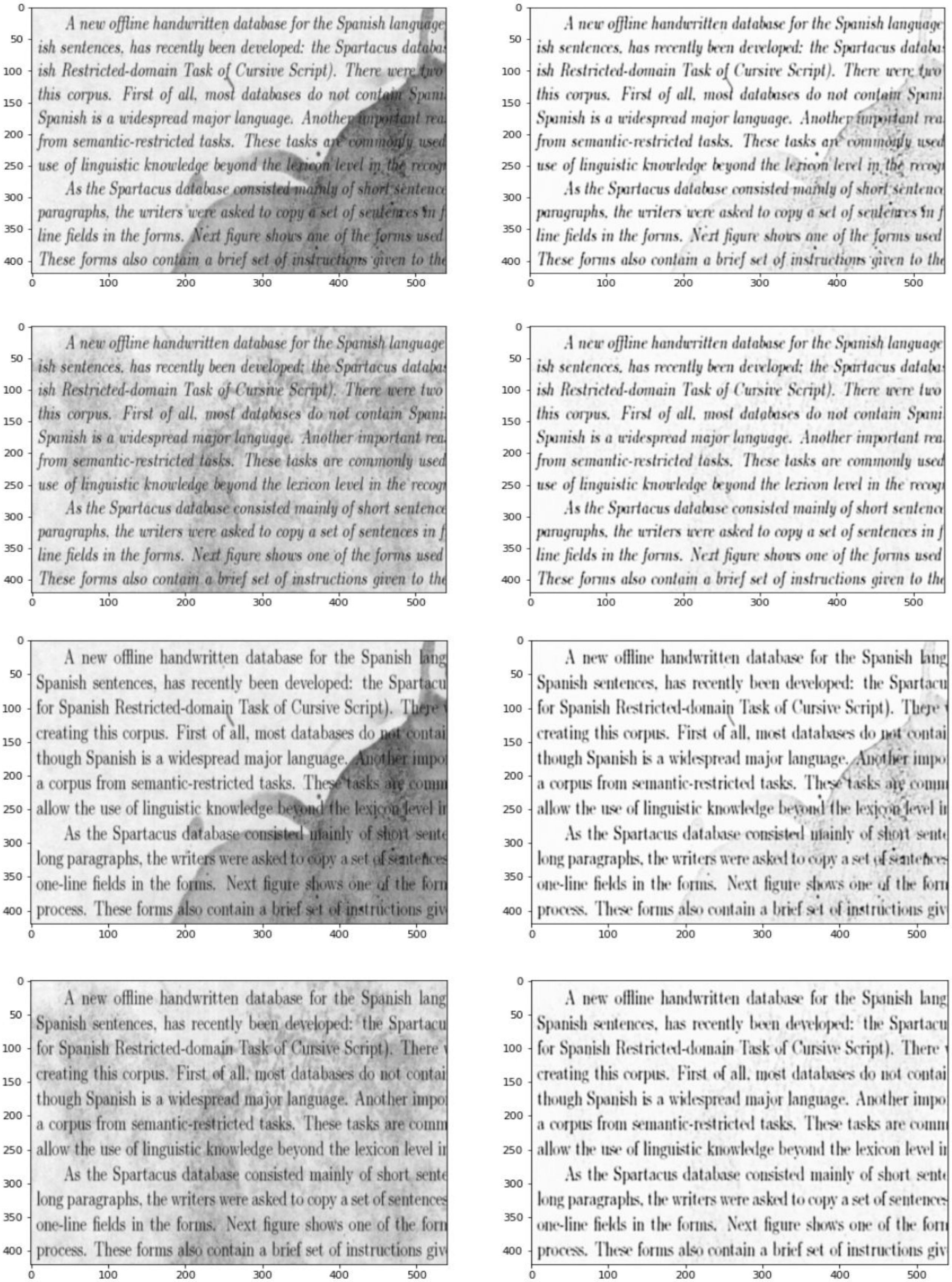
- With Data Augmentation

```
Epoch 1/100
54/54 [==============================] - 12s 230ms/step - loss: 0.0965 - accuracy: 0.4510 - val_loss: 0.0646 - val_accuracy: 0.6411
Epoch 2/100
54/54 [==============================] - 12s 216ms/step - loss: 0.0641 - accuracy: 0.5114 - val_loss: 0.0622 - val_accuracy: 0.6411
Epoch 3/100
54/54 [==============================] - 12s 218ms/step - loss: 0.0598 - accuracy: 0.5484 - val_loss: 0.0596 - val_accuracy: 0.6411
Epoch 4/100
54/54 [==============================] - 12s 218ms/step - loss: 0.0548 - accuracy: 0.5499 - val_loss: 0.0559 - val_accuracy: 0.6410
Epoch 5/100
54/54 [==============================] - 12s 222ms/step - loss: 0.0487 - accuracy: 0.5503 - val_loss: 0.0509 - val_accuracy: 0.6402
Epoch 6/100
54/54 [==============================] - 12s 220ms/step - loss: 0.0413 - accuracy: 0.5496 - val_loss: 0.0448 - val_accuracy: 0.6406
Epoch 7/100
54/54 [==============================] - 12s 222ms/step - loss: 0.0336 - accuracy: 0.5489 - val_loss: 0.0389 - val_accuracy: 0.6435
Epoch 8/100
54/54 [==============================] - 12s 223ms/step - loss: 0.0279 - accuracy: 0.5494 - val_loss: 0.0348 - val_accuracy: 0.6465
Epoch 9/100
54/54 [==============================] - 12s 223ms/step - loss: 0.0244 - accuracy: 0.5499 - val_loss: 0.0318 - val_accuracy: 0.6485
Epoch 10/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0221 - accuracy: 0.5504 - val_loss: 0.0295 - val_accuracy: 0.6500

Epoch 90/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0059 - accuracy: 0.5570 - val_loss: 0.0096 - val_accuracy: 0.6615
Epoch 91/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0059 - accuracy: 0.5570 - val_loss: 0.0093 - val_accuracy: 0.6616
Epoch 92/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0059 - accuracy: 0.5570 - val_loss: 0.0093 - val_accuracy: 0.6616
Epoch 93/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0058 - accuracy: 0.5570 - val_loss: 0.0095 - val_accuracy: 0.6615
Epoch 94/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0058 - accuracy: 0.5570 - val_loss: 0.0092 - val_accuracy: 0.6616
Epoch 95/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0058 - accuracy: 0.5570 - val_loss: 0.0092 - val_accuracy: 0.6616
Epoch 96/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0058 - accuracy: 0.5570 - val_loss: 0.0093 - val_accuracy: 0.6616
Epoch 97/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0057 - accuracy: 0.5570 - val_loss: 0.0093 - val_accuracy: 0.6616
Epoch 98/100
54/54 [==============================] - 12s 225ms/step - loss: 0.0057 - accuracy: 0.5570 - val_loss: 0.0090 - val_accuracy: 0.6617
Epoch 99/100
54/54 [==============================] - 12s 223ms/step - loss: 0.0057 - accuracy: 0.5570 - val_loss: 0.0091 - val_accuracy: 0.6616
Epoch 100/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0057 - accuracy: 0.5570 - val_loss: 0.0088 - val_accuracy: 0.6617
```



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2) Adam

- Without Data Augmentation

```
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13/13 [==============================] - 1s 95ms/step - loss: 0.1197 - accuracy: 0.6508 - val_loss: 0.0652 - val_accuracy: 0.6411
Epoch 2/100
13/13 [==============================] - 1s 66ms/step - loss: 0.0667 - accuracy: 0.6509 - val_loss: 0.0673 - val_accuracy: 0.6411
Epoch 3/100
13/13 [==============================] - 1s 66ms/step - loss: 0.0614 - accuracy: 0.6509 - val_loss: 0.0568 - val_accuracy: 0.6411
Epoch 4/100
13/13 [==============================] - 1s 66ms/step - loss: 0.0505 - accuracy: 0.6510 - val_loss: 0.0432 - val_accuracy: 0.6432
Epoch 5/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0361 - accuracy: 0.6562 - val_loss: 0.0281 - val_accuracy: 0.6549
Epoch 6/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0239 - accuracy: 0.6659 - val_loss: 0.0202 - val_accuracy: 0.6579
Epoch 7/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0185 - accuracy: 0.6683 - val_loss: 0.0163 - val_accuracy: 0.6598
Epoch 8/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0154 - accuracy: 0.6697 - val_loss: 0.0138 - val_accuracy: 0.6608
Epoch 9/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0133 - accuracy: 0.6707 - val_loss: 0.0119 - val_accuracy: 0.6613
Epoch 10/100
13/13 [==============================] - 1s 67ms/step - loss: 0.0116 - accuracy: 0.6715 - val_loss: 0.0106 - val_accuracy: 0.6617

Epoch 90/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0031 - accuracy: 0.6729 - val_loss: 0.0030 - val_accuracy: 0.6626
Epoch 91/100
13/13 [==============================] - 1s 70ms/step - loss: 0.0031 - accuracy: 0.6729 - val_loss: 0.0030 - val_accuracy: 0.6626
Epoch 92/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0031 - accuracy: 0.6729 - val_loss: 0.0030 - val_accuracy: 0.6626
Epoch 93/100
13/13 [==============================] - 1s 68ms/step - loss: 0.0032 - accuracy: 0.6729 - val_loss: 0.0031 - val_accuracy: 0.6626
Epoch 94/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0031 - accuracy: 0.6729 - val_loss: 0.0029 - val_accuracy: 0.6626
Epoch 95/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0030 - accuracy: 0.6729 - val_loss: 0.0029 - val_accuracy: 0.6626
Epoch 96/100
13/13 [==============================] - 1s 69ms/step - loss: 0.0030 - accuracy: 0.6729 - val_loss: 0.0030 - val_accuracy: 0.6626
Epoch 97/100
13/13 [==============================] - 1s 71ms/step - loss: 0.0030 - accuracy: 0.6729 - val_loss: 0.0030 - val_accuracy: 0.6626
Epoch 98/100
13/13 [==============================] - 1s 70ms/step - loss: 0.0030 - accuracy: 0.6729 - val_loss: 0.0031 - val_accuracy: 0.6626
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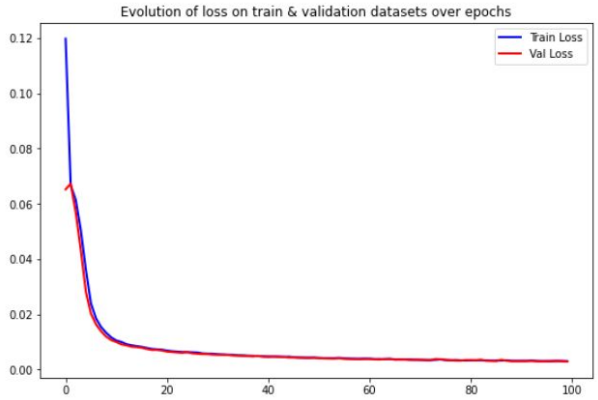

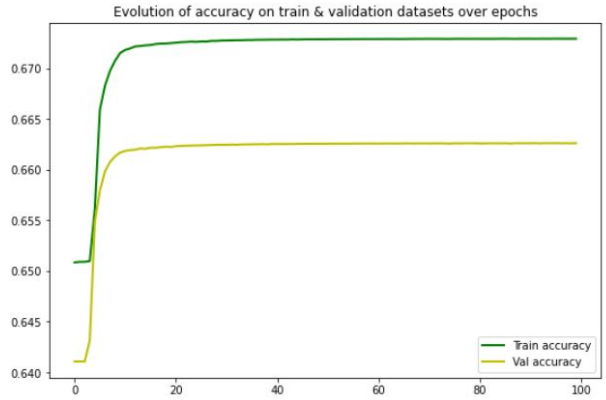

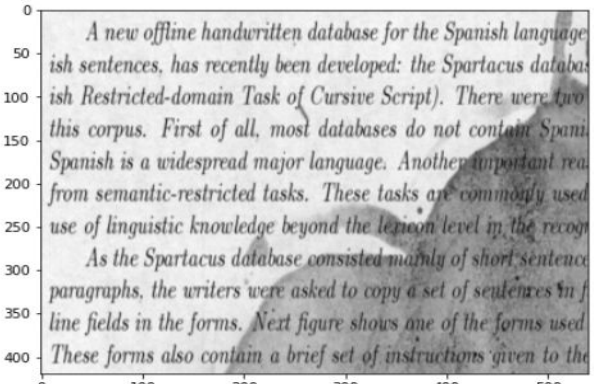
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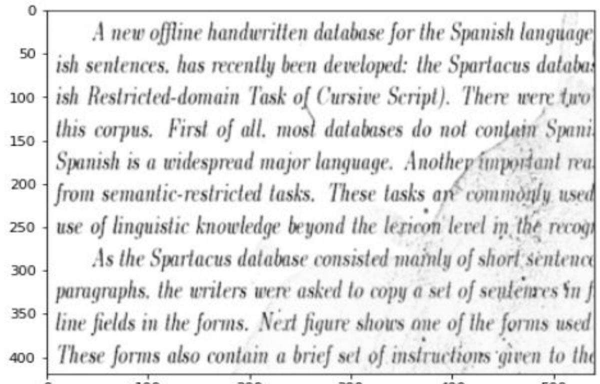
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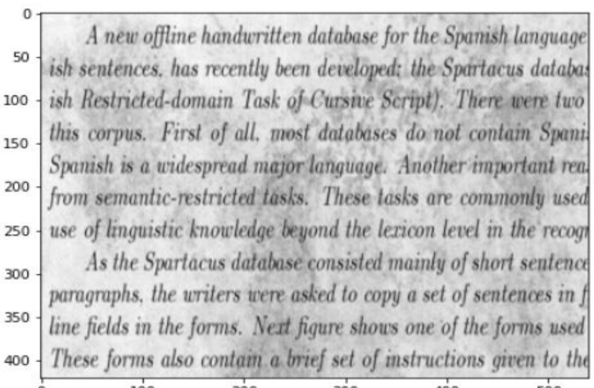
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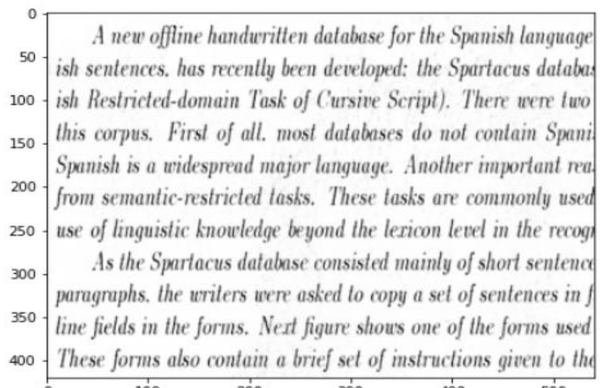
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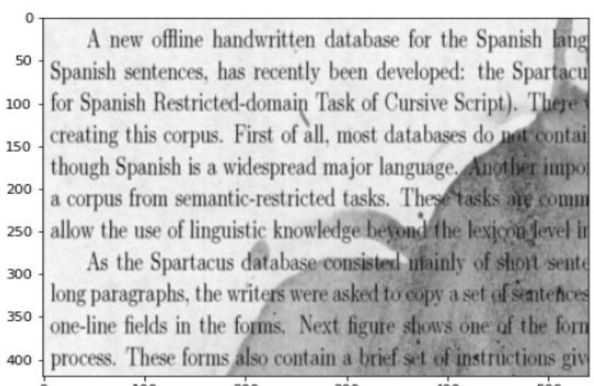
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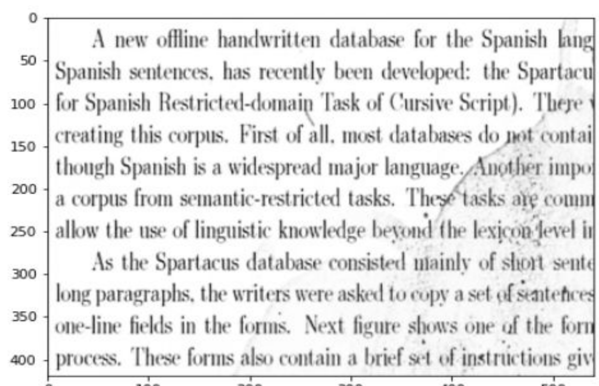
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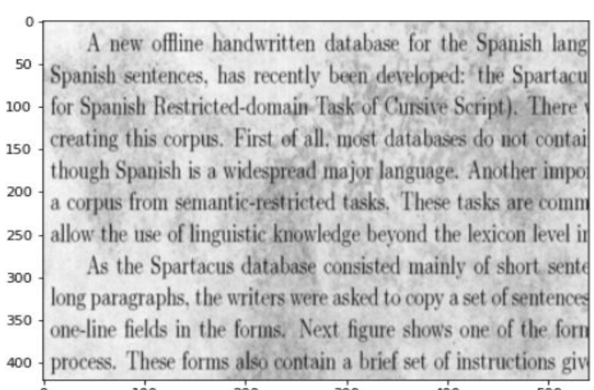
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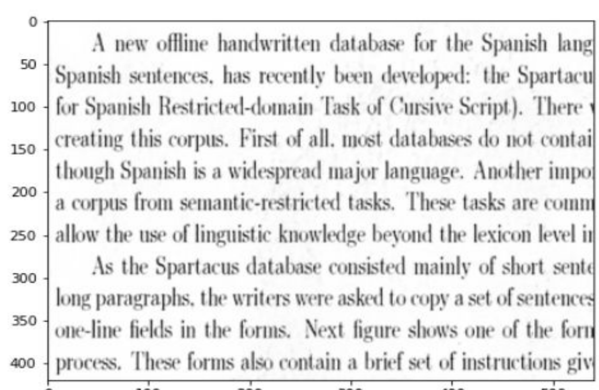
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- Without Data Augmentation

```
Epoch 1/100
54/54 [==============================] - 13s 234ms/step - loss: 0.0650 - accuracy: 0.5295 - val_loss: 0.0376 - val_accuracy: 0.6476
Epoch 2/100
54/54 [==============================] - 12s 219ms/step - loss: 0.0182 - accuracy: 0.5538 - val_loss: 0.0199 - val_accuracy: 0.6577
Epoch 3/100
54/54 [==============================] - 12s 220ms/step - loss: 0.0100 - accuracy: 0.5560 - val_loss: 0.0141 - val_accuracy: 0.6603
Epoch 4/100
54/54 [==============================] - 12s 223ms/step - loss: 0.0080 - accuracy: 0.5566 - val_loss: 0.0124 - val_accuracy: 0.6609
Epoch 5/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0070 - accuracy: 0.5568 - val_loss: 0.0102 - val_accuracy: 0.6615
Epoch 6/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0063 - accuracy: 0.5570 - val_loss: 0.0089 - val_accuracy: 0.6618
Epoch 7/100
54/54 [==============================] - 12s 224ms/step - loss: 0.0058 - accuracy: 0.5571 - val_loss: 0.0080 - val_accuracy: 0.6620
Epoch 8/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0053 - accuracy: 0.5572 - val_loss: 0.0074 - val_accuracy: 0.6622
Epoch 9/100
54/54 [==============================] - 12s 230ms/step - loss: 0.0050 - accuracy: 0.5572 - val_loss: 0.0076 - val_accuracy: 0.6622
Epoch 10/100
54/54 [==============================] - 12s 231ms/step - loss: 0.0047 - accuracy: 0.5572 - val_loss: 0.0077 - val_accuracy: 0.6623

Epoch 90/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0020 - val_accuracy: 0.6626
Epoch 91/100
54/54 [==============================] - 12s 227ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0019 - val_accuracy: 0.6626
Epoch 92/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0020 - val_accuracy: 0.6626
Epoch 93/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0014 - accuracy: 0.5573 - val_loss: 0.0019 - val_accuracy: 0.6626
Epoch 94/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0020 - val_accuracy: 0.6626
Epoch 95/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0018 - val_accuracy: 0.6626
Epoch 96/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0019 - val_accuracy: 0.6626
Epoch 97/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0018 - val_accuracy: 0.6626
Epoch 98/100
54/54 [==============================] - 12s 229ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0018 - val_accuracy: 0.6626
Epoch 99/100
54/54 [==============================] - 12s 228ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0019 - val_accuracy: 0.6626
Epoch 100/100
54/54 [==============================] - 12s 227ms/step - loss: 0.0013 - accuracy: 0.5573 - val_loss: 0.0018 - val_accuracy: 0.6626
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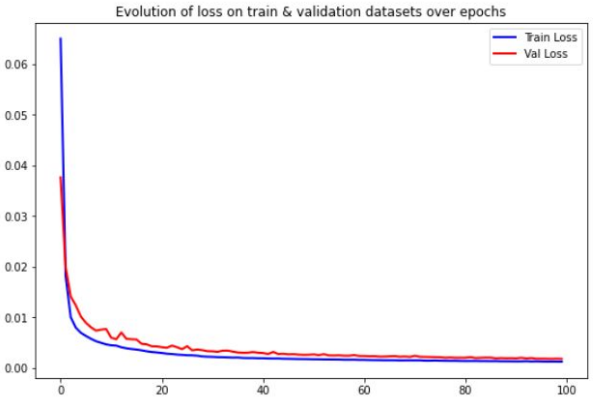

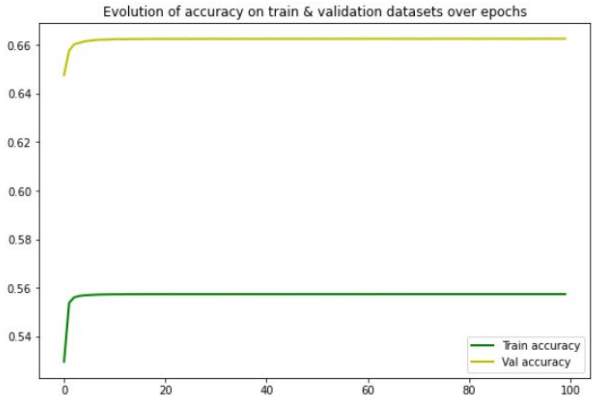

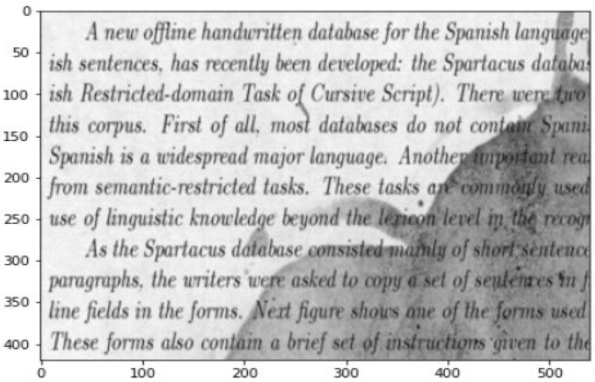

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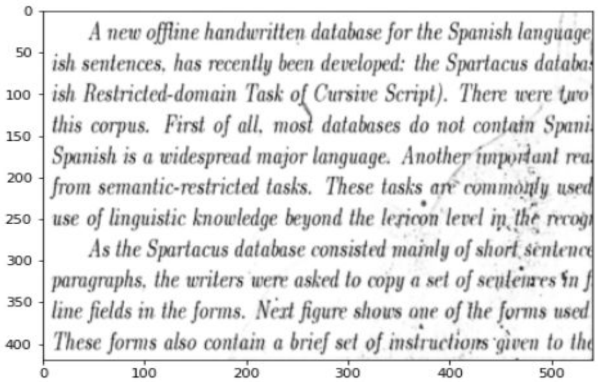

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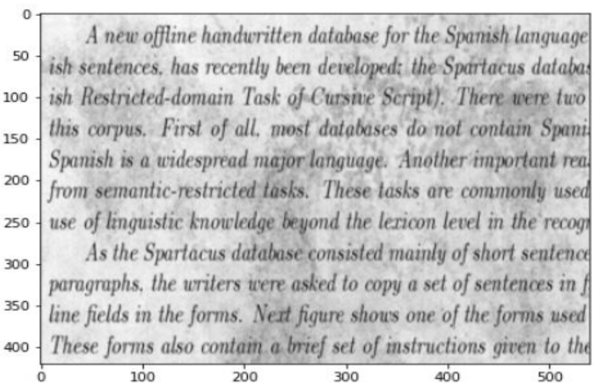

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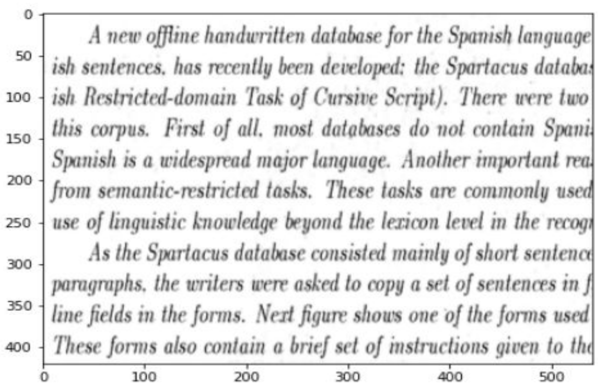

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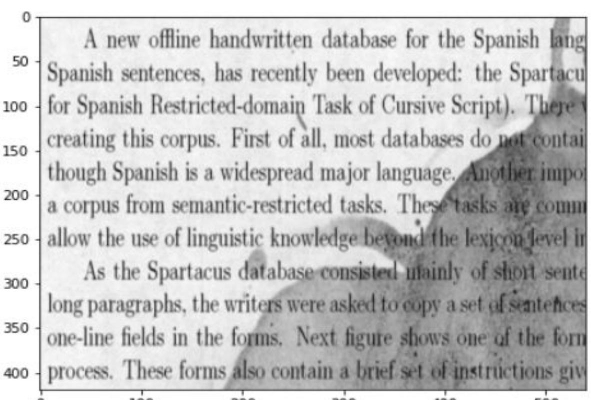

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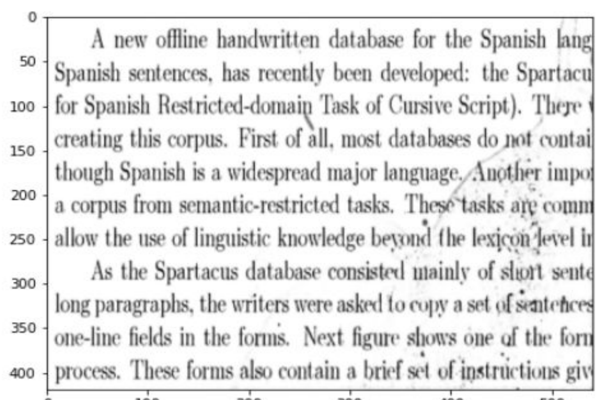

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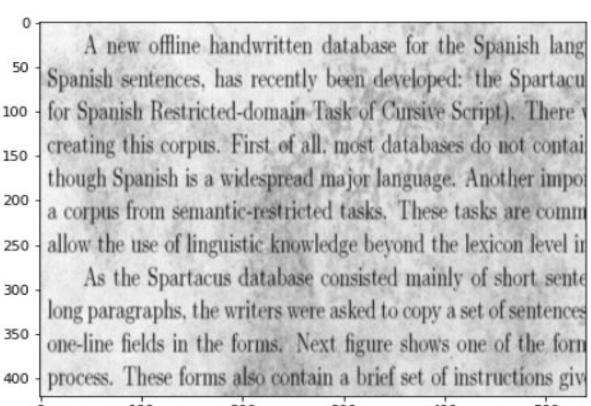

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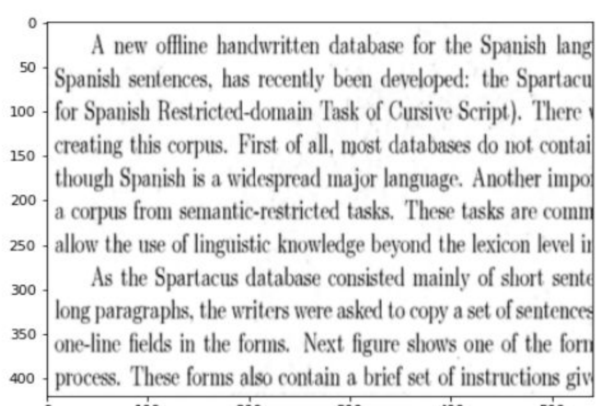

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long paragraphs, the writers were asked to copy a set of sentences
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3) Deep CNN

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54/54 [==============================] - 16s 291ms/step - loss: 0.0669 - accuracy: 0.5305 - val_loss: 0.0574 - val_accuracy: 0.6318
Epoch 2/100
54/54 [==============================] - 15s 274ms/step - loss: 0.0314 - accuracy: 0.5511 - val_loss: 0.0410 - val_accuracy: 0.6436
Epoch 3/100
54/54 [==============================] - 15s 277ms/step - loss: 0.0230 - accuracy: 0.5529 - val_loss: 0.0335 - val_accuracy: 0.6487
Epoch 4/100
54/54 [==============================] - 15s 276ms/step - loss: 0.0187 - accuracy: 0.5542 - val_loss: 0.0293 - val_accuracy: 0.6522
Epoch 5/100
54/54 [==============================] - 15s 279ms/step - loss: 0.0157 - accuracy: 0.5549 - val_loss: 0.0255 - val_accuracy: 0.6539
Epoch 6/100
54/54 [==============================] - 15s 280ms/step - loss: 0.0139 - accuracy: 0.5553 - val_loss: 0.0228 - val_accuracy: 0.6557
Epoch 7/100
54/54 [==============================] - 15s 283ms/step - loss: 0.0124 - accuracy: 0.5556 - val_loss: 0.0210 - val_accuracy: 0.6568
Epoch 8/100
54/54 [==============================] - 15s 284ms/step - loss: 0.0111 - accuracy: 0.5559 - val_loss: 0.0195 - val_accuracy: 0.6577
Epoch 9/100
54/54 [==============================] - 15s 284ms/step - loss: 0.0103 - accuracy: 0.5561 - val_loss: 0.0180 - val_accuracy: 0.6583
Epoch 10/100

Epoch 90/100
54/54 [==============================] - 16s 294ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0050 - val_accuracy: 0.6624
Epoch 91/100
54/54 [==============================] - 16s 296ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0049 - val_accuracy: 0.6624
Epoch 92/100
54/54 [==============================] - 16s 294ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0050 - val_accuracy: 0.6624
Epoch 93/100
54/54 [==============================] - 16s 296ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0050 - val_accuracy: 0.6624
Epoch 94/100
54/54 [==============================] - 16s 293ms/step - loss: 0.0030 - accuracy: 0.5573 - val_loss: 0.0049 - val_accuracy: 0.6624
Epoch 95/100
54/54 [==============================] - 16s 294ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0048 - val_accuracy: 0.6624
Epoch 96/100
54/54 [==============================] - 16s 295ms/step - loss: 0.0028 - accuracy: 0.5573 - val_loss: 0.0048 - val_accuracy: 0.6624
Epoch 97/100
54/54 [==============================] - 16s 295ms/step - loss: 0.0028 - accuracy: 0.5573 - val_loss: 0.0049 - val_accuracy: 0.6624
Epoch 98/100
54/54 [==============================] - 16s 294ms/step - loss: 0.0029 - accuracy: 0.5573 - val_loss: 0.0049 - val_accuracy: 0.6624
Epoch 99/100
54/54 [==============================] - 16s 295ms/step - loss: 0.0028 - accuracy: 0.5573 - val_loss: 0.0047 - val_accuracy: 0.6624
Epoch 100/100
54/54 [==============================] - 16s 293ms/step - loss: 0.0028 - accuracy: 0.5573 - val_loss: 0.0047 - val_accuracy: 0.6624
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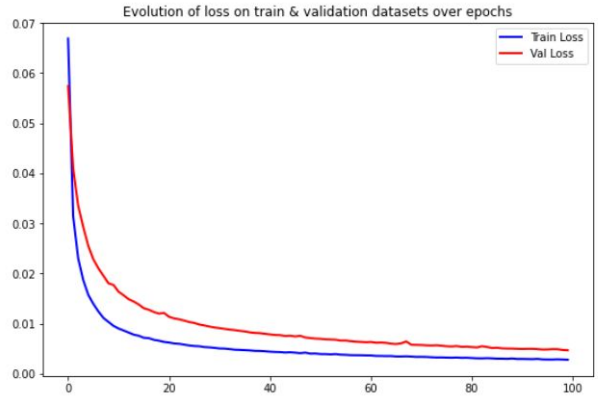
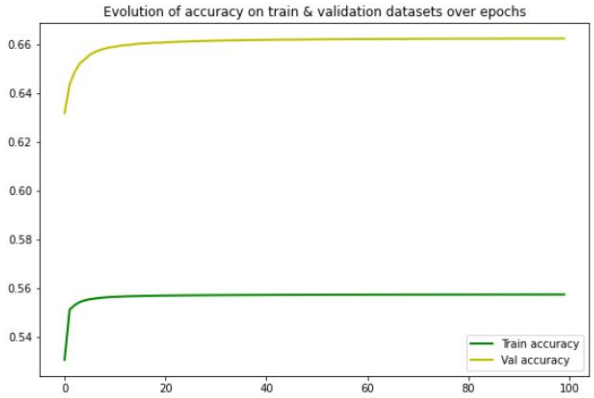
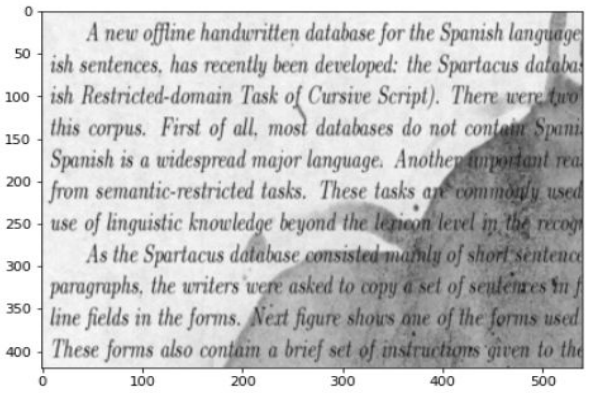
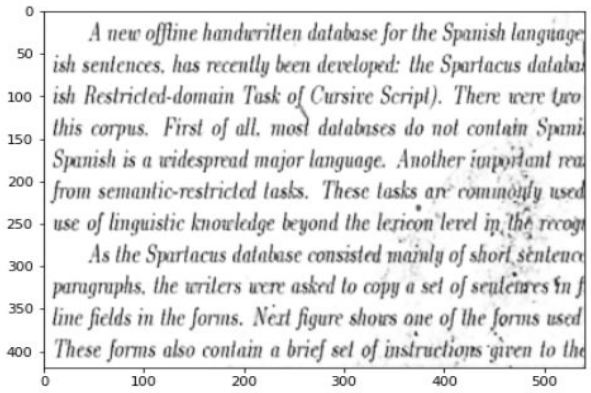
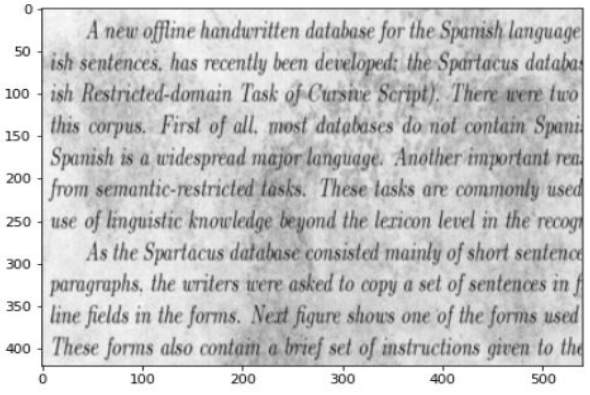
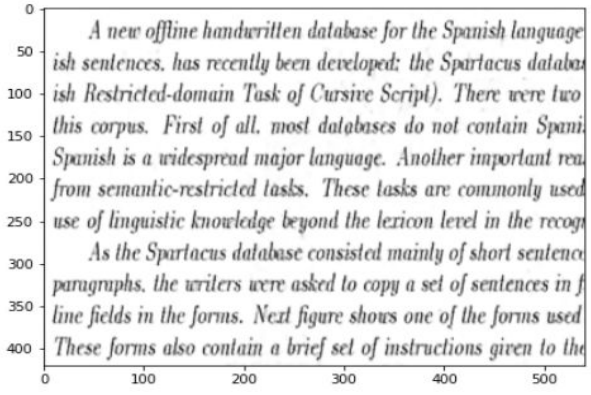
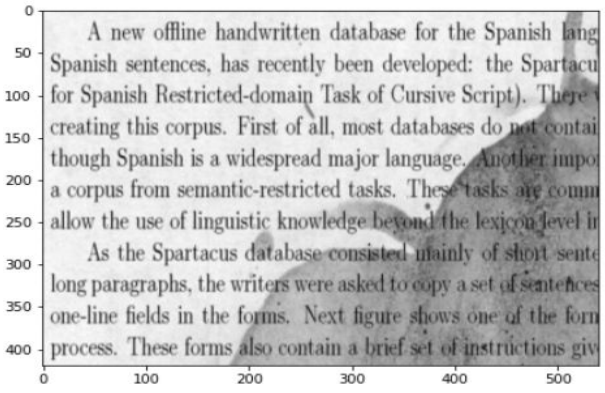
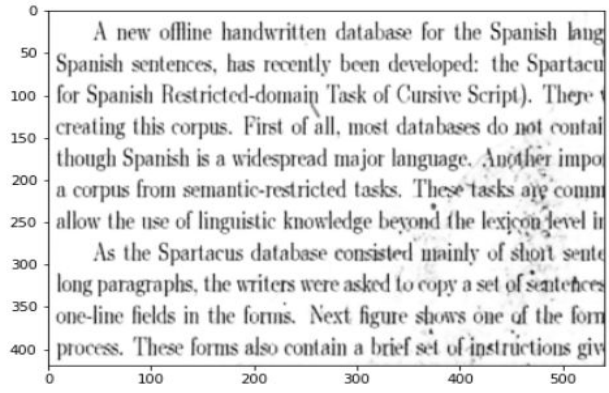
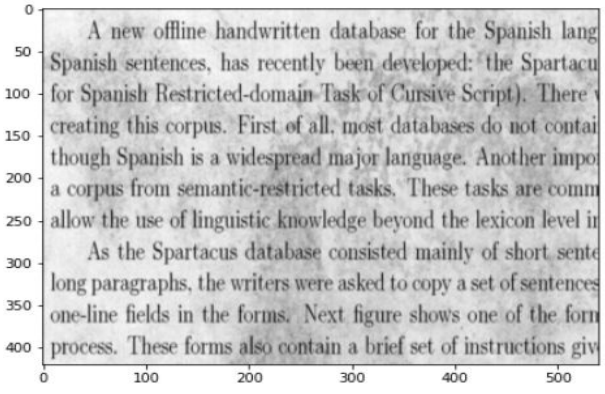
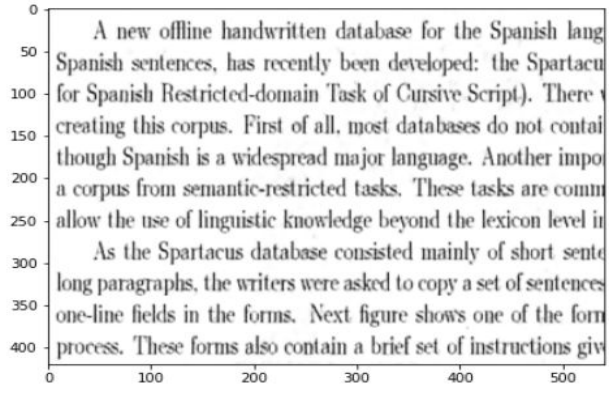


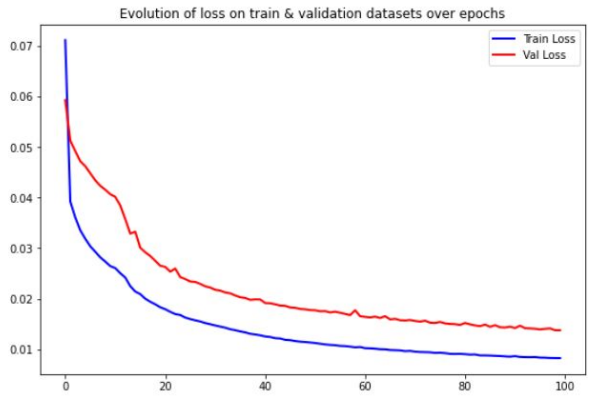


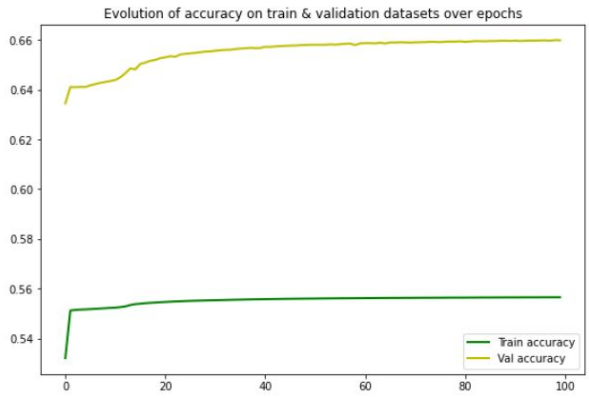









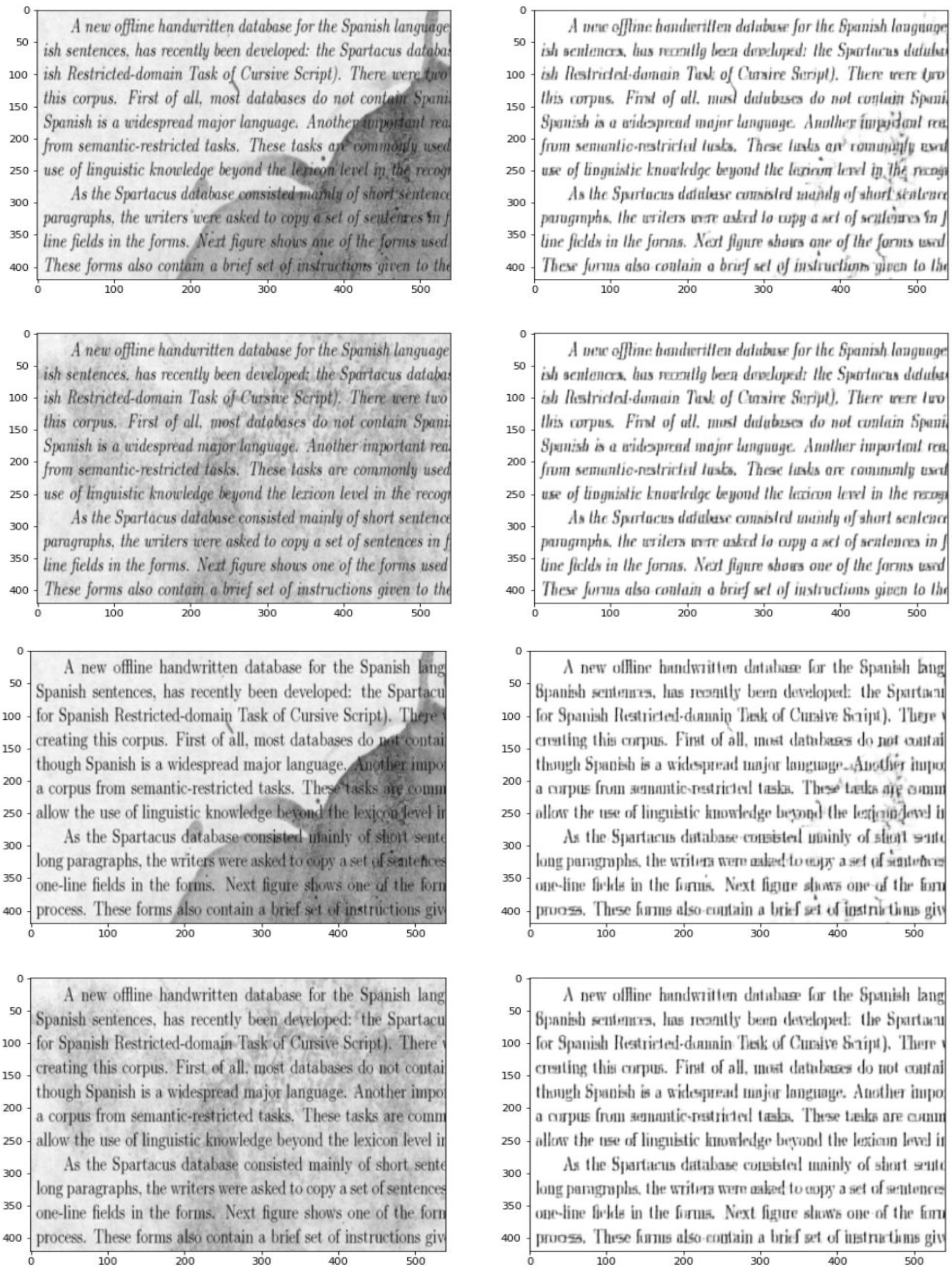
4) Deeper CNN

```
Epoch 1/100
54/54 [==============================] - 17s 317ms/step - loss: 0.0711 - accuracy: 0.5321 - val_loss: 0.0592 - val_accuracy: 0.6345
Epoch 2/100
54/54 [==============================] - 16s 294ms/step - loss: 0.0392 - accuracy: 0.5512 - val_loss: 0.0512 - val_accuracy: 0.6410
Epoch 3/100
54/54 [==============================] - 16s 298ms/step - loss: 0.0361 - accuracy: 0.5515 - val_loss: 0.0491 - val_accuracy: 0.6410
Epoch 4/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0335 - accuracy: 0.5516 - val_loss: 0.0472 - val_accuracy: 0.6411
Epoch 5/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0318 - accuracy: 0.5517 - val_loss: 0.0462 - val_accuracy: 0.6410
Epoch 6/100
54/54 [==============================] - 16s 298ms/step - loss: 0.0304 - accuracy: 0.5518 - val_loss: 0.0448 - val_accuracy: 0.6417
Epoch 7/100
54/54 [==============================] - 16s 297ms/step - loss: 0.0293 - accuracy: 0.5519 - val_loss: 0.0434 - val_accuracy: 0.6422
Epoch 8/100
54/54 [==============================] - 16s 301ms/step - loss: 0.0282 - accuracy: 0.5520 - val_loss: 0.0423 - val_accuracy: 0.6427
Epoch 9/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0273 - accuracy: 0.5522 - val_loss: 0.0415 - val_accuracy: 0.6430
Epoch 10/100
```

```
Epoch 90/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0086 - accuracy: 0.5565 - val_loss: 0.0145 - val_accuracy: 0.6595
Epoch 91/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0087 - accuracy: 0.5565 - val_loss: 0.0142 - val_accuracy: 0.6596
Epoch 92/100
54/54 [==============================] - 16s 299ms/step - loss: 0.0085 - accuracy: 0.5565 - val_loss: 0.0147 - val_accuracy: 0.6595
Epoch 93/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0085 - accuracy: 0.5565 - val_loss: 0.0142 - val_accuracy: 0.6596
Epoch 94/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0085 - accuracy: 0.5565 - val_loss: 0.0141 - val_accuracy: 0.6597
Epoch 95/100
54/54 [==============================] - 16s 299ms/step - loss: 0.0085 - accuracy: 0.5565 - val_loss: 0.0141 - val_accuracy: 0.6596
Epoch 96/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0084 - accuracy: 0.5565 - val_loss: 0.0139 - val_accuracy: 0.6597
Epoch 97/100
54/54 [==============================] - 16s 302ms/step - loss: 0.0084 - accuracy: 0.5566 - val_loss: 0.0141 - val_accuracy: 0.6598
Epoch 98/100
54/54 [==============================] - 16s 300ms/step - loss: 0.0083 - accuracy: 0.5566 - val_loss: 0.0141 - val_accuracy: 0.6596
Epoch 99/100
54/54 [==============================] - 16s 303ms/step - loss: 0.0083 - accuracy: 0.5566 - val_loss: 0.0138 - val_accuracy: 0.6599
Epoch 100/100
54/54 [==============================] - 16s 302ms/step - loss: 0.0083 - accuracy: 0.5566 - val_loss: 0.0138 - val_accuracy: 0.6598
```






A new offline handwritten database for the Spanish language
ish sentences, has recently been developed: the Spartacus databa
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this corpus. First of all, most databases do not contain Spani
Spanish is a widespread major language. Another important rea
from semantic-restricted tasks. These tasks are commonly used
use of linguistic knowledge beyond the lexicon level in the recog
As the Spartacus database consisted mainly of short sentence
paragraphs, the writers were asked to copy a set of sentences in f
line fields in the forms. Next figure shows one of the forms used
These forms also contain a brief set of instructions given to the
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Comparing output