Rozpoznawanie tekstu

Od zdjęcia do tekstu cyfrowego.

[1]:
```
import json
import multiprocessing
import os
import random
import string
import time

import matplotlib.pyplot as plt
from mxboard import SummaryWriter
import mxnet as mx
from mxnet import nd, autograd, gluon
from mxnet.gluon.model_zoo.vision import resnet34_v1
import numpy as np
from skimage import transform as skimage_tf
from skimage import exposure
from tqdm import tqdm
np.seterr(all='raise')

mx.random.seed(1)

from ocr.utils.iam_dataset import IAMDataset
from ocr.utils.draw_text_on_image import draw_text_on_image

alphabet_encoding = r' !"#&\'()*+,-./0123456789:;?
 ↪ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz'
alphabet_dict = {alphabet_encoding[i]:i for i in␣
 ↪range(len(alphabet_encoding))}
```

Definicja sieci

Definiujemy sieć CNN-biLSTM do rozpoznawania pisma ręcznego. Cechy obrazu na dwóch poziomach zostały uzyskane z obciętego Resnet34 i poddane próbkowaniu w dół za pomocą prostego CNN.

[2]:
```
class EncoderLayer(gluon.HybridBlock):
    '''
    The encoder layer takes the image features from a CNN. The image␣
 ↪features are transposed so that the LSTM
    slices of the image features can be sequentially fed into the LSTM from␣
 ↪left to right (and back via the
    bidirectional LSTM).
    '''
    def __init__(self, hidden_states=200, rnn_layers=1, max_seq_len=100,␣
↪**kwargs):
        self.max_seq_len = max_seq_len
        super(EncoderLayer, self).__init__(**kwargs)
        with self.name_scope():
            self.lstm = mx.gluon.rnn.LSTM(hidden_states, rnn_layers,␣
↪bidirectional=True)

    def hybrid_forward(self, F, x):
        x = x.transpose((0, 3, 1, 2))
        x = x.flatten()
        x = x.split(num_outputs=self.max_seq_len, axis=1) # (SEQ_LEN, N,␣
↪CHANNELS)
        x = F.concat(*[elem.expand_dims(axis=0) for elem in x], dim=0)
        x = self.lstm(x)
        x = x.transpose((1, 0, 2)) #(N, SEQ_LEN, HIDDEN_UNITS)
        return x

class CNNBiLSTM(gluon.HybridBlock):
    '''
    The CNN-biLSTM to recognise handwriting text given an image of␣
↪handwriten text.
    Parameters
    ----------
    num_downsamples: int, default 2
        The number of times to downsample the image features. Each time the␣
↪features are downsampled, a new LSTM
        is created.
    resnet_layer_id: int, default 4
        The layer ID to obtain features from the resnet34
    lstm_hidden_states: int, default 200
        The number of hidden states used in the LSTMs
    lstm_layers: int, default 1
        The number of layers of LSTMs to use
    '''
    FEATURE_EXTRACTOR_FILTER = 64
    def __init__(self, num_downsamples=2, resnet_layer_id=4,␣
↪rnn_hidden_states=200, rnn_layers=1, max_seq_len=100, ctx=mx.gpu(0),␣
↪**kwargs):
        super(CNNBiLSTM, self).__init__(**kwargs)
        self.p_dropout = 0.5
        self.num_downsamples = num_downsamples
        self.max_seq_len = max_seq_len
        self.ctx = ctx
        with self.name_scope():
            self.body = self.get_body(resnet_layer_id=resnet_layer_id)

            self.encoders = gluon.nn.HybridSequential()
            with self.encoders.name_scope():
                for i in range(self.num_downsamples):
                    encoder = self.
↪get_encoder(rnn_hidden_states=rnn_hidden_states, rnn_layers=rnn_layers,␣
↪max_seq_len=max_seq_len)
                    self.encoders.add(encoder)
            self.decoder = self.get_decoder()
            self.downsampler = self.get_down_sampler(self.
↪FEATURE_EXTRACTOR_FILTER)

    def get_down_sampler(self, num_filters):
        '''
        Creates a two-stacked Conv-BatchNorm-Relu and then a pooling layer to
        downsample the image features by half.

        Parameters
        ----------
        num_filters: int
            To select the number of filters in used the downsampling␣
↪convolutional layer.
        Returns
        -------
        network: gluon.nn.HybridSequential
            The downsampler network that decreases the width and height of␣
↪the image features by half.

        '''
        out = gluon.nn.HybridSequential()
        with out.name_scope():
            for _ in range(2):
                out.add(gluon.nn.Conv2D(num_filters, 3, strides=1, padding=1))
                out.add(gluon.nn.BatchNorm(in_channels=num_filters))
                out.add(gluon.nn.Activation('relu'))
            out.add(gluon.nn.MaxPool2D(2))
            out.collect_params().initialize(mx.init.Normal(), ctx=self.ctx)
        out.hybridize()
        return out

    def get_body(self, resnet_layer_id):
        '''
        Create the feature extraction network based on resnet34.
        The first layer of the res-net is converted into grayscale by␣
↪averaging the weights of the 3 channels
        of the original resnet.

        Parameters
        ----------
        resnet_layer_id: int
            The resnet_layer_id specifies which layer to take from
            the bottom of the network.
        Returns
        -------
        network: gluon.nn.HybridSequential
            The body network for feature extraction based on resnet
        '''

        pretrained = resnet34_v1(pretrained=True, ctx=self.ctx)
        pretrained_2 = resnet34_v1(pretrained=True, ctx=mx.cpu(0))
        first_weights = pretrained_2.features[0].weight.data().mean(axis=1).
↪expand_dims(axis=1)
        # First weights could be replaced with individual channels.

        body = gluon.nn.HybridSequential()
        with body.name_scope():
            first_layer = gluon.nn.Conv2D(channels=64, kernel_size=(7, 7),␣
↪padding=(3, 3), strides=(2, 2), in_channels=1, use_bias=False)
```

```
            first_layer.initialize(mx.init.Xavier(), ctx=self.ctx)
            first_layer.weight.set_data(first_weights)
            body.add(first_layer)
            body.add(*pretrained.features[1:-resnet_layer_id])
        return body

    def get_encoder(self, rnn_hidden_states, rnn_layers, max_seq_len):
        '''
        Creates an LSTM to learn the sequential component of the image␣
↪features.

        Parameters
        ----------

        rnn_hidden_states: int
            The number of hidden states in the RNN

        rnn_layers: int
            The number of layers to stack the RNN
        Returns
        -------

        network: gluon.nn.Sequential
            The encoder network to learn the sequential information of the␣
↪image features
        '''

        encoder = gluon.nn.HybridSequential()
        with encoder.name_scope():
            encoder.add(EncoderLayer(hidden_states=rnn_hidden_states,␣
↪rnn_layers=rnn_layers, max_seq_len=max_seq_len))
            encoder.add(gluon.nn.Dropout(self.p_dropout))
        encoder.collect_params().initialize(mx.init.Xavier(), ctx=self.ctx)
        return encoder

    def get_decoder(self):
        '''
        Creates a network to convert the output of the encoder into␣
↪characters.
```

```
        '''

        alphabet_size = len(alphabet_encoding) + 1
        decoder = mx.gluon.nn.Dense(units=alphabet_size, flatten=False)
        decoder.collect_params().initialize(mx.init.Xavier(), ctx=self.ctx)
        return decoder

    def hybrid_forward(self, F, x):
        features = self.body(x)
        hidden_states = []
        hs = self.encoders[0](features)
        hidden_states.append(hs)
        for i, _ in enumerate(range(self.num_downsamples - 1)):
            features = self.downsampler(features)
            hs = self.encoders[i+1](features)
            hidden_states.append(hs)
        hs = F.concat(*hidden_states, dim=2)
        output = self.decoder(hs)
        return output
```

Funkcja pomocnicza do trenowania sieci

[3]:
```
def transform(image, label):
    '''
    This function resizes the input image and converts so that it could be␣
 ↪fed into the network.
    Furthermore, the label (text) is one-hot encoded.
    '''
    image = np.expand_dims(image, axis=0).astype(np.float32)
    if image[0, 0, 0] > 1:
        image = image/255.
    image = (image - 0.942532484060557) / 0.15926149044640417
    label_encoded = np.zeros(max_seq_len, dtype=np.float32)-1
    i = 0
    for word in label:
        word = word.replace("&quot", r'"')
        word = word.replace("&amp", r'&')
        word = word.replace('";', '\"')
        for letter in word:
            label_encoded[i] = alphabet_dict[letter]
            i += 1
    return image, label_encoded

def augment_transform(image, label):
    '''
    This function randomly:
        - translates the input image by +-width_range and +-height_range␣
↪(percentage).
        - scales the image by y_scaling and x_scaling (percentage)
        - shears the image by shearing_factor (radians)
    '''

    ty = random.uniform(-random_y_translation, random_y_translation)
    tx = random.uniform(-random_x_translation, random_x_translation)

    sx = random.uniform(1. - random_y_scaling, 1. + random_y_scaling)
    sy = random.uniform(1. - random_x_scaling, 1. + random_x_scaling)

    s = random.uniform(-random_shearing, random_shearing)

    gamma = random.uniform(0.001, 2)
    image = exposure.adjust_gamma(image, gamma)
    st = skimage_tf.AffineTransform(scale=(sx, sy),
                                    shear=s,
                                    translation=(tx*image.shape[1], ty*image.
↪shape[0]))
    augmented_image = skimage_tf.warp(image, st, cval=1.0)

    return transform(augmented_image*255., label)


def decode(prediction):
    '''
    Returns the string given one-hot encoded vectors.
    '''

    results = []
    for word in prediction:
        result = []
        for i, index in enumerate(word):
            if i < len(word) - 1 and word[i] == word[i+1] and word[-1] != -1:␣
↪#Hack to decode label as well
                continue
            if index == len(alphabet_dict) or index == -1:
                continue
            else:
                result.append(alphabet_encoding[int(index)])
        results.append(result)
    words = [''.join(word) for word in results]
    return words
```

[4]:
```
def run_epoch(e, network, dataloader, trainer, log_dir, print_name, is_train):
    total_loss = nd.zeros(1, ctx)
    for i, (x, y) in enumerate(dataloader):
        x = x.as_in_context(ctx)
        y = y.as_in_context(ctx)

        with autograd.record(train_mode=is_train):
            output = network(x)
            loss_ctc = ctc_loss(output, y)

        if is_train:
            loss_ctc.backward()
            trainer.step(x.shape[0])

        if i == 0 and e % send_image_every_n == 0 and e > 0:
            predictions = output.softmax().topk(axis=2).asnumpy()
            decoded_text = decode(predictions)
            output_image = draw_text_on_image(x.asnumpy(), decoded_text)
            output_image[output_image < 0] = 0
            output_image[output_image > 1] = 1
            print("{} first decoded text = {}".format(print_name,␣
↪decoded_text[0]))
            with SummaryWriter(logdir=log_dir, verbose=False, flush_secs=5)␣
↪as sw:
                sw.add_image('bb_{}_image'.format(print_name), output_image,␣
↪global_step=e)

        total_loss += loss_ctc.mean()
    epoch_loss = float(total_loss.asscalar())/len(dataloader)

    with SummaryWriter(logdir=log_dir, verbose=False, flush_secs=5) as sw:
        sw.add_scalar('loss', {print_name: epoch_loss}, global_step=e)

    return epoch_loss
```

[5]:
```
ctx = mx.gpu()

epochs = 120
learning_rate = 0.0001
batch_size = 32

max_seq_len = 160
print_every_n = 5
send_image_every_n = 5

num_downsamples = 2
resnet_layer_id = 4
lstm_hidden_states = 512
lstm_layers = 2

random_y_translation, random_x_translation = 0.03, 0.03
random_y_scaling, random_x_scaling = 0.1, 0.1
random_shearing = 0.7

log_dir = "./logs/handwriting_recognition"
checkpoint_dir = "model_checkpoint"
checkpoint_name = "handwriting.params"
```

[6]:
```
train_ds = IAMDataset("line", output_data="text", train=True)
print("Number of training samples: {}".format(len(train_ds)))

test_ds = IAMDataset("line", output_data="text", train=False)
print("Number of testing samples: {}".format(len(test_ds)))
```

```
Number of training samples: 7998
Number of testing samples: 1860
```

[7]:
```
train_data = gluon.data.DataLoader(train_ds.transform(augment_transform),␣
 ↪batch_size, shuffle=True, last_batch="rollover", num_workers=4)
```

```
test_data = gluon.data.DataLoader(test_ds.transform(transform), batch_size,␣
↪shuffle=True, last_batch="keep", num_workers=4)#,␣
↪num_workers=multiprocessing.cpu_count()-2)
```

Trenowanie

[8]:
```
net = CNNBiLSTM(num_downsamples=num_downsamples,␣
↪resnet_layer_id=resnet_layer_id , rnn_hidden_states=lstm_hidden_states,␣
↪rnn_layers=lstm_layers, max_seq_len=max_seq_len, ctx=ctx)
net.hybridize()
```

[9]:
```
ctc_loss = gluon.loss.CTCLoss(weight=0.2)
best_test_loss = 10e5
```

[10]:
```
if (os.path.isfile(os.path.join(checkpoint_dir, checkpoint_name))):
    net.load_parameters(os.path.join(checkpoint_dir, checkpoint_name))
    print("Parameters loaded")
    print(run_epoch(0, net, test_data, None, log_dir,␣
↪print_name="pretrained", is_train=False))
```

```
Parameters loaded

[10:47:58] ../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)

3.2815163822497353
```

[11]:
```
pretrained = "models/handwriting_line8.params"
if (os.path.isfile(pretrained)):
    net.load_parameters(pretrained, ctx=ctx)
    print("Parameters loaded")
    print(run_epoch(0, net, test_data, None, log_dir,␣
↪print_name="pretrained", is_train=False))
```

```
Parameters loaded
3.148574570478019
```

[12]:
```
trainer = gluon.Trainer(net.collect_params(), 'adam', {'learning_rate':␣
↪learning_rate})
```

[13]:
```python
for e in range(epochs):
    train_loss = run_epoch(e, net, train_data, trainer, log_dir,␣
↪print_name="train", is_train=True)
    test_loss = run_epoch(e, net, test_data, trainer, log_dir,␣
↪print_name="test", is_train=False)
    if test_loss < best_test_loss:
        print("Saving network, previous best test loss {:.6f}, current test␣
↪loss {:.6f}".format(best_test_loss, test_loss))
        net.save_parameters(os.path.join(checkpoint_dir, checkpoint_name))
        best_test_loss = test_loss

    if e % print_every_n == 0 and e > 0:
        print("Epoch {0}, train_loss {1:.6f}, test_loss {2:.6f}".format(e,␣
↪train_loss, test_loss))
```

```
Saving network, previous best test loss 1000000.000000, current test loss 3.
↪226774
Saving network, previous best test loss 3.226774, current test loss 3.221990
Saving network, previous best test loss 3.221990, current test loss 3.175999
Saving network, previous best test loss 3.175999, current test loss 3.144639
train first decoded text = to the disturbance.
test first decoded text = Gavin and the gire who had, got
Epoch 5, train_loss 1.740869, test_loss 3.253646
Saving network, previous best test loss 3.144639, current test loss 3.134337
train first decoded text = Common Market, we should not be able to
test first decoded text = steely. "I see.' Scom lashed his
Epoch 10, train_loss 1.621259, test_loss 3.184207
train first decoded text = When the final miracle os occur, it is accepted as a
test first decoded text = knowing that they wew real, even its they were new␣
↪ones
Epoch 15, train_loss 1.592264, test_loss 3.234424
train first decoded text = that reflects true creative talent
test first decoded text = all that was part of the past, she would put it␣
↪behind her. She
Epoch 20, train_loss 1.455223, test_loss 3.306064
train first decoded text = in the newly planed surfaces, and these treated
test first decoded text = nomalter how one might want to
Epoch 25, train_loss 1.382877, test_loss 3.318641
train first decoded text = stest? That is the exciting competition going of
test first decoded text = nation. Pew there was no-
```

```
Epoch 30, train_loss 1.398240, test_loss 3.379477
train first decoded text = save at feast times, when he, too, let
test first decoded text = the restibule, the two men were well
Epoch 35, train_loss 1.286968, test_loss 3.444602
train first decoded text = closed session to discuss Weaver's appointment.
test first decoded text = be open. It was. He entered, and reated himself
Epoch 40, train_loss 1.233580, test_loss 3.429129
train first decoded text = of Rhodesia and Nyasaland (10,. 30 p.4.).
test first decoded text = we werre to go no further unless and
Epoch 45, train_loss 1.190958, test_loss 3.462927
train first decoded text = of individual instrumental timbres and "person
test first decoded text = "No,"Di said immediatly. "It isn't at
Epoch 50, train_loss 1.194443, test_loss 3.564218
train first decoded text = which takes place at company expense in a country or
test first decoded text = Mashal," I added  His lace was Pixed,
Epoch 55, train_loss 1.150544, test_loss 3.634075
train first decoded text = in and out of the country wanted to see
test first decoded text = I'm going with a shooting paity. What eise can Ido
Epoch 60, train_loss 1.113685, test_loss 3.594981
train first decoded text = to learn. Education is always the most important␣
 ↪task.
test first decoded text = will we?" "No," he eyed her strangely. "I wish we
Epoch 65, train_loss 1.115654, test_loss 3.652062
train first decoded text = Marty (280,00 members) and Mr. Harry Nkumbula's Ari
test first decoded text = words.'I wondus you dared trust
Epoch 70, train_loss 1.041880, test_loss 3.593034
train first decoded text = dollars have been drained into Germany.
test first decoded text = come to you, kily-po, ' Band Appa Bondi added.
Epoch 75, train_loss 1.054608, test_loss 3.627492
train first decoded text = forthcoming about any carriage with an opern
test first decoded text = libe a masquerade of buriness interents in dir-
Epoch 80, train_loss 0.997064, test_loss 3.656280
train first decoded text = method known as homoeopathy had been
test first decoded text = for Mr. Pell and his bunch," observed
Epoch 85, train_loss 1.013440, test_loss 3.838312
train first decoded text = Order" which Himmler on October 4, 1943, exxpa.
test first decoded text = Therefore Mr. Robests must have been mistahen.
Epoch 90, train_loss 0.978611, test_loss 3.844655
train first decoded text = Living the life of the Torah ("dipping-in") maves us
```

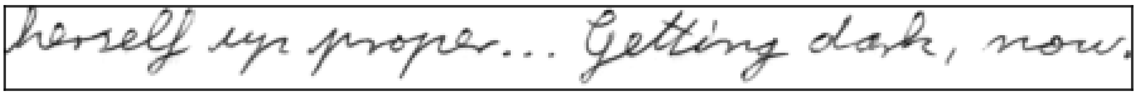
```
test first decoded text = too." He folded his armss protectively over the bas␣
↪hat .
Epoch 95, train_loss 0.977277, test_loss 3.868610
train first decoded text = At 9.40 Mr. Edusei, Minister of Transport and pprao
test first decoded text = "Intended for Plap Neayodd, thir lot is. Paid for,
Epoch 100, train_loss 0.954446, test_loss 3.942502
train first decoded text = A natural transition from gardens and
test first decoded text = ramier, he baket to a screeching otop. A
Epoch 105, train_loss 0.923657, test_loss 3.970261
train first decoded text = troops. His main theme was that nuclear
test first decoded text = "Yo should Stert time youire in Towon
Epoch 110, train_loss 0.894633, test_loss 3.906029
train first decoded text = temperature is high & I have not yet thought of
test first decoded text = there' gold and women there's ahwags trouble,"
Epoch 115, train_loss 0.900366, test_loss 3.925975
```

Wyniki

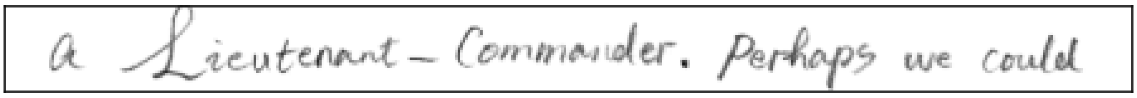
Wizualizacja wyników. Rozpoznany tekst oraz zdjęcie.

[14]:
```python
figs_to_plot = 10
fig, axs = plt.subplots(figs_to_plot, figsize=(8, 1.3*figs_to_plot))

for i in range(figs_to_plot):
    n = int(random.random()*len(test_ds))
    image, actual_label = test_ds[n]
    image, _ = transform(image, actual_label)

    image = nd.array(image)
    image = image.as_in_context(ctx)
    image = image.expand_dims(axis=0)
    output = net(image)
    predictions = output.softmax().topk(axis=2).asnumpy()
    decoded_prediction_text = decode(predictions)[0].replace("&quot", '\"').
↪replace("&amp", "&").replace('";', '\"')
    axs[i].imshow(image.asnumpy().squeeze(), cmap='Greys_r')
    axs[i].set_title("[Label]: {}\n[Pred]:  {}".format(actual_label[0].
↪replace("&quot", '\"').replace("&amp", "&").replace('";', '\"'),␣
↪decoded_prediction_text),
                     fontdict={"horizontalalignment":"left", "family":
↪"monospace"}, x=0)
    axs[i].tick_params(axis='both',
                        which='both',
                        bottom=False,
                        top=False,
                        left=False,
                        right=False,
                        labelleft=False,
                        labelbottom=False)
```

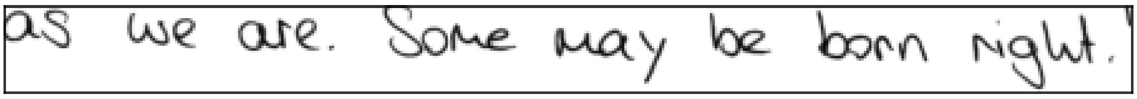
```
[Label]: herself up proper... Getting dark, now.
[Pred]:  herself uy proper... Getting dark, now
```


herself up proper... Getting dark, now.

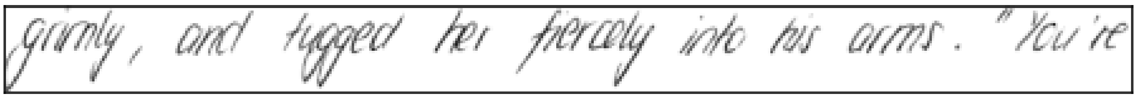
```
[Label]: a Lieutenant-Commander. Perhaps we could
[Pred]:  A Sientenant-Commander. Perhaps we could
```


a Lieutenant-Commander. Perhaps we could

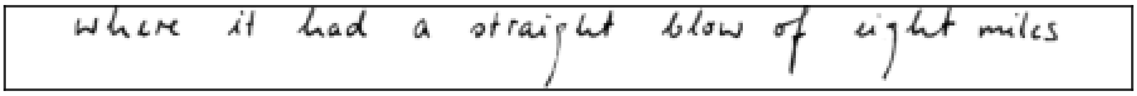
```
[Label]: as we are. Some may be born right.'
[Pred]:  as we are. Some may be born night.'
```


as we are. Some may be born right.'

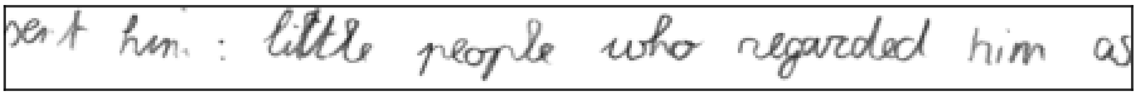
```
[Label]: grimly, and tugged her fiercely into his arms. "You're
[Pred]:  grimly, and tuaged her fiercely into his arms. "You're
```


grimly, and tugged her fiercely into his arms. "You're

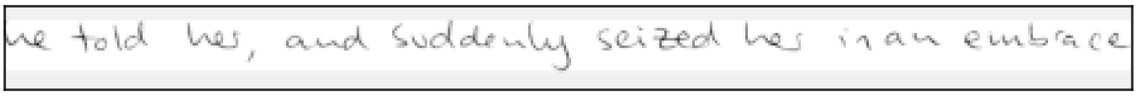
```
[Label]: where it had a straight blow of eight miles
[Pred]:  whare it had a straight blow of eight miles
```


where it had a straight blow of eight miles

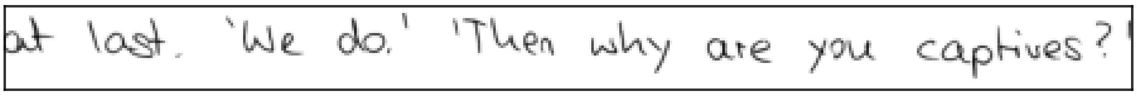
```
[Label]: sent him: little people who regarded him as
[Pred]:  pent him.: liltle people who negarded him as
```


sent him: little people who regarded him as

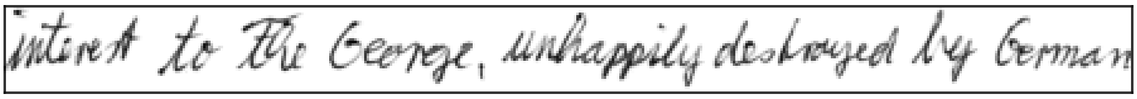
```
[Label]: he told her, and suddenly seized her in an embrace
[Pred]:  The told her, and suddenly seized her in an embrace
```


he told her, and suddenly seized her in an embrace

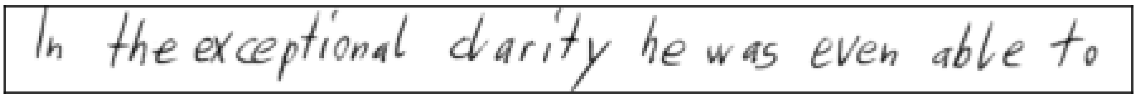
```
[Label]: at last. 'We do.' 'Then why are you captives?'
[Pred]:  at last. "We do." "Then why are you captives?
```


at last. 'We do.' 'Then why are you captives?'

```
[Label]: interest to The George, unhappily destroyed by German
[Pred]:  snterest to The Geaorge, unhappily destrayed by German
```


interest to The George, unhappily destroyed by German

```
[Label]: In the exceptional clarity he was even able to
[Pred]:  In the exceptional charity he was even able to
```


In the exceptional clarity he was even able to

Zapisanie przekształconego testowego zestawu danych w celu sprawdzenia odszu-

miania.

[15]:
```
ds_lm = test_ds.transform(transform)
```

[16]:
```
outputs = []
for image, actual_label in tqdm(ds_lm):
    image = nd.array(image)
    image = image.as_in_context(ctx)
    image = image.expand_dims(axis=0)
    output = net(image)
    predictions = output.softmax().topk(axis=2).asnumpy()
    decoded_prediction_text = decode(predictions)[0]
    outputs.append([decode([actual_label])[0].replace("&quot;", '"').
 ↪replace("&amp;", "&"), decoded_prediction_text.replace("&quot", '\"').
 ↪replace("&amp", "&").replace('";', '\"')])
```

```
100%|                              | 1860/1860 [01:21<00:00,
22.92it/s]
```

[17]:
```
json.dump(outputs, open('dataset/typo/validating.json', 'w'))
```

[18]:
```
ds_lm = train_ds
with open('dataset/typo/text_train.txt', 'w') as f:
    for _, actual_label in ds_lm:
        f.write(str(actual_label[0].replace("&quot;", '"').replace("&amp;",␣
 ↪"&"))+"\n")
```