

Klasyfikacja całych słów

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

Rozpocznę 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.

```
[1]: ### 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
import cv2 as cv
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

```

[07:20:20] ../src/c_api/./operator/custom/custom-inl.h:57: New registration is overriding existing custom operator _smoothing_with_dim

```
[2]: ctx = mx.gpu(0)
```

Przygotowanie zbioru danych.

Badanie przeprowadzimy na czterech przygotowanych przeze mnie formularz. Jeden z formularzy został zapisany w języku polskim. Pozostałe formularze zostały zapisane w języku angielskim.

```

[3]: import json

files = [
    'A00-000',
    'A00-002',
    'A00-003',
    'A00-001'
]

words = json.load(open('my-dataset/words.json',))

test_ds = []

for x in files:
    img = cv.imread(f'my-dataset/{x}.png')[:, :, 0]
    img = np.array(img)
    text = np.array(words[x])
    test_ds.append([img, text])

```

```
[4]: random.seed(1)
```

```

[5]: figs_to_plot = 4
images = []

n = 0
for i in range(0, figs_to_plot):

```

```
image, _ = test_ds[i]
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')
```

Nobody really knows why some tomatoes grow ugly. One farmer says that bees are the reason. Bees take the pollen from one flower to another. Something goes wrong sometimes. Then, the tomatoes are ugly. Mariol and Vincente Martinez win the competition this year. They say that they do not plan to grow ugly tomatoes. It just happens. They bring the tomatoes to Tudela. Then, they win.

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A group of scientists from all over the world have some news about a COVID-19 booster vaccine. A booster vaccine is a vaccine which makes a previous vaccine stronger. A vaccine is a medicine that stops you from getting sick. Some scientists believe that the booster vaccine is important. It protects people from the coronavirus. Then, the latest study says that older COVID-19 vaccines work well.

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Segmentacja akapitów

Na załadowanym obrazie należy przewidzieć obszar w którym występuje tekst pisany odręcznie. Model został przeszkolony przy użyciu algorytmu omówionego w notatniku segmentacja akapitów.

```
[7]: paragraph_segmentation_net = SegmentationNetwork(ctx=ctx)
paragraph_segmentation_net.cnn.load_parameters("models/paragraph_segmentation2.
↳params", ctx=ctx)
```

```
[8]: paragraph_segmentation_net.hybridize()
```

```
[9]: 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')
```

[07:20:40] ../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)

Nobody really knows why some tomatoes grow ugly. One farmer says that bees are the reason. Bees take the pollen from one flower to another. Something goes wrong sometimes. Then, the tomatoes are ugly. Mariol and Vincent Martinez win the competition this year. They say that they do not plan to grow ugly tomatoes. It just happens. They bring the tomatoes to Tudela. Then, they win.

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Przygotowanie zdjęć

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

```
[10]: 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')

```

Nobody really knows why some tomatoes grow ugly. One farmer says that bees are the reason. Bees take the pollen from one flower to another. Something goes wrong sometimes. Then, the tomatoes are ugly. Hansel and Vincente Martinez win the competition this year. They say ~~that~~ they do not plan to grow ugly tomatoes. It just happens. They bring the tomatoes to Tudela. Then, they win.

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Od razu po przyjeździe udało im się znaleźć kortow i zobaczyć Rynek Główny, to ulubione miejsce dla wszystkich turystów, który jeszcze nie byli w Krakowie. Atmosfera jest tu szczególnie - to związka tradycyjnych zwyczajów: Sukiennic, kościoła Mariackiego, unikatowe rzeźby, kościoła św. Józefa i przepięknych starych kamienic.

Segmentacja lini tekstu 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.

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

```
[12]: 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')
```


Nobody really knows why some tomatoes grow
 right the farmer says some trees are not
 really trees take the garden from one
 flower to another something goes wrong
 sometimes they are tomatoes are ugly.
 Harold and Vincent Marlowe are the
 companion this year they say that
 they do not plan to grow ugly tomatoes
 if just happen they bring in tomatoes
 to include from they are

Britain is the world's largest currency
 Britain is the name of the country
 It is not a lot of people who are happy to
 problem for the whole world the rules for
 Britain is to say that all things without limits
 Susan Nakamura is the founder of Nakamura
 that it is not the new name Nakamura
 on the family party is not and is
 more a state in Nakamura

A group of friends from an area in Scotland
 that some are about a lot of friends
 there is a lot of people in a vacation house
 makes a person who is a lot of people
 is a person who is a lot of people
 some friends believe that the location
 because it is important in people's lives
 from the experience from the last day
 they had a lot of friends who were

On the way to the city of London
 London is a city of people who are
 people who are people who are
 we are a lot of people who are
 people who are people who are
 people who are people who are
 people who are people who are
 people who are people who are
 people who are people who are
 people who are people who are

Dopasowanie pojedynczych słów do linii

Następnie musimy z tekstu wydobyć całe lini posiadające tekst odreczny.

```
[13]: 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)

```

0

Nobody really knows why some tomatoes grow ugly. One farmer says that bees are the reason. Bees take the pollen from one flower to another. Something goes wrong sometimes. Then, the tomatoes are ugly. Harish and Vincente Martinez win the competition this year. They say ~~that~~ they do not plan to grow ugly tomatoes. It just happens. They bring the tomatoes to Tudela. Then, they win.

2

A group of scientists from all over the world have some news about a COVID-19 booster vaccine. A booster vaccine is a vaccine which makes a previous vaccine stronger. A vaccine is a medicine that stop you from getting sick. Some scientists believe that the booster vaccine is important. It protects people from the coronavirus. Then, the latest study says that older COVID-19 vaccines work well.

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Rozpoznawanie pisma

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

```
[14]: 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()
```

```
[15]: 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

```
[16]: 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]
```

```
[17]: 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.

```
[18]: 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)
```

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

```
[20]: 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()
```

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

```
[22]: generator = SequenceGenerator(beam_sampler, language_model, vocab, ctx_nlp,
↳moses_tokenizer, moses_detokenizer)
```

```
[23]: 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()
```

```
[24]: sentence = "This sentnce has an error"
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.ctx, 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

```

[25]: 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("\n\n\n\n[AM]: {} \n [BS]: {} \n [D ]: {} \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] vlobody ceally knows why some tomatoes grow

[D] s o m e b o d y r e a l l y k n o w s w

[AM] ngly. Ohe fammer says that bees ane the
[D] u g l y . T h e f a r m e r s a y s
[AM] reasam. Bees take the pollen from come
[D] r e a s o n . B e e s t a k e t h
[AM] flomser to another. Something gues wrong
[D] f l o w e r t o a n o t h e r . S o
[AM] sometimes. Thery the tomatoes are ugly.
[D] s o m e t i m e s . T h e r e b y t h
[AM] Marieal and Vincente Mantimere win the
[D] M a r i e l a n d V i n c e n t e
[AM] competitian this yeorr. They sany that
[D] c o m p e t i t i o n t h i s y e a
[AM] they do not plan to grous mgly tomatoes.
[D] t h e y d o n o t p l a n t o g
[AM] It just happens. They bring the tomatues
[D] I t j u s t h a p p e n s . T h e y
[AM] to Tudela. Ther; they sin-
[D] t o J u d e a . T h e n
[AM] Bitcain is the workd's digital currewcs.
[D] B r i t a i n i s t h e w o r l d '
[AM] Britcin is the marre of the mosery.
[D] B r i t a i n i s t h e m e r e
[AM] It starks in 1L00). H happerts aflen on very bard marcy.
[D] I t s h a r k s i n 1 0 0) . H e s u p p o r t
[AM] probrems for tne whole workd. The idea for
[D] p r o b l e m s f o r t h e w h o l e
[AM] Britain is to buy and well things without Banks.
[D] B r i t a i n i s t o b u y a n d w e l l t h i n g s w i t h o u t B a n k s .
[AM] Satolti Maxcamatd is the foundior of Bitcain.
[D] S a t a l l i M e x i c a m a t e d i n t
[AM] That is not the seal name. Maborly knows
[D] T h a t i s n o t t h e r e a l
[AM] wtho the foundar really as Two arlistes
[D] w i t h o u t t h e f o u n d e r r
[AM] mate a stnturd it Malismats
[D] m a d e a s t a n d a r d
[AM] A group of sccentists from all over the world
[D] A g r o u p o f s c i e n t i s t s f r
[AM] have some news about a coun9-49 bccster
[D] h a v e s o m e n e w s a b o u t

[AM] vacaine. A coostor vacaine is a vacime which
 [D] vaccine. A coast or vaci
 [AM] mates a previous vacime stronger. A vaccinse
 [D] mates a previous vacime
 [AM] is a melicine, that stop you from getting side.
 [D] is medicine, that stop yo
 [AM] Somic scensistis" Soviere" that" the Soostert
 [D] Somic ascensist is "Sove
 [AM] raccine, is imporeant. It protects people
 [D] practice, is impotent.
 [AM] from the corioiaines. Then, the "atest stuaey
 [D] from the contradictines.
 [AM] says that ololen covio. 19vacines worke were.
 [D] says that wholen convict
 [AM] Od natn po pruyjesiduic udaro in sie unilme.
 [D] had nothing upon your p
 [AM] Konkohs i rdkacryd aymen Grduny, to mlulcieme
 [D] monkous in ordinary day
 [AM] miejoce da worysttich turystdws, ktdry jesuse
 [D] which since was a very s
 [AM] ie uyin is trationie. Aemoofera just th
 [D] like buying his tradi
 [AM] secregama - to rasinge orolicanych rabytrcin"
 [D] secregame - to rising th
 [AM] Suxiennic, robcidia Mariactiegs, wieing ratuseoney.
 [D] Susannic, soliciticial Marc
 [AM] Rosccia du. Uigciecka is preepierengch stawyoh
 [D] Rebecca du. Micnicka is
 [AM] Camienic.
 [D] Americ.

[AM]: vlobody ceally knows why some tomatoes grow
[BS]: vlobody ceally knows why some tomatoes grow
[D]: s o m e b o d y r e a l l y k n o w s w

Nobody really knows why some tomatoes grow

[AM]: ngly. Ohe fammer says that bees ane the
[BS]: ngly. Ohe farmer says that bees ane the
[D]: u g l y . T h e f a r m e r s a y s

ugly. One farmer says that bees are the

[AM]: reasam. Bees take the pollen from come
[BS]: reasam. Bees take the pollen from come
[D]: r e a s o n . B e e s t a k e t h

reason. Bees take the pollen from one

[AM]: flomser to another. Something gues wrong
[BS]: flomser to another. Something gues wrong
[D]: f l o w e r t o a n o t h e r . S o

flower to another. Something goes wrong

[AM]: sometimes. Thery the tomatoes are ugly.
[BS]: sometimes. Thery the tomatoes are ugly.
[D]: s o m e t i m e s . T h e r e b y t h

sometimes. Then, the tomatoes are ugly.

[AM]: Marieal and Vincente Mantimere win the
[BS]: Marieal and Vincente Mantimere win the
[D]: M a r i e l a n d V i n c e n t e

Marisol and Vincente Mantimere win the

[AM]: competitian this yeorr. They sany that
[BS]: competitian this yeorr. They sany that
[D]: c o m p e t i t i o n t h i s y e a

competition this year. They say ~~that~~

[AM]: they do not plan to grous mgly tomatoes.
[BS]: they do not plan to grous mgly tomatoes.
[D]: t h e y d o n o t p l a n t o g

they do not plan to grow ugly tomatoes.

[AM]: It just happens. They bring the tomatues
[BS]: It just happens. They bring the tomatues
[D]: I t j u s t h a p p e n s . T h e y

It just happens. They bring the tomatoes

[AM]: to Tudela. Ther; they sin-
[BS]: to Tudela. Ther; they sin-
[D]: t o J u d e a . T h e n

to Tudela. Then, they win.



[AM]: Bitcain is the workd's digital currewcs.
[BS]: Bitcain is the workd's digital currewcs.
[D]: B r i t a i n i s t h e w o r l d '

Bitcoin is the world's digital currency.

[AM]: Britcin is the marre of the mosery.
[BS]: Britcin is the marre of the mosey.
[D]: B r i t a i n i s t h e m e r e

Bitcoin is the name of the money.

[AM]: It starks in 1L00). H happerts aflen on very bard marcy.
[BS]: It starks in 100). H happerts aflen on very bard marcy.
[D]: I t s h a r k s i n 1 0 0) . H e s u p p o r t

It starts in 1008. It happens after a very bad money.

[AM]: probrems for tne whole workd. The idea for
[BS]: probrems for tne whole workd. The idea for
[D]: p r o b l e m s f o r t h e w h o l e

problems for the whole world. The idea for

[AM]: Britain is to buy and well things without Banks.
[BS]: Britain is to buy and well things without Banks.
[D]: B r i t a i n i s t o b u y a n d w e l l t h i n g s w i t h o u t B a n k s .

Bitcoin is to buy and sell things without banks.

[AM]: Satolti Maxcamatd is the foundior of Bitcain.
[BS]: Satolti Maxcamatd is the foundior of Bitcain.
[D]: S a t a l l i M e x i c a m a t e d i n t

Satoshi Nakamoto is the founder of Bitcoin.

[AM]: That is not the seal name. Maborly knows
[BS]: That is not the seal name. Maborly knows
[D]: T h a t i s n o t t h e r e a l

That is not the real name. Nobody knows

[AM]: wtho the foundar really as Two arlistes
[BS]: wtho the foundar really as Two arlistes
[D]: w i t h o u t t h e f o u n d e r r

who the founder really is. Two artists

[AM]: mate a stnturd it Malismats
[BS]: mate a stnturd it Malismats
[D]: m a d e a s t a n d a r d

make a statue of Nakamoto



[AM]: A group of scientists from all over the world
[BS]: A group of scientists from all over the world
[D]: A group of scientists from

A group of scientists from all over the world

[AM]: have some news about a COVID-19 booster
[BS]: have some news about a COVID-19 booster
[D]: have some news about

have some news about a COVID-19 booster

[AM]: vaccine. A booster vaccine is a vaccine which
[BS]: vaccine. A booster vaccine is a vaccine which
[D]: vaccine. A booster vaccine is a vaccine which

vaccine. A booster vaccine is a vaccine which

[AM]: makes a previous vaccine stronger. A vaccine
[BS]: makes a previous vaccine stronger. A vaccine
[D]: makes a previous vaccine stronger. A vaccine

makes a previous vaccine stronger. A vaccine

[AM]: is a medicine, that stop you from getting sick.
[BS]: is a medicine, that stop you from getting sick.
[D]: is a medicine, that stop you from getting sick.

is a medicine that stop you from getting sick.

[AM]: Some scientists believe that the booster
[BS]: Some scientists believe that the booster
[D]: Some scientists believe that the booster

Some scientists believe that the booster

[AM]: vaccine, is important. It protects people
[BS]: vaccine, is important. It protects people
[D]: vaccine, is important. It protects people.

vaccine is important. It protects people

[AM]: from the coronavirus. Then, the latest study
[BS]: from the coronavirus. Then, the latest study
[D]: from the coronavirus. Then, the latest study.

from the coronavirus. Then, the latest study

[AM]: says that older COVID-19 vaccines work well.
[BS]: says that older COVID-19 vaccines work well.
[D]: says that older COVID-19 vaccines work well.

says that older COVID-19 vaccines work well.

[AM]: Od natn po pruyjesiduic udaro in sie unilme.
[BS]: Od natn po pruyjesiduic udaro in sie unilme.
[D]: had nothing upon your p

Od razu po przyjeździe udało im się uniknąć

[AM]: Konkohs i rdkacryd aymen Grduny, to mlulcieme
[BS]: Konkohs i rdkacryd aymen Grduny, to mlulcieme
[D]: monkous in ordinary day

Konkoha i zderzyć Rynek Główny, to ulubione

[AM]: miejoe da worysttich turystdws, ktdry jesuse
[BS]: miejoe da worysttich turystdws, ktdry jesuse
[D]: which since was a very s

miejsce dla wszystkich turystów, którzy jeszcze

[AM]: ie uyin is trationie. Aemoofera just th
[BS]: ie uyin is trationie. Aemoofera just th
[D]: like buying his tradi

ie byli w Krakowie. Atmosfera jest tu

[AM]: seeregama - to rasinge orolicanych rabytrcin"
[BS]: seeregama - to rasinge orolicanych rabytrcin"
[D]: se regame - to rising th

szczególna - to zasługa okolicznych zabytków:

[AM]: Suxiennic, robcidia Mariactiegs, wieing ratuseoney.
[BS]: Suxiennic, robcidia Mariactiegs, wieing ratuseoney.
[D]: Susannic, soliciticial Marc

Sukiennic, kościół Mariacki, wież ratuszowej,

[AM]: Rosccia du. Uigciecka is preepierengch stawyoh
[BS]: Rosccia du. Uigciecka is preepierengch stawyoh
[D]: Rebecca du. Micnicka is

kościół św. Włodzisława i przepięknych starych
[AM]: Camienic.
[BS]: Camienic.
[D]: Cameric.

Kamienic.



Wyniki ilościowe

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

```
[26]: 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

[27]: 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

[28]: get_qualitative_results_lines(get_arg_max)

100%| | 1859/1859 [01:24<00:00,
22.12it/s]

Mean CER = 8.4

[28]: 8.4

[29]: get_qualitative_results_lines(get_denoised)

100%| | 1859/1859 [13:18<00:00,
2.33it/s]

Mean CER = 38.3

[29]: 38.3

```
[30]: get_qualitative_results(get_arg_max)
```

100%| | 3/3 [00:01<00:00,
2.27it/s]

Mean CER = 45.4

[30]: 45.4

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

100%| | 3/3 [00:11<00:00,
3.70s/it]

Mean CER = 45.3

[31]: 45.3

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

100%| | 3/3 [00:11<00:00,
3.70s/it]

Mean CER = 65.4

[32]: 65.4

Podsumowanie

Algorytm poradził sobie dobrze z tekstem zapisanym w języku angielskim. Przewidziany tekst zawierał drobne błędy, jednak w większości słowa pokrywają się z słowami pierwotnie zapisanymi.

W przypadku języku polskiego, niestety algorytm nie dał sobie rady. Ze względu na to że był szkolony na języku angielskim, nie udało się rozpoznać słów zapisanych w języku polskim.