Captcha_FixCaptcha

April 20, 2025

[1]:
```
import os
import glob
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch.utils.data import Dataset, DataLoader
from torchvision import transforms
from torchvision.models import resnet18

import string
from tqdm.notebook import tqdm
import cv2
from PIL import Image
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score
import multiprocessing as mp
```

[2]:
```
cpu_count = mp.cpu_count()
print(cpu_count)
```

```
2
```

[7]:
```
data_path = "/content/drive/MyDrive/archive (1)/samples"
```

[9]:
```
image_fns = os.listdir(data_path)
print(len(image_fns))
print(np.unique([len(image_fn.split(".")[0]) for image_fn in image_fns]))
```

```
1080
[5 9]
```

[10]:
```
for idx, image_fn in enumerate(image_fns):
    if len(image_fn.split(".")[0]) != 5:
            print(idx, image_fn)
```

```
2 3mxdn (1).png
3 3fbxd (1).png
5 3n7mx (1).png
7 3n3cf (1).png
10 3eny7 (1).png
17 3n2b4 (1).png
20 3ndxd (1).png
1076 3g2w6 (1).png
1077 3ebnn (1).png
1078 3ebpw (1).png
```

[12]:
```
image_fns_train, image_fns_test = train_test_split(image_fns, random_state=0)
print(len(image_fns_train), len(image_fns_test))
```

```
810 270
```

[13]:
```
image_ns = [image_fn.split(".")[0] for image_fn in image_fns]
image_ns = "".join(image_ns)
letters = sorted(list(set(list(image_ns))))
print(len(letters))
print(letters)
```

```
23
[' ', '(', ')', '1', '2', '3', '4', '5', '6', '7', '8', 'b', 'c', 'd', 'e', 'f',
'g', 'm', 'n', 'p', 'w', 'x', 'y']
```

[14]:
```
vocabulary = ["-"] + letters
print(len(vocabulary))
print(vocabulary)
idx2char = {k:v for k,v in enumerate(vocabulary, start=0)}
print(idx2char)
char2idx = {v:k for k,v in idx2char.items()}
print(char2idx)
```

```
24
['-', ' ', '(', ')', '1', '2', '3', '4', '5', '6', '7', '8', 'b', 'c', 'd', 'e',
'f', 'g', 'm', 'n', 'p', 'w', 'x', 'y']
{0: '-', 1: ' ', 2: '(', 3: ')', 4: '1', 5: '2', 6: '3', 7: '4', 8: '5', 9: '6',
10: '7', 11: '8', 12: 'b', 13: 'c', 14: 'd', 15: 'e', 16: 'f', 17: 'g', 18: 'm',
19: 'n', 20: 'p', 21: 'w', 22: 'x', 23: 'y'}
{'-': 0, ' ': 1, '(': 2, ')': 3, '1': 4, '2': 5, '3': 6, '4': 7, '5': 8, '6': 9,
'7': 10, '8': 11, 'b': 12, 'c': 13, 'd': 14, 'e': 15, 'f': 16, 'g': 17, 'm': 18,
'n': 19, 'p': 20, 'w': 21, 'x': 22, 'y': 23}
```

[15]:
```
batch_size = 16
```

[16]:
```
class CAPTCHADataset(Dataset):

    def __init__(self, data_dir, image_fns):
```

```
        self.data_dir = data_dir
        self.image_fns = image_fns

    def __len__(self):
        return len(self.image_fns)

    def __getitem__(self, index):
        image_fn = self.image_fns[index]
        image_fp = os.path.join(self.data_dir, image_fn)
        image = Image.open(image_fp).convert('RGB')
        image = self.transform(image)
        text = image_fn.split(".")[0]
        return image, text

    def transform(self, image):

        transform_ops = transforms.Compose([
            transforms.ToTensor(),
            transforms.Normalize(mean=(0.485, 0.456, 0.406), std=(0.229, 0.224,␣
 ↪0.225))
        ])
        return transform_ops(image)
```

[17]:
```
trainset = CAPTCHADataset(data_path, image_fns_train)
testset = CAPTCHADataset(data_path, image_fns_test)
train_loader = DataLoader(trainset, batch_size=batch_size,␣
 ↪num_workers=cpu_count, shuffle=True)
test_loader = DataLoader(testset, batch_size=batch_size, num_workers=cpu_count,␣
 ↪shuffle=False)
print(len(train_loader), len(test_loader))
```

```
51 17
```

[21]:
```
image_batch, text_batch = next(iter(train_loader))
print(image_batch.size(), text_batch)
```

```
torch.Size([16, 3, 50, 200]) ('78dw6', '3n2b4 (1)', 'pcpg6', '56m6y', '4fp5g',
'byfgn', 'g78gn', 'mdxpn', 'bpwd7', '8n34n', 'f2fge', 'b4ndb', 'nwg2m', 'gp7c5',
'pg2yx', '3n7mx')
```

[22]:
```
num_chars = len(char2idx)
print(num_chars)
rnn_hidden_size = 256
```

```
24
```

[23]:
```
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cpu
```

[24]:
```
resnet = resnet18(pretrained=True)
```

```
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208:
UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be
removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223:
UserWarning: Arguments other than a weight enum or `None` for 'weights' are
deprecated since 0.13 and may be removed in the future. The current behavior is
equivalent to passing `weights=ResNet18_Weights.IMAGENET1K_V1`. You can also use
`weights=ResNet18_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to
/root/.cache/torch/hub/checkpoints/resnet18-f37072fd.pth
100%|      | 44.7M/44.7M [00:00<00:00, 96.1MB/s]
```

[25]:
```
print(resnet)
```

```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3),
bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1,
ceil_mode=False)
  (layer1): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
    (1): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
```

```
track_running_stats=True)
    )
  )
  (layer2): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer3): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
```

```
    )
    (1): BasicBlock(
      (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer4): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=512, out_features=1000, bias=True)
)
```

[26]:
```
class CRNN(nn.Module):

    def __init__(self, num_chars, rnn_hidden_size=256, dropout=0.1):

        super(CRNN, self).__init__()
        self.num_chars = num_chars
        self.rnn_hidden_size = rnn_hidden_size
        self.dropout = dropout

        # CNN Part 1
        resnet_modules = list(resnet.children())[:-3]
        self.cnn_p1 = nn.Sequential(*resnet_modules)

        # CNN Part 2
        self.cnn_p2 = nn.Sequential(
            nn.Conv2d(256, 256, kernel_size=(3,6), stride=1, padding=1),
            nn.BatchNorm2d(256),
            nn.ReLU(inplace=True)
        )
        self.linear1 = nn.Linear(1024, 256)

        # RNN
        self.rnn1 = nn.GRU(input_size=rnn_hidden_size,
                           hidden_size=rnn_hidden_size,
                           bidirectional=True,
                           batch_first=True)
        self.rnn2 = nn.GRU(input_size=rnn_hidden_size,
                           hidden_size=rnn_hidden_size,
                           bidirectional=True,
                           batch_first=True)
        self.linear2 = nn.Linear(self.rnn_hidden_size*2, num_chars)


    def forward(self, batch):

        batch = self.cnn_p1(batch)
        # print(batch.size()) # torch.Size([-1, 256, 4, 13])

        batch = self.cnn_p2(batch) # [batch_size, channels, height, width]
        # print(batch.size())# torch.Size([-1, 256, 4, 10])

        batch = batch.permute(0, 3, 1, 2) # [batch_size, width, channels,␣
↪height]
        # print(batch.size()) # torch.Size([-1, 10, 256, 4])

        batch_size = batch.size(0)
        T = batch.size(1)
```

```
        batch = batch.view(batch_size, T, -1) # [batch_size, T==width,␣
↪num_features==channels*height]
        # print(batch.size()) # torch.Size([-1, 10, 1024])

        batch = self.linear1(batch)
        # print(batch.size()) # torch.Size([-1, 10, 256])

        batch, hidden = self.rnn1(batch)
        feature_size = batch.size(2)
        batch = batch[:, :, :feature_size//2] + batch[:, :, feature_size//2:]
        # print(batch.size()) # torch.Size([-1, 10, 256])

        batch, hidden = self.rnn2(batch)
        # print(batch.size()) # torch.Size([-1, 10, 512])

        batch = self.linear2(batch)
        # print(batch.size()) # torch.Size([-1, 10, 20])

        batch = batch.permute(1, 0, 2) # [T==10, batch_size,␣
↪num_classes==num_features]
        # print(batch.size()) # torch.Size([10, -1, 20])

        return batch
```

[27]:
```
def weights_init(m):
    classname = m.__class__.__name__
    if type(m) in [nn.Linear, nn.Conv2d, nn.Conv1d]:
        torch.nn.init.xavier_uniform_(m.weight)
        if m.bias is not None:
            m.bias.data.fill_(0.01)
    elif classname.find('BatchNorm') != -1:
        m.weight.data.normal_(1.0, 0.02)
        m.bias.data.fill_(0)
```

[28]:
```
crnn = CRNN(num_chars, rnn_hidden_size=rnn_hidden_size)
crnn.apply(weights_init)
crnn = crnn.to(device)
```

[29]:
```
text_batch_logits = crnn(image_batch.to(device))
print(text_batch)
print(text_batch_logits.shape)
```

```
('78dw6', '3n2b4 (1)', 'pcpg6', '56m6y', '4fp5g', 'byfgn', 'g78gn', 'mdxpn',
'bpwd7', '8n34n', 'f2fge', 'b4ndb', 'nwg2m', 'gp7c5', 'pg2yx', '3n7mx')
torch.Size([10, 16, 24])
```

[30]:
```
criterion = nn.CTCLoss(blank=0)
```

[31]:
```
def encode_text_batch(text_batch):

    text_batch_targets_lens = [len(text) for text in text_batch]
    text_batch_targets_lens = torch.IntTensor(text_batch_targets_lens)

    text_batch_concat = "".join(text_batch)
    text_batch_targets = [char2idx[c] for c in text_batch_concat]
    text_batch_targets = torch.IntTensor(text_batch_targets)

    return text_batch_targets, text_batch_targets_lens
```

[32]:
```
def compute_loss(text_batch, text_batch_logits):
    """
    text_batch: list of strings of length equal to batch size
    text_batch_logits: Tensor of size([T, batch_size, num_classes])
    """
    text_batch_logps = F.log_softmax(text_batch_logits, 2) # [T, batch_size,␣
 ↪num_classes]
    text_batch_logps_lens = torch.full(size=(text_batch_logps.size(1),),
                                       fill_value=text_batch_logps.size(0),
                                       dtype=torch.int32).to(device) #␣
 ↪[batch_size]
    #print(text_batch_logps.shape)
    #print(text_batch_logps_lens)
    text_batch_targets, text_batch_targets_lens = encode_text_batch(text_batch)
    #print(text_batch_targets)
    #print(text_batch_targets_lens)
    loss = criterion(text_batch_logps, text_batch_targets,␣
 ↪text_batch_logps_lens, text_batch_targets_lens)

    return loss
```

[33]:
```
compute_loss(text_batch, text_batch_logits)
```

[33]:
```
tensor(4.6650, grad_fn=<MeanBackward0>)
```

[35]:
```
num_epochs = 50
lr = 0.001
weight_decay = 1e-3
clip_norm = 5
```

[37]:
```
optimizer = optim.Adam(crnn.parameters(), lr=lr, weight_decay=weight_decay)
lr_scheduler = optim.lr_scheduler.ReduceLROnPlateau(optimizer, verbose=True,␣
 ↪patience=5)
```

[38]:
```
crnn = CRNN(num_chars, rnn_hidden_size=rnn_hidden_size)
crnn.apply(weights_init)
```

```
crnn = crnn.to(device)
```

[39]:
```
epoch_losses = []
iteration_losses = []
num_updates_epochs = []
for epoch in tqdm(range(1, num_epochs+1)):
    epoch_loss_list = []
    num_updates_epoch = 0
    for image_batch, text_batch in tqdm(train_loader, leave=False):
        optimizer.zero_grad()
        text_batch_logits = crnn(image_batch.to(device))
        loss = compute_loss(text_batch, text_batch_logits)
        iteration_loss = loss.item()

        if np.isnan(iteration_loss) or np.isinf(iteration_loss):
            continue

        num_updates_epoch += 1
        iteration_losses.append(iteration_loss)
        epoch_loss_list.append(iteration_loss)
        loss.backward()
        nn.utils.clip_grad_norm_(crnn.parameters(), clip_norm)
        optimizer.step()

    epoch_loss = np.mean(epoch_loss_list)
    print("Epoch:{}    Loss:{}    NumUpdates:{}".format(epoch, epoch_loss,␣
 ↪num_updates_epoch))
    epoch_losses.append(epoch_loss)
    num_updates_epochs.append(num_updates_epoch)
    lr_scheduler.step(epoch_loss)
```

```
  0%|          | 0/50 [00:00<?, ?it/s]

  0%|          | 0/51 [00:00<?, ?it/s]

Epoch:1    Loss:3.0916408090030445    NumUpdates:51

  0%|          | 0/51 [00:00<?, ?it/s]

Epoch:2    Loss:2.4448012838176654    NumUpdates:51

  0%|          | 0/51 [00:00<?, ?it/s]

Epoch:3    Loss:1.9191021241393744    NumUpdates:51

  0%|          | 0/51 [00:00<?, ?it/s]

Epoch:4    Loss:1.6287312788121842    NumUpdates:51

  0%|          | 0/51 [00:00<?, ?it/s]

Epoch:5    Loss:1.462795521698746    NumUpdates:51
```

```
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:6    Loss:1.338064009068059    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:7    Loss:1.2598869286331476    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:8    Loss:1.1965055465698242    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:9    Loss:1.1697289639828252    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:10    Loss:1.134702811054155    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:11    Loss:1.13827491274067    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:12    Loss:1.074782133102417    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:13    Loss:1.047883411248525    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:14    Loss:1.0220145910393958    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:15    Loss:0.9577525573618272    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:16    Loss:0.8911933723618003    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:17    Loss:0.8617152314560086    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:18    Loss:0.8544135900104747    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:19    Loss:0.8854422499151791    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:20    Loss:0.966071111314437    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:21    Loss:0.8648616204074785    NumUpdates:51
```

```
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:22    Loss:0.8023002206110487    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:23    Loss:0.7963328618629306    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:24    Loss:0.8482310070711023    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:25    Loss:0.8287536209704829    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:26    Loss:0.8210709305370555    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:27    Loss:0.7841405611412198    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:28    Loss:0.7642733326145247    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:29    Loss:0.7630844875877979    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:30    Loss:0.7558378530483619    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:31    Loss:0.7394053316583821    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:32    Loss:0.7397293647130331    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:33    Loss:0.7359461270126642    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:34    Loss:0.7334616149173063    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:35    Loss:0.912491943321976    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:36    Loss:0.857014349862641    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:37    Loss:0.7864211680842381    NumUpdates:51
```

```
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:38    Loss:0.7335886768266267    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:39    Loss:0.708309413171282    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:40    Loss:0.7032125019559673    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:41    Loss:0.6993528288953444    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:42    Loss:0.6973183973162782    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:43    Loss:0.7001666940894782    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:44    Loss:0.6976179211747413    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:45    Loss:0.698658942007551    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:46    Loss:0.7139831839823255    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:47    Loss:0.7137583131883659    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:48    Loss:0.8418545652838314    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:49    Loss:0.7703956272087845    NumUpdates:51
  0%|          | 0/51 [00:00<?, ?it/s]
Epoch:50    Loss:0.6744280749676275    NumUpdates:51
```

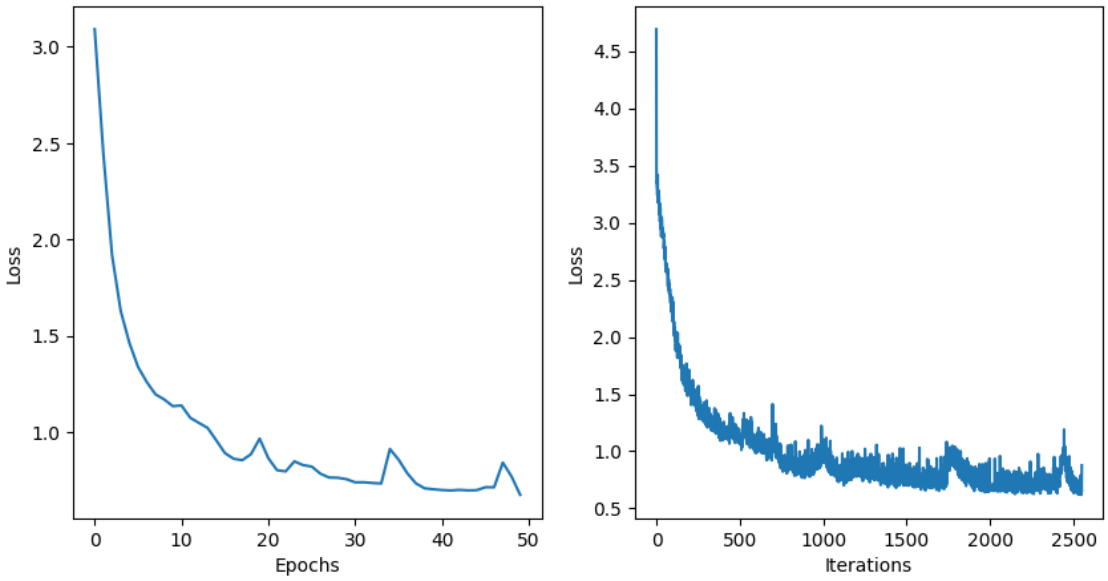
[40]:
```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 5))

ax1.plot(epoch_losses)
ax1.set_xlabel("Epochs")
ax1.set_ylabel("Loss")

ax2.plot(iteration_losses)
ax2.set_xlabel("Iterations")
```

```
ax2.set_ylabel("Loss")

plt.show()
```



[41]:
```
def decode_predictions(text_batch_logits):

    text_batch_tokens = F.softmax(text_batch_logits, 2).argmax(2) # [T,␣
 ↪batch_size]
    text_batch_tokens = text_batch_tokens.numpy().T # [batch_size, T]

    text_batch_tokens_new = []
    for text_tokens in text_batch_tokens:
        text = [idx2char[idx] for idx in text_tokens]
        text = "".join(text)
        text_batch_tokens_new.append(text)

    return text_batch_tokens_new
```

[42]:
```
results_train = pd.DataFrame(columns=['actual', 'prediction'])
train_loader = DataLoader(trainset, batch_size=16, num_workers=1, shuffle=False)
with torch.no_grad():
    for image_batch, text_batch in tqdm(train_loader, leave=True):
        text_batch_logits = crnn(image_batch.to(device)) # [T, batch_size,␣
 ↪num_classes==num_features]
        text_batch_pred = decode_predictions(text_batch_logits.cpu())
        #print(text_batch, text_batch_pred)
        df = pd.DataFrame(columns=['actual', 'prediction'])
```

```
        df['actual'] = text_batch
        df['prediction'] = text_batch_pred
        results_train = pd.concat([results_train, df])
results_train = results_train.reset_index(drop=True)
```

```
  0%|          | 0/51 [00:00<?, ?it/s]
```

[43]:
```
results_test = pd.DataFrame(columns=['actual', 'prediction'])
test_loader = DataLoader(testset, batch_size=16, num_workers=1, shuffle=False)
with torch.no_grad():
    for image_batch, text_batch in tqdm(test_loader, leave=True):
        text_batch_logits = crnn(image_batch.to(device)) # [T, batch_size,␣
 ↪num_classes==num_features]
        text_batch_pred = decode_predictions(text_batch_logits.cpu())
        #print(text_batch, text_batch_pred)
        df = pd.DataFrame(columns=['actual', 'prediction'])
        df['actual'] = text_batch
        df['prediction'] = text_batch_pred
        results_test = pd.concat([results_test, df])
results_test = results_test.reset_index(drop=True)
```

```
  0%|          | 0/17 [00:00<?, ?it/s]
```

[44]:
```
print(results_train.shape)
results_train.head()
```

```
(810, 2)
```

[44]:

	actual	prediction
0	ndecc	nnddeecccc
1	gecmf	ggeeccmmff
2	325fb	332255ffbb
3	6f857	66ff885577
4	87nym	8877nnyymm

[45]:
```
print(results_test.shape)
results_test.head()
```

```
(270, 2)
```

[45]:

	actual	prediction
0	x362g	xx336622gg
1	xemyg	xxeemmyygg
2	mye68	mmyyee6688
3	fbp2c	ffbbpp22cc
4	mggce	mmggggccee

[46]:
```
def remove_duplicates(text):
    if len(text) > 1:
```

```
        letters = [text[0]] + [letter for idx, letter in enumerate(text[1:],␣
 ↪start=1) if text[idx] != text[idx-1]]
    elif len(text) == 1:
        letters = [text[0]]
    else:
        return ""
    return "".join(letters)

def correct_prediction(word):
    parts = word.split("-")
    parts = [remove_duplicates(part) for part in parts]
    corrected_word = "".join(parts)
    return corrected_word
```

[47]:
```
results_train['prediction_corrected'] = results_train['prediction'].
 ↪apply(correct_prediction)
results_train.head()
```

[47]:

	actual	prediction	prediction_corrected
0	ndecc	nnddeecccc	ndec
1	gecmf	ggeeccmmff	gecmf
2	325fb	332255ffbb	325fb
3	6f857	66ff885577	6f857
4	87nym	8877nnyymm	87nym

[48]:
```
results_test['prediction_corrected'] = results_test['prediction'].
 ↪apply(correct_prediction)
results_test.head()
```

[48]:

	actual	prediction	prediction_corrected
0	x362g	xx336622gg	x362g
1	xemyg	xxeemmyygg	xemyg
2	mye68	mmyyee6688	mye68
3	fbp2c	ffbbpp22cc	fbp2c
4	mggce	mmggggccee	mgce

[49]:
```
mistakes_df = results_test[results_test['actual'] !=␣
 ↪results_test['prediction_corrected']]
mistakes_df
```

[49]:

	actual	prediction	prediction_corrected
4	mggce	mmggggccee	mgce
5	y5dpp	yy55ddpppp	y5dp
6	3nfdn	33nnndddnn	3ndn
9	e2d66	ee22dd6666	e2d6
19	enn7n	eennnn77nn	en7n
20	x44n4	xx4444nn44	x4n4

```
30       77387  7777788877                787
47       8cccc  88c-----cc                 8cc
49       n3ffn  nn33ffffnn                n3fn
53       8bbm4  88bbbbmm44                8bm4
62       cdcb3  eeddccbb33               edcb3
63       d75b5  dd77555555                 d75
73       ppwyd  ppppwwyydd                pwyd
90       mmc5n  mmmmmmccnn                 mcn
94       m3588  mm33558888                m358
102      gfxcc  ggffxxcccc                 gfxc
110      yyn57  yyyynn5577                 yn57
111      474ff  447744ffff                 474f
136      p8wwf  pp88wwwwff                 p8wf
144  3n7mx (1)  33nn77mmxx               3n7mx
146      mmfm6  mmmmmmffmm                  mfm
147  3mxdn (1)  33mmxxddnn               3mxdn
163      nn4wx  nnnn44wwxx                 n4wx
164      c353e  cc335533cc                c353c
166      wddcp  wwddddccpp                 wdcp
167      w52fn  ww555fffnn                 w5fn
173      x775w  xx777755ww                 x75w
174      e667x  ee666677xx                 e67x
178      bxxfc  bbxxxxffcc                 bxfc
181      gymmn  ggyymmmnnn                 gymn
184      mmy5n  mmmmyy55nn                 my5n
191      8nn73  88nnnn7733                 8n73
194      wgnwp  wwggmmwwpp                wgmwp
200      3nnpw  33nnnnppww                 3npw
201      nnp4e  nnnnpp44ee                 np4e
206      ncww7  nnccwwww77                 ncw7
207      ddxpp  ddddxxpppp                  dxp
208      g2577  gg22557777                 g257
211      x7746  xx77774466                 x746
220      e5n66  ee55nn6666                 e5n6
226      44xe8  4444xxee88                 4xe8
227      dnne7  ddnnnnee77                 dne7
231      nny5e  nnnnyy55ee                 ny5e
237      gy433  ggyy443333                 gy43
238      d66cn  dd6666ccnn                 d6cn
239      nn6w6  nnnn66ww66                 n6w6
244      pmg55  ppmmgg5555                 pmg5
254      wwmn6  wwwwmmnn66                 wmn6
256      d666m  dd6----6mm                 d66m
262      nxx25  nnxxxx2255                 nx25
```

[50]:
```
print(mistakes_df['prediction_corrected'].str.len().value_counts())
```

```
prediction_corrected
```

```
4    39
3     6
5     5
Name: count, dtype: int64
```

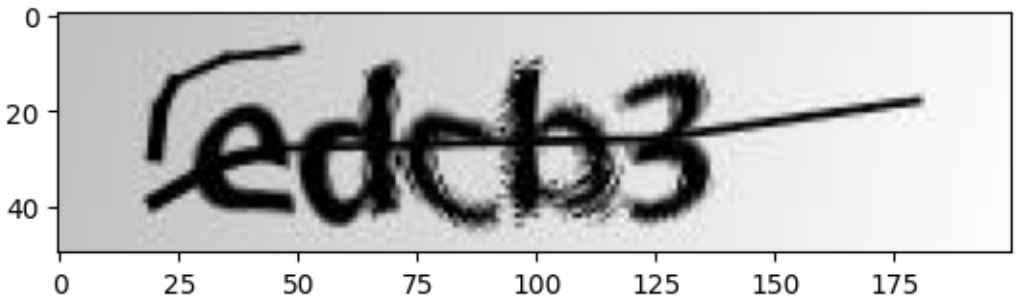
[51]:
```
mask = mistakes_df['prediction_corrected'].str.len() == 5
mistakes_df[mask]
```

[51]:

	actual	prediction	prediction_corrected
62	cdcb3	eeddccbb33	edcb3
144	3n7mx (1)	33nn77mmxx	3n7mx
147	3mxdn (1)	33mmxxddnn	3mxdn
164	c353e	cc335533cc	c353c
194	wgnwp	wwggmmwwpp	wgmwp

[52]:
```
mistake_image_fp = os.path.join(data_path, mistakes_df[mask]['actual'].
  ↪values[0] + ".png")
print(mistake_image_fp)
mistake_image = Image.open(mistake_image_fp)
plt.imshow(mistake_image)
plt.show()
```

```
/content/drive/MyDrive/archive (1)/samples/cdcb3.png
```



[53]:
```
train_accuracy = accuracy_score(results_train['actual'],␣
  ↪results_train['prediction_corrected'])
print(train_accuracy)
test_accuracy = accuracy_score(results_test['actual'],␣
  ↪results_test['prediction_corrected'])
print(test_accuracy)
```

```
0.8580246913580247
0.8148148148148148
```