OCR_iam

September 18, 2021

0.0.1 Klasyfikacja całych słów

Zagdnieniem jakie poruszymy w tym rodziale jest rozpoznawanie całych słów zapisanych pismem odręcznym.

Rozpoczynam od załadowania niezbędnych bibliotek. Będziemy używać biblioteki "Mxnet" oraz "GluonNLP" do trenowania sieci neuronowej, która posłuży do rozpoznawania pisma odręcznego. Dane testowe pochodzą ze zbioru odręcznie zapisanych formularzy iam.

Do przygotowania zbioru danych użyjemy biblioteki pochodzącej ze zbioru AWS o nazwie OCR. Dzięki tej bibliotece możemy wczytać zbiór i przygotować go do przetwarzania. Ważne jest aby w pliku credentials.json określić dane dostępowe do api serwisu iam.

[30]:

```
### Import  bibliotek

import random

random.seed(123)

import matplotlib.pyplot as plt
import matplotlib.patches as patches
import mxnet as mx
import gluonnlp as nlp
import numpy as np
from skimage import transform as skimage_tf, exposure
from tqdm import tqdm

from ocr.utils.expand_bounding_box import expand_bounding_box
from ocr.utils.sclite_helper import ScliteHelper
from ocr.utils.iam_dataset import IAMDataset, resize_image, crop_image,␣
 ↪crop_handwriting_page
from ocr.utils.word_to_line import sort_bbs_line_by_line, crop_line_images
from ocr.paragraph_segmentation_dcnn import SegmentationNetwork,␣
 ↪paragraph_segmentation_transform
from ocr.utils.encoder_decoder import Denoiser, ALPHABET, encode_char,␣
 ↪decode_char, EOS, BOS

from ocr.utils.denoiser_utils import SequenceGenerator
from ocr.utils.beam_search import ctcBeamSearch

from ocr.word_and_line_segmentation import SSD as WordSegmentationNet,␣
 ↪predict_bounding_boxes
from ocr.handwriting_line_recognition import Network as␣
 ↪HandwritingRecognitionNet, handwriting_recognition_transform
from ocr.handwriting_line_recognition import decode as decoder_handwriting,␣
 ↪alphabet_encoding
```

[2]:

```
ctx = mx.gpu(0)
```

Przygotowanie zbioru danych. Zbiór pobieramy z serwera iam. Następnie losowo wybieramy 4 formularze do analizy. Poniżej zostały wyświetlone formularze.

[3]:

```
test_ds = IAMDataset("form_original", train=False)
```

[4]:

```
random.seed(1)
```

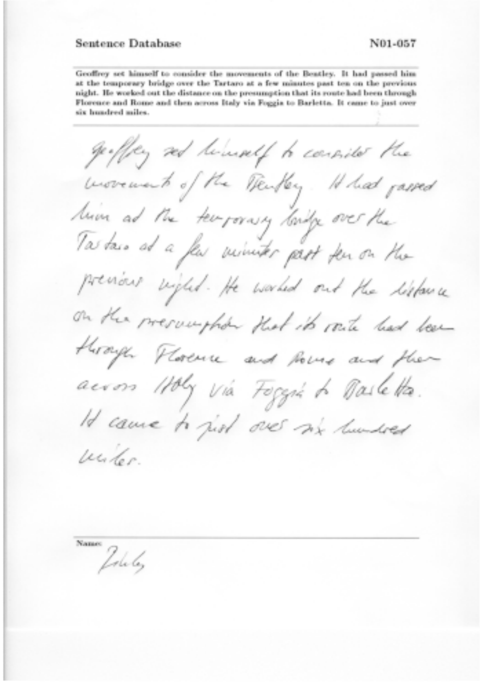
[5]:

```
figs_to_plot = 4
images = []

n = 0
for i in range(0, figs_to_plot):
    n = int(random.random()*len(test_ds))
    image, _ = test_ds[n]
    images.append(image)
```

[6]:

```
fig, axs = plt.subplots(int(len(images)/2), 2, figsize=(15, 10 * len(images)/2))
for i, image in enumerate(images):
    y, x = int(i/2), int(i%2)
    axs[y, x].imshow(image, cmap='Greys_r')
    axs[y, x].axis('off')
```


Sentence Database N01-057

Geoffrey set himself to consider the movements of the Bentley. It had passed him at the temporary bridge over the Tartaro at a few minutes past ten on the previous night. He worked out the distance on the presumption that its route had been through Florence and Rome and then across Italy via Foggia to Barletta. It came to just over six hundred miles.

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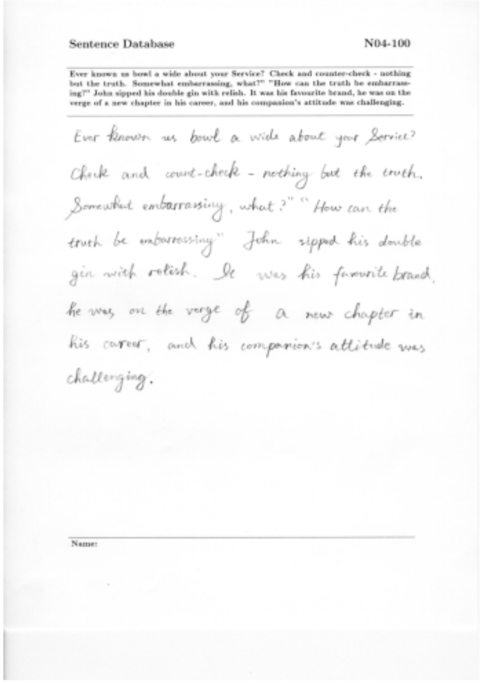
Sentence Database N04-100

Ever known us bowl a wide about your Service? Check and counter-check - nothing but the truth. Somewhat embarrassing, what?" "How can the truth be embarrassing?" John sipped his double gin with relish. It was his favourite brand, he was on the verge of a new chapter in his career, and his companion's attitude was challenging.

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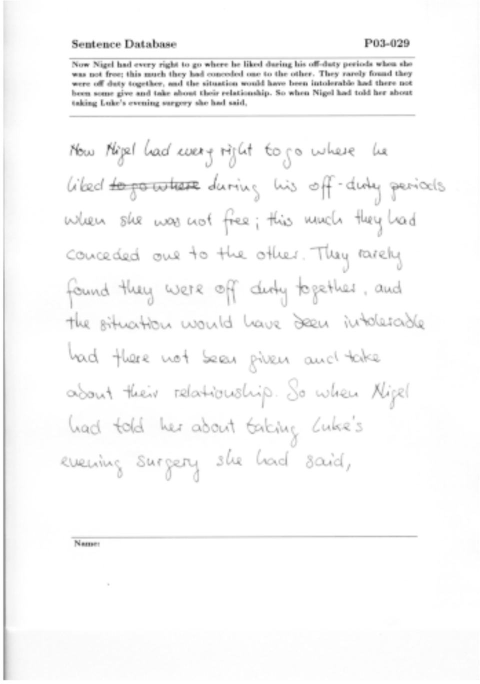
Sentence Database P03-029

Now Nigel had every right to go where he liked during his off-duty periods when she was not free; this much they had conceded one to the other. They rarely found they were off duty together, and the situation would have been intolerable had there not been some give and take about their relationship. So when Nigel had told her about taking Luke's evening surgery she had said,

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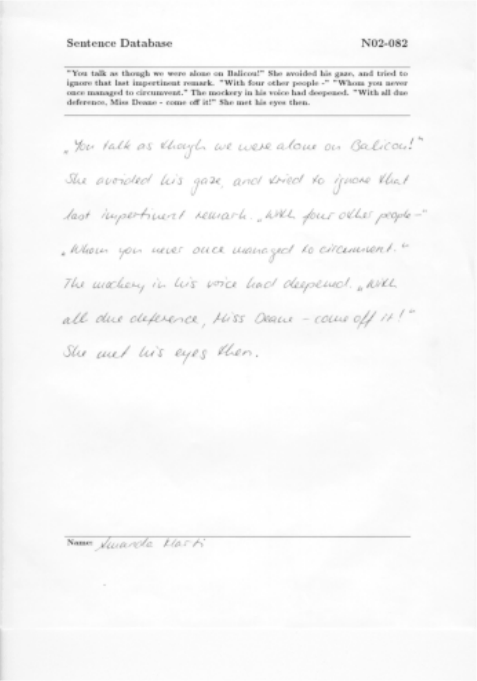
Sentence Database N02-082

"You talk as though we were alone on Balicou!" She avoided his gaze, and tried to ignore that last impertinent remark. "With four other people -" "Whom you never once managed to circumvent." The mockery in his voice had deepened. "With all due deference, Miss Deane - come off it!" She met his eyes then.

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The mockery in his voice had deepened. „With
all due deference, Miss Deane - come off it!"
She met his eyes then.

Name: Amanda Harts

Segmentacja akapitów Mając obraz formularza w zbiorze danych IAM, należy przewidzieć obszar w którym występuje tekst pisany odręcznie. Model został przeszkolony przy użyciu algorytmu omówionego w notatniku segmentacja akapitów.

[8]:

```
paragraph_segmentation_net = SegmentationNetwork(ctx=ctx)
paragraph_segmentation_net.cnn.load_parameters("models/paragraph_segmentation2.
 ↪params", ctx=ctx)
```

[9]:

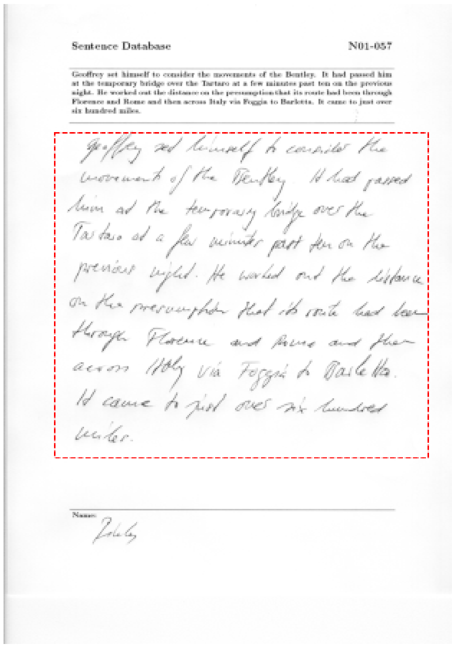
```
paragraph_segmentation_net.hybridize()
```

[10]:

```
form_size = (1120, 800)

predicted_bbs = []

fig, axs = plt.subplots(int(len(images)/2), 2, figsize=(15, 9 * len(images)/2))
for i, image in enumerate(images):
    s_y, s_x = int(i/2), int(i%2)
    resized_image = paragraph_segmentation_transform(image, form_size)
    bb_predicted = paragraph_segmentation_net(resized_image.as_in_context(ctx))
    bb_predicted = bb_predicted[0].asnumpy()
    bb_predicted = expand_bounding_box(bb_predicted, expand_bb_scale_x=0.03,
                                        expand_bb_scale_y=0.03)
    predicted_bbs.append(bb_predicted)

    axs[s_y, s_x].imshow(image, cmap='Greys_r')
    axs[s_y, s_x].set_title("{}".format(i))

    (x, y, w, h) = bb_predicted
    image_h, image_w = image.shape[-2:]
    (x, y, w, h) = (x * image_w, y * image_h, w * image_w, h * image_h)
    rect = patches.Rectangle((x, y), w, h, fill=False, color="r", ls="--")
    axs[s_y, s_x].add_patch(rect)
    axs[s_y, s_x].axis('off')
```

```
[05:11:06] ../src/operator/nn/./cudnn/./cudnn_algoreg-inl.h:97: Running
performance tests to find the best convolution algorithm, this can take a
while… (set the environment variable MXNET_CUDNN_AUTOTUNE_DEFAULT to 0 to
disable)
```

0



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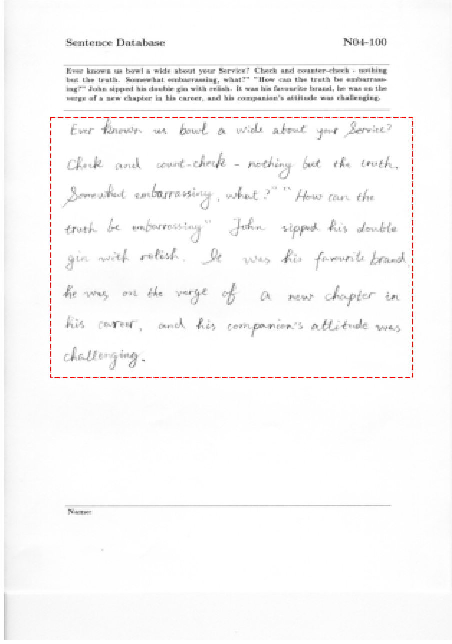
1



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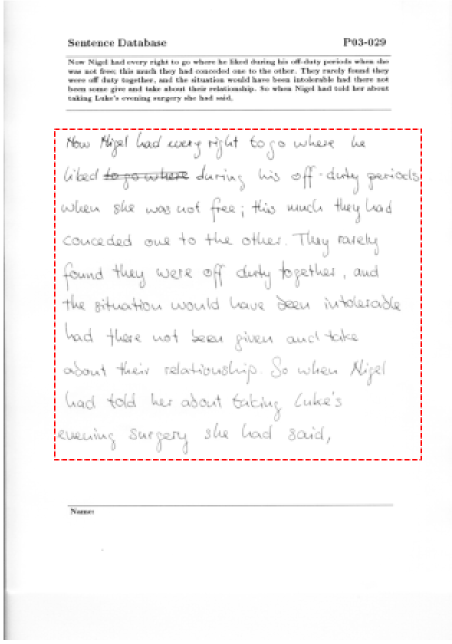
2



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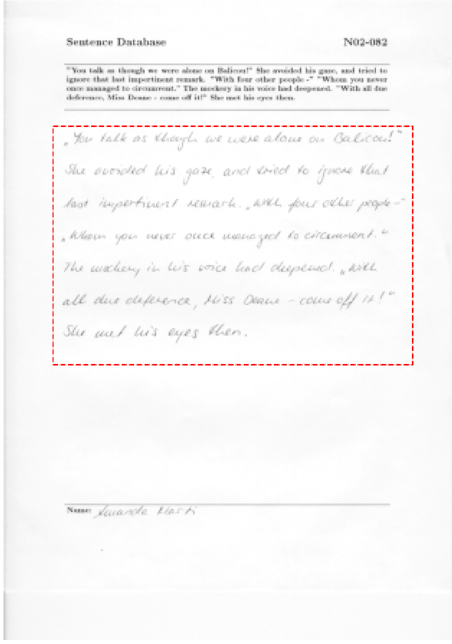
3



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"You talk as though we were alone on Balicou!" She avoided his gaze, and tried to ignore that last impertinent remark. "With four other people -" "Whom you never once managed to circumvent." The mockery in his voice had deepened. "With all due deference, Miss Deane - come off it!" She met his eyes then.

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Przygotowanie zdjęć Wycinamy z obrazu tylko ramkę z ręcznie pisanym tekstem i dostarczamy ją dalej do algorytmu.

[11]:

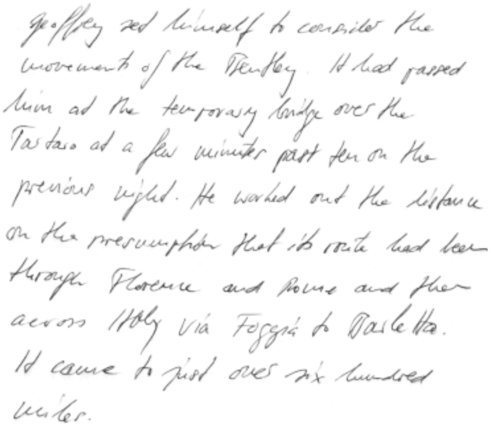
```
segmented_paragraph_size = (700, 700)
fig, axs = plt.subplots(int(len(images)/2), 2, figsize=(15, 9 * len(images)/2))

paragraph_segmented_images = []

for i, image in enumerate(images):
    s_y, s_x = int(i/2), int(i%2)

    bb = predicted_bbs[i]
    image = crop_handwriting_page(image, bb,␣
 ↪image_size=segmented_paragraph_size)
    paragraph_segmented_images.append(image)

    axs[s_y, s_x].imshow(image, cmap='Greys_r')
    axs[s_y, s_x].axis('off')
```



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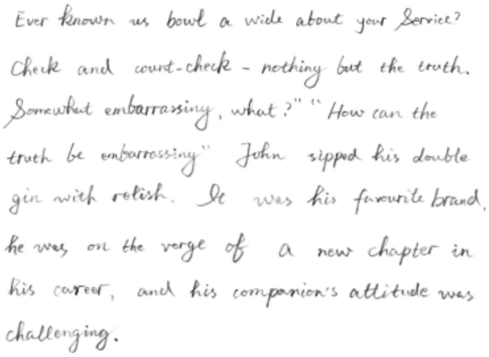

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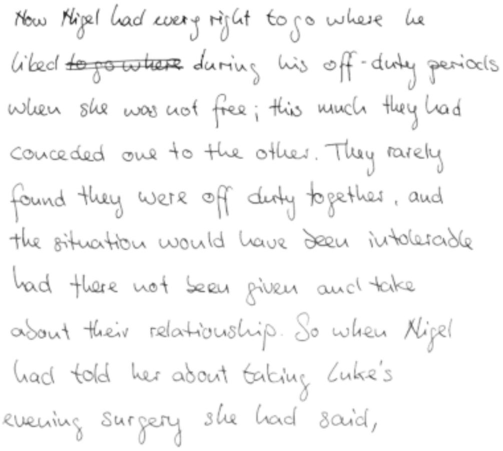

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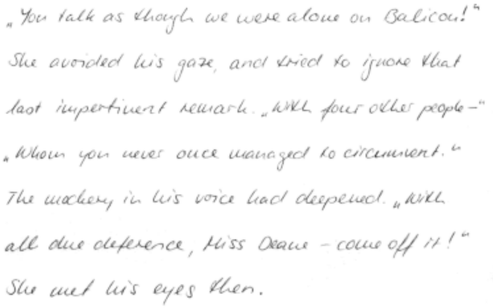


„You talk as though we were alone on Balicou!" She avoided his gaze, and tried to ignore that last impertinent remark. „With four other people –" „Whom you never once managed to circumvent." The mockery in his voice had deepened. „With all due deference, Miss Deane – come off it!" She met his eyes then.

Segmentacja lini tesktu i słów Mając formularz zawierający wyłącznie tekst pisany odręcznie, należy przewidzieć ramkę dla każdego słowa. Sposób działania modelu został przedstawiony w notatniku segmentacja tekstu i słów.

[12]:
```
word_segmentation_net = WordSegmentationNet(2, ctx=ctx)
word_segmentation_net.load_parameters("models/word_segmentation2.params")
word_segmentation_net.hybridize()
```

[13]:
```
min_c = 0.1
overlap_thres = 0.1
```

```
topk = 600

fig, axs = plt.subplots(int(len(paragraph_segmented_images)/2), 2,
                        figsize=(15, 5 * int(len(paragraph_segmented_images)/
 ↪2)))
predicted_words_bbs_array = []

for i, paragraph_segmented_image in enumerate(paragraph_segmented_images):
    s_y, s_x = int(i/2), int(i%2)

    predicted_bb = predict_bounding_boxes(
        word_segmentation_net, paragraph_segmented_image, min_c, overlap_thres,␣
 ↪topk, ctx)

    predicted_words_bbs_array.append(predicted_bb)

    axs[s_y, s_x].imshow(paragraph_segmented_image, cmap='Greys_r')
    for j in range(predicted_bb.shape[0]):
        (x, y, w, h) = predicted_bb[j]
        image_h, image_w = paragraph_segmented_image.shape[-2:]
        (x, y, w, h) = (x * image_w, y * image_h, w * image_w, h * image_h)
        rect = patches.Rectangle((x, y), w, h, fill=False, color="r")
        axs[s_y, s_x].add_patch(rect)
        axs[s_y, s_x].axis('off')
```

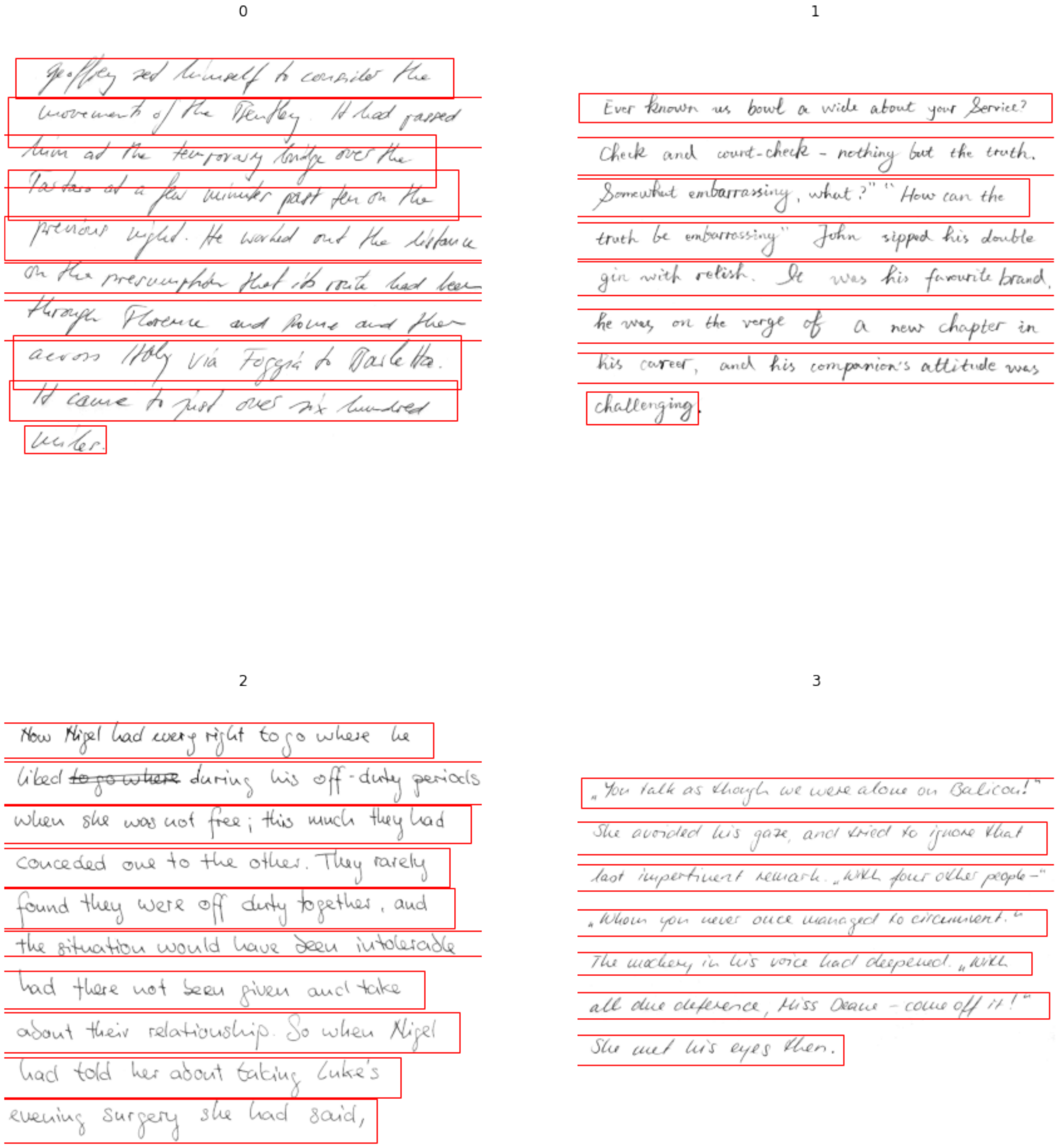
Dopasowanie pojedyńczych słów do lini Następnie musimy z tekstu wydobyć całe lini posiadające tekst odreczny.

[14]:
```
line_images_array = []
fig, axs = plt.subplots(int(len(paragraph_segmented_images)/2), 2,
                        figsize=(15, 9 * int(len(paragraph_segmented_images)/
 ↪2)))

for i, paragraph_segmented_image in enumerate(paragraph_segmented_images):
    s_y, s_x = int(i/2), int(i%2)
    axs[s_y, s_x].imshow(paragraph_segmented_image, cmap='Greys_r')
    axs[s_y, s_x].axis('off')
    axs[s_y, s_x].set_title("{}".format(i))

    predicted_bbs = predicted_words_bbs_array[i]
    line_bbs = sort_bbs_line_by_line(predicted_bbs, y_overlap=0.4)
    line_images = crop_line_images(paragraph_segmented_image, line_bbs)
    line_images_array.append(line_images)
    for line_bb in line_bbs:
        (x, y, w, h) = line_bb
        image_h, image_w = paragraph_segmented_image.shape[-2:]
        (x, y, w, h) = (x * image_w, y * image_h, w * image_w, h * image_h)

        rect = patches.Rectangle((x, y), w, h, fill=False, color="r")
        axs[s_y, s_x].add_patch(rect)
```



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Rozpoznawanie pisma Biorąc pod uwagę każdy wiersz tekstu, przewidujemy ciąg tekstu pisanego odręcznie. Działanie tej sieci został przedstawione w notatniku rozpoznawanie pisma.

[15]:
```
handwriting_line_recognition_net =␣
 ↪HandwritingRecognitionNet(rnn_hidden_states=512,
                                                              rnn_layers=2,␣
 ↪ctx=ctx, max_seq_len=160)
handwriting_line_recognition_net.load_parameters("models/handwriting_line8.
 ↪params", ctx=ctx)
handwriting_line_recognition_net.hybridize()
```

[16]:
```
line_image_size = (60, 800)
character_probs = []
for line_images in line_images_array:
    form_character_prob = []
    for i, line_image in enumerate(line_images):
        line_image = handwriting_recognition_transform(line_image,␣
 ↪line_image_size)
        line_character_prob = handwriting_line_recognition_net(line_image.
 ↪as_in_context(ctx))
        form_character_prob.append(line_character_prob)
    character_probs.append(form_character_prob)
```

Prawdopodobieństwo znaków w tekście

[17]:
```
def get_arg_max(prob):
    '''
    The greedy algorithm convert the output of the handwriting recognition␣
 ↪network
    into strings.
    '''
    arg_max = prob.topk(axis=2).asnumpy()
    return decoder_handwriting(arg_max)[0]
```

[18]:
```
def get_beam_search(prob, width=5):
    possibilities = ctcBeamSearch(prob.softmax()[0].asnumpy(),␣
 ↪alphabet_encoding, None, width)
    return possibilities[0]
```

Odszumianie tekstu wyjściowego Używamy denoisera seq2seq, aby przetłumaczyć zaszumione wejście na lepsze jakościowo wyjście.

[19]:
```
FEATURE_LEN = 150
denoiser = Denoiser(alphabet_size=len(ALPHABET), max_src_length=FEATURE_LEN,␣
 ↪max_tgt_length=FEATURE_LEN, num_heads=16, embed_size=256, num_layers=2)
denoiser.load_parameters('models/denoiser2.params', ctx=ctx)
```

[20]:
```
denoiser.hybridize(static_alloc=True)
```

[21]:
```
ctx_nlp = mx.gpu(0)
language_model, vocab = nlp.model.big_rnn_lm_2048_512(dataset_name='gbw',␣
 ↪pretrained=True, ctx=ctx_nlp)
moses_tokenizer = nlp.data.SacreMosesTokenizer()
moses_detokenizer = nlp.data.SacreMosesDetokenizer()
```

[22]:
```
beam_sampler = nlp.model.BeamSearchSampler(beam_size=20,
                                           decoder=denoiser.decode_logprob,
                                           eos_id=EOS,
                                           scorer=nlp.model.BeamSearchScorer(),
                                           max_length=150)
```

[23]:
```
generator = SequenceGenerator(beam_sampler, language_model, vocab, ctx_nlp,␣
 ↪moses_tokenizer, moses_detokenizer)
```

[24]:
```
def get_denoised(prob, ctc_bs=False):
    if ctc_bs: # Using ctc beam search before denoising yields only limited␣
 ↪improvements a is very slow
        text = get_beam_search(prob)
    else:
        text = get_arg_max(prob)
    src_seq, src_valid_length = encode_char(text)
    src_seq = mx.nd.array([src_seq], ctx=ctx)
    src_valid_length = mx.nd.array(src_valid_length, ctx=ctx)
    encoder_outputs, _ = denoiser.encode(src_seq, valid_length=src_valid_length)
    states = denoiser.decoder.init_state_from_encoder(encoder_outputs,
                                                                   ␣
 ↪encoder_valid_length=src_valid_length)
    inputs = mx.nd.full(shape=(1,), ctx=src_seq.context, dtype=np.float32,␣
 ↪val=BOS)
    output = generator.generate_sequences(inputs, states, text)
    return output.strip()
```

[25]:
```
sentence = "This sentnce has an eror"
src_seq, src_valid_length = encode_char(sentence)
src_seq = mx.nd.array([src_seq], ctx=ctx)
src_valid_length = mx.nd.array(src_valid_length, ctx=ctx)
encoder_outputs, _ = denoiser.encode(src_seq, valid_length=src_valid_length)
states = denoiser.decoder.init_state_from_encoder(encoder_outputs,
                                                               ␣
 ↪encoder_valid_length=src_valid_length)
inputs = mx.nd.full(shape=(1,), ctx=src_seq.context, dtype=np.float32, val=BOS)
print(sentence)
print("Choice")
print(generator.generate_sequences(inputs, states, sentence))
```

```
This sentnce has an eror
Choice
T h i s   s e n t e n c e
```

Wyniki jakościowe

- [AM] Arg Max CTC Decoding
- [BS] Beam Search CTC Decoding
- [D] Adding Text Denoiser

[26]:
```
for i, form_character_probs in enumerate(character_probs):
    fig, axs = plt.subplots(len(form_character_probs) + 1,
                            figsize=(10, int(1 + 2.3 *␣
 ↪len(form_character_probs))))
    for j, line_character_probs in enumerate(form_character_probs):
        decoded_line_am = get_arg_max(line_character_probs)
        print("[AM]",decoded_line_am)
        decoded_line_bs = get_beam_search(line_character_probs)
        decoded_line_denoiser = get_denoised(line_character_probs, ctc_bs=False)
        print("[D ]",decoded_line_denoiser)

        line_image = line_images_array[i][j]
        axs[j].imshow(line_image.squeeze(), cmap='Greys_r')
        axs[j].set_title("[AM]: {}\n[BS]: {}\n[D ]: {}\n\n".
 ↪format(decoded_line_am, decoded_line_bs, decoded_line_denoiser),␣
 ↪fontdict={"horizontalalignment":"left", "family":"monospace"}, x=0)
        axs[j].axis('off')
    axs[-1].imshow(np.zeros(shape=line_image_size), cmap='Greys_r')
    axs[-1].axis('off')
```

```
[AM] Gerfbey sed himself to considedr the
[D ] G e o r l y   u s e d   h i m s e l f
[AM] movement of the Pentey. It had gassed
[D ] m o v e m e n t   o f   t h e   e n e m
[AM] bing at tie temroray, budge over the
[D ] k i n g   a t   t h e   t e m p o r a
[AM] Tartars ot a few minister past ten on the
[D ] Tartars ot a few minister past ten on the
[AM] previous night. He worked out the distance
[D ] previous night. He worked out the distance
[AM] on the presumphor that its raite had been
[D ] o n   t h e   p r e s u m p t i o n   t h a
[AM] through Florence and some and thar
[D ] through Florence and some and thar
[AM] across Itoly via Togggin to Barletta.
[D ] a c r o s s   I t a l y   v i a   T o g
```

```
[AM] It came 't just over sit hundred
[D ] It came 't just over sit hundred
[AM] miler.
[D ] miler.
[AM] Ever known us boul a wie about your Bervice?
[D ] E v e r   k n o w n   u s   a b o u t   a   w
[AM] Check and count-checke - nothing but the truth.
[D ] C h e c k   a n d   c o u n t - c h e c k s -   n
[AM] Somewhut embarrassiny, what?" "How can the
[D ] S o m e w h a t   e m b a r r a s s i n g ,
[AM] truch be emburrassiny" John sipped his double
[D ] t o u c h   b e   e m b a r r a s s i n g   " J
[AM] gir with rotish. He was his favourite brand,
[D ] g i r l   w i t h   B r o t i s h .   H e   w
[AM] he was on the verge of a new chapter in
[D ] he was on the verge of a new chapter in
[AM] his career, and his componion's attitude was
[D ] h i s   c a r e e e r ,   a n d   h i s   c o m
[AM] challenging
[D ] challenging
[AM] How Migel had every right to go where he
[D ] How Migel had every right to go where he
[AM] Liked t during his off-duty gerianls
[D ] L i k e d   i t   d u r i n g   h i s
[AM] when she was not free; this much they had
[D ] when she was not free; this much they had
[AM] conceded one to the other. They rarely
[D ] conceded one to the other. They rarely
[AM] found they were off duty together, and
[D ] found they were off duty together, and
[AM] the situation would have deen intoleradle
[D ] t h e   s i t u a t i o n   w o u l d   h a
[AM] had there not been given and take
[D ] had there not been given and take
[AM] adout their relatiouship. So when Migel
[D ] a b o u t   t h e i r   r e l a t i o n s
[AM] had told her about taking Lutre's
[D ] h a d   t o l d   h e r   a b o u t
[AM] evening surgery she had said,
[D ] evening surgery she had said,
[AM] "You talk as though we were aloue on Balicon!."
[D ] " Y o u   t a l k   a s   t h o u g h   w e   w e
[AM] She avoided his gaze, and tried to iuore that
[D ] S h e   a v o i d e d   h i s   g a z e ,   a n
[AM] last impertiment remark."With four other people-"
[D ] l a s t   i m p e r t i n e n t   r e m a r k .   "
[AM] "Whom you never ouce managed to circumient."
[D ] " W h o m   y o u   n e v e r   o n c e   m a
```

```
[AM] The mackery, in his voice had deepened. "with
[D ] T h e   m o c k e r y ,   i n   h i s   v o i c
[AM] all due deference, Miss Deaue-come off it!"
[D ] a l l   t h e   d e f e r e n c e ,   M i s s
[AM] She met his eyes then.
[D ] She met his eyes then.
```

```
[AM]: Gerfbey sed himself to considedr the
[BS]: Gerfbey sed himself to consider the
[D ]: Georly used himself
```

Geoffrey sed himself to consider the

```
[AM]: movement of the Pentey. It had gassed
[BS]: movement of the Pentey. It had gassed
[D ]: movement of the enem
```

movement of the Pentley. It had passed

```
[AM]: bing at tie temroray, budge over the
[BS]: bing at tie temforary, budge over the
[D ]: king at the tempora
```

him at the temporary bridge over the

```
[AM]: Tartars ot a few minister past ten on the
[BS]: Tartars ot a few minister past ten on the
[D ]: Tartars ot a few minister past ten on the
```

Tartars at a few minutes past ten on the

```
[AM]: previous night. He worked out the distance
[BS]: previous night. He worked out the distance
[D ]: previous night. He worked out the distance
```

previous night. He worked out the distance

```
[AM]: on the presumphor that its raite had been
[BS]: on the presumphor that its raite had been
[D ]: on the presumption tha
```

on the presumphon that its route had been

```
[AM]: through Florence and some and thar
[BS]: through Florence and some and thar
[D ]: through Florence and some and thar
```

through Florence and Rome and then

```
[AM]: across Itoly via Togggin to Barletta.
[BS]: across Itoly via Togggin to Barletta.
[D ]: across Italy via Tog
```

across Italy via Foggia to Barletta.

```
[AM]: It came 't just over sit hundred
[BS]: It came 't just over sit hundred
[D ]: It came 't just over sit hundred
```

It came to just over six hundred

```
[AM]: miler.
[BS]: miler.
[D ]: miler.
```

miles.

[redacted]

```
[AM]: Ever known us boul a wie about your Bervice?
[BS]: Ever known us boul a wide about your Bervice?
[D ]: E v e r   k n o w n   u s   a b o u t   a   w
```

Ever known us bowl a wide about your Service?

```
[AM]: Check and count-checke - nothing but the truth.
[BS]: Check and count-checke - nothing but the truth.
[D ]: C h e c k   a n d   c o u n t - c h e c k s -   n
```

Check and count-check - nothing but the truth.

```
[AM]: Somewhut embarrassiny, what?" "How can the
[BS]: Somewhut embarrassiny, what?" "How can the
[D ]: S o m e w h a t   e m b a r r a s s i n g ,
```

Somewhat embarrassing, what?" "How can the

```
[AM]: truch be emburrassiny" John sipped his double
[BS]: truch be emburrassiny" John sipped his double
[D ]: t o u c h   b e   e m b a r r a s s i n g   " J
```

truth be embarrassing" John sipped his double

```
[AM]: gir with rotish. He was his favourite brand,
[BS]: gir with rotish. He was his favourite brand,
[D ]: g i r l   w i t h   B r o t i s h .   H e   w
```

gin with relish. He was his favourite brand,

```
[AM]: he was on the verge of a new chapter in
[BS]: he was on the verge of a new chapter in
[D ]: he was on the verge of a new chapter in
```

he was on the verge of a new chapter in

```
[AM]: his career, and his componion's attitude was
[BS]: his career, and his componion's attitude was
[D ]: h i s   c a r e e r ,   a n d   h i s   c o m
```

his career, and his companion's attitude was

```
[AM]: challenging
[BS]: challenging
[D ]: challenging
```

challenging

[redacted]

```
[AM]: How Migel had every right to go where he
[BS]: How Migel had every right to go where he
[D ]: How Migel had every right to go where he
```

How Nigel had every right to go where he

```
[AM]: Liked t during his off-duty gerianls
[BS]: Liked t during his off-duty gerianls
[D ]: L i k e d   i t   d u r i n g   h i s
```

liked ~~to go where~~ during his off-duty periods

```
[AM]: when she was not free; this much they had
[BS]: when she was not free; this much they had
[D ]: when she was not free; this much they had
```

when she was not free; this much they had

```
[AM]: conceded one to the other. They rarely
[BS]: conceded one to the other. They rarely
[D ]: conceded one to the other. They rarely
```

conceded one to the other. They rarely

```
[AM]: found they were off duty together, and
[BS]: found they were off duty together, and
[D ]: found they were off duty together, and
```

found they were off duty together, and

```
[AM]: the situation would have deen intoleradle
[BS]: the situation would have deen intoleradle
[D ]: t h e   s i t u a t i o n   w o u l d   h a
```

the situation would have been intolerable

```
[AM]: had there not been given and take
[BS]: had there not been given and take
[D ]: had there not been given and take
```

had there not been given and take

```
[AM]: adout their relatioushp. So when Migel
[BS]: adout their relatioushp. So when Migel
[D ]: a b o u t   t h e i r   r e l a t i o n s
```

about their relationship. So when Nigel

```
[AM]: had told her about taking Lutre's
[BS]: had told her about taking Lutre's
[D ]: h a d   t o l d   h e r   a b o u t
```

had told her about taking Luke's

```
[AM]: evening surgery she had said,
[BS]: evening surgery she had said,
[D ]: evening surgery she had said,
```

evening surgery she had said,

[redacted]

```
[AM]: "You talk as though we were aloue on Balicon!."
[BS]: "You talk as though we were aloue on Balicon."
[D ]: " Y o u   t a l k   a s   t h o u g h   w e   w e
```

„You talk as though we were alone on Balicon!"

```
[AM]: She avoided his gaze, and tried to iuore that
[BS]: She avoided his gaze, and tried to iuore that
[D ]: S h e   a v o i d e d   h i s   g a z e ,   a n
```

She avoided his gaze, and tried to ignore that

```
[AM]: last impertiment remark."With four other people-"
[BS]: last impertiment remark."With four other people-"
[D ]: l a s t   i m p e r t i n e n t   r e m a r k .   "
```

last impertinent remark. „With four other people –"

```
[AM]: "Whom you never ouce managed to circumient."
[BS]: "Whom you never ouce managed to circumient."
[D ]: " W h o m   y o u   n e v e r   o n c e   m a
```

„Whom you never once managed to circumvent."

```
[AM]: The mackery, in his voice had deepened. "with
[BS]: The mackery, in his voice had deepened. "with
[D ]: T h e   m o c k e r y ,   i n   h i s   v o i c
```

The mockery in his voice had deepened. „With

```
[AM]: all due deference, Miss Deaue-come off it!"
[BS]: all due deference, Miss Deaue-come off it!"
[D ]: a l l   t h e   d e f e r e n c e ,   M i s s
```

all due deference, Miss Deane – come off it!"

```
[AM]: She met his eyes then.
[BS]: She met his eyes then.
[D ]: She met his eyes then.
```

She met his eyes then.

[redacted]

Wyniki ilościowe Iterujemy przez zbiór testowy, aby otrzymać wskaźnik błędu znaku (ang. Character Error Rate, CER).

[27]:
```
sclite = ScliteHelper('../SCTK/bin')

def get_qualitative_results_lines(denoise_func):
    sclite.clear()
    test_ds_line = IAMDataset("line", train=False)
    for i in tqdm(range(1, len(test_ds_line))):
        image, text = test_ds_line[i]
        line_image = exposure.adjust_gamma(image, 1)
        line_image = handwriting_recognition_transform(line_image,␣
 ↪line_image_size)
        character_probabilities = handwriting_line_recognition_net(line_image.
 ↪as_in_context(ctx))
        decoded_text = denoise_func(character_probabilities)
        actual_text = text[0].replace("&quot;", '"').replace("&apos;","'").
 ↪replace("&amp;", "&")
        sclite.add_text([decoded_text], [actual_text])

    cer, er = sclite.get_cer()
    print("Mean CER = {}".format(cer))
    return cer
```

[28]:
```
def get_qualitative_results(denoise_func):
    sclite.clear()
    for i in tqdm(range(1, len(test_ds))):
        image, text = test_ds[i]
        resized_image = paragraph_segmentation_transform(image,␣
 ↪image_size=form_size)
        paragraph_bb = paragraph_segmentation_net(resized_image.
 ↪as_in_context(ctx))
        paragraph_bb = paragraph_bb[0].asnumpy()
        paragraph_bb = expand_bounding_box(paragraph_bb, expand_bb_scale_x=0.01,
                                           expand_bb_scale_y=0.01)
        paragraph_segmented_image = crop_handwriting_page(image, paragraph_bb,␣
 ↪image_size=segmented_paragraph_size)
        word_bb = predict_bounding_boxes(word_segmentation_net,␣
 ↪paragraph_segmented_image, min_c, overlap_thres, topk, ctx)
        line_bbs = sort_bbs_line_by_line(word_bb, y_overlap=0.4)
        line_images = crop_line_images(paragraph_segmented_image, line_bbs)

        predicted_text = []
        for line_image in line_images:
            line_image = exposure.adjust_gamma(line_image, 1)
            line_image = handwriting_recognition_transform(line_image,␣
↪line_image_size)
            character_probabilities =␣
↪handwriting_line_recognition_net(line_image.as_in_context(ctx))
            decoded_text = denoise_func(character_probabilities)
            predicted_text.append(decoded_text)

        actual_text = text[0].replace("&quot;", '"').replace("&apos;","'").
↪replace("&amp;", "&")
        actual_text = actual_text.split("\n")
        if len(predicted_text) > len(actual_text):
            predicted_text = predicted_text[:len(actual_text)]
        sclite.add_text(predicted_text, actual_text)

    cer, _ = sclite.get_cer()
    print("Mean CER = {}".format(cer))
    return cer
```

CER z liniami wstępnie segmentowanymi

[32]:

```
get_qualitative_results_lines(get_arg_max)
```

```
100%|                     | 1859/1859 [01:23<00:00, 22.29it/s]

Mean CER = 8.4
```

[32]:

```
8.4
```

[33]:

```
get_qualitative_results_lines(get_denoised)
```

```
100%|                     | 1859/1859 [13:04<00:00,  2.37it/s]

Mean CER = 38.3
```

[33]:

```
38.3
```

[34]:

```
get_qualitative_results(get_arg_max)
```

```
100%|                      | 231/231 [01:30<00:00,  2.54it/s]
Warning: The comment designation is now **, the line below
         has only one comment info character, this may be an error
         *?2s as 'Seaweed', and a youngish, sharp-eyed(spk125_8)


Mean CER = 11.6
```

[34]:

```
11.6
```

```
[35]: get_qualitative_results(get_beam_search)
```

```
100%|                      | 231/231 [14:46<00:00,  3.84s/it]
Warning: The comment designation is now **, the line below
         has only one comment info character, this may be an error
         *?2s as 'Seaweed', and a youngish, sharp-eyed(spk125_8)


Mean CER = 11.5
```

```
[35]: 11.5
```

```
[37]: get_qualitative_results(get_denoised)
```

```
100%|                      | 231/231 [13:18<00:00,  3.46s/it]
Warning: The comment designation is now **, the line below
         has only one comment info character, this may be an error
         *?2s as 'Seaweed', and a youngish, sharp-eyed(spk125_8)


Mean CER = 42.7
```

```
[37]: 42.7
```