OCR for Chinese City Parking Dataset

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1. Setup

1.1. Load data

```python
import torch
import torch.nn as nn
import PIL
import numpy as np

from matplotlib import pyplot as plt
from torchmetrics.functional import char_error_rate
from tqdm.notebook import tqdm
from torchvision import transforms, models
from torch.utils.data import Dataset, DataLoader
from PIL import Image
from pathlib import Path
from IPython.display import clear_output
```

```python
TRAIN_DIR = Path("./CCPD2019-dl1/train")
TEST_DIR = Path("./CCPD2019-dl1/test")

DEVICE = torch.device("cuda")
```

```python
train_val_files = list(TRAIN_DIR.rglob('*.jpg'))
test_files = list(TEST_DIR.rglob('*.jpg'))
print("Train files -- ", len(train_val_files))
print("Test files -- ", len(test_files))
```

```
Train files --  199980
Test files --  9999
```

```python
# checking all samples have the same length

for file in test_files:
    assert len(file.stem[-7:]) == 7
```

```python
# getting all possible characters from train_files

characters = []
for train_file in train_val_files:
    for train_file_letter in list(train_file.stem[-7:]):
        if train_file_letter not in characters:
            characters.append(train_file_letter)
```

```python
characters = sorted(characters)
''.join(characters)
```

```
'0123456789ABCDEFGHJKLMNOPQRSTUVWXYZ云京冀吉宁川新晋桂沪津浙渝湘琼甘皖粤苏蒙藏豫贵赣辽鄂闽陕青鲁黑'
```

```python
len(characters)
```

```
66
```

1.2. Visualizing tools

```python
%matplotlib inline
plt.style.use('seaborn-v0_8-whitegrid')
```

```python
def imshow(inp, title=None, plt_ax=plt, preds=None, default=False):
    """Imshow for tensors"""
    inp = inp.numpy().transpose((1, 2, 0))
    mean = np.array([0.485, 0.456, 0.406])
    std = np.array([0.229, 0.224, 0.225])
    inp = std * inp + mean
    inp = np.clip(inp, 0, 1)
    plt_ax.imshow(inp)
    if title:
        plt_ax.set_title("Ground truth: " + title, fontsize=14)
    if preds:
        plt_ax.set_xlabel("Predicted: " + preds, fontsize=14)
    plt_ax.grid(False)
```

```python
plt.rcParams['font.family'] = ['SimHei', 'sans-serif']
plt.rcParams['axes.unicode_minus'] = False


def draw_samples(test_dataset, preds=None, error_idxs=None):
    """Draw samples from dataset with 3 options:
        1. Samples with ground truth title
        2. Samples with ground truth and predicted title
        3. Samples with ground truth and mispredicted title
        """

    fig, ax = plt.subplots(nrows=3, ncols=3, figsize=(12, 8),
                           sharey=True, sharex=True)
    if error_idxs:
        for fig_x, error_idx in zip(ax.flatten(), error_idxs):
            pred = preds[error_idx]
            im_val, label = test_dataset[error_idx]
            img_label = label
            imshow(im_val.data.cpu(),
                   title=img_label, plt_ax=fig_x, preds=pred)

    elif preds:
        for fig_x in ax.flatten():
            random_characters = int(np.random.uniform(0, 1000))
            pred = preds[random_characters]
            im_val, label = test_dataset[random_characters]
            img_label = label
            imshow(im_val.data.cpu(),
                   title=img_label, plt_ax=fig_x, preds=pred)

    else:
        for fig_x in ax.flatten():
            random_characters = int(np.random.uniform(0, 1000))
            im_val, label = test_dataset[random_characters]
            img_label = label
            imshow(im_val.data.cpu(),
                   title=img_label, plt_ax=fig_x)
```

1.3. Label Encoder

```python
class LabelEncoder():
    """Label encoder and decoder for CTC loss
    Insert `blank` token in the characters for CTC-loss
    """

    def __init__(self, characters):
        self.characters = characters + '-'  # for `-1` index
        self.char2idx = {}

        for i, char in enumerate(characters):
            self.char2idx[char] = i + 1     #  0 ind is reserved for 'blank' in CTC-loss

        self.idx2char = {idx: char for char, idx in self.char2idx.items()}

    def encode_sample(self, text):
        """Converts string label to indexes"""
        text = [self.char2idx[char] for char in text]
        length = [len(text)]
        return (torch.IntTensor(text), torch.IntTensor(length))

    def encode(self, batch):
        """Converts labels in batch to indexes"""
        length = [len(sample) for sample in batch]
        text = ''.join(batch)
        text = [self.char2idx[char] for char in text]
        return (torch.IntTensor(text), torch.IntTensor(length))

    def decode_sample(self, text, length):
        """Converts indexes to string labels"""
        chars = []
        for i in range(length):
            if text[i] != 0 and (not (i > 0 and text[i - 1] == text[i])):
                chars.append(self.characters[text[i] - 1])
        return ''.join(chars)

    def decode(self, batch, length):
        """Converts indexes in batch to labels"""
        ind = 0
        texts = []
        for i in range(length.numel()):
            sample_len = length[i]
            texts.append(self.decode_sample(
                batch[ind: ind + sample_len], sample_len))
            ind += sample_len
        return texts
```

2. Dataset

```python
class CCPD(Dataset):
    def __init__(self, files):
        super().__init__()
        self.files = sorted(files)

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

    def load_sample(self, file):
        label = file.stem[-7:]     # get label: 1126-皖A5U628.jpg --> 皖A5U628
        img = Image.open(file)
        img.load()
        return img, label

    def __getitem__(self, index):
        transform = transforms.Compose([
            transforms.ToTensor(),
            transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225]),
            transforms.Resize(size=(32, 96))
        ])
        x, y = self.load_sample(self.files[index])
        x = transform(x)
        return x, y
```

```python
#splitting train files to train and val datasets

train_size = int(len(train_val_files) * 0.8)
val_size = len(train_val_files) - train_size

train_dataset, val_dataset = torch.utils.data.random_split(
    CCPD(train_val_files), [train_size, val_size])
test_dataset = CCPD(test_files)
```

```python
batch_size = 64

train_dataloader = DataLoader(
    train_dataset, batch_size=batch_size, shuffle=True)
val_dataloader = DataLoader(val_dataset, batch_size=batch_size, shuffle=True)
test_dataloader = DataLoader(
    test_dataset, batch_size=batch_size, shuffle=False)
```

```python
draw_samples(test_dataset)
```

3. Define Model

3.1. Build model

I tried to recreate model from given img

alt text

```python
class CRNN(nn.Module):
    def __init__(self, num_characters):
        super().__init__()
        self.num_characters = num_characters

        # [batch_size, 3, 32, 96]
        self.conv1 = nn.Sequential(
            nn.Conv2d(in_channels=3, out_channels=8, kernel_size=3, padding=2),
            nn.BatchNorm2d(8),
            nn.ReLU(),
            nn.MaxPool2d(kernel_size=2)
        )
        # [batch_size, 8, 17, 49]
        self.conv2 = nn.Sequential(
            nn.Conv2d(in_channels=8, out_channels=16,
                      kernel_size=3, padding=2),
            nn.BatchNorm2d(16),
            nn.ReLU(),
            nn.MaxPool2d(kernel_size=2)
        )
        # [batch_size, 16, 9, 25]
        self.conv3 = nn.Sequential(
            nn.Conv2d(in_channels=16, out_channels=32,
                      kernel_size=3, padding=1),
            nn.BatchNorm2d(32),
            nn.ReLU(),
            nn.MaxPool2d(kernel_size=2)
        )
        # [batch_size, 32, 4, 12]
        self.rnn = nn.Sequential(
            nn.LSTM(32 * 4, 512, batch_first=True, num_layers=2,
                    dropout=0.2, bidirectional=True),

        )
        # [batch_size, 12, 1024]
        self.clf = nn.Linear(1024, num_characters)

        # [12, batch_size, 67]

    def forward(self, x):
        x = self.conv1(x)
        x = self.conv2(x)
        x = self.conv3(x)
        b, c, h, w = x.size()
        x, _ = self.rnn(x.view(b, w, c * h))
        x = self.clf(x)
        return x.permute(1, 0, 2)
```

3.2. Training and testing tools

```python
def accuracy(preds, y):
    accuracy = np.mean(np.array(preds) == np.array(y))
    return accuracy
```

```python
def decode_preds(logits, label_encoder):
    """Decode logits into labels"""

    logits = logits.softmax(2).argmax(2).cpu()  # --> [12, 64]
    logits = logits.permute(1, 0).numpy()  # --> [64, 12]

    masked_tokens = []
    for label_decoded in logits:
        chars = []
        for char_idx in label_decoded:
            chars.append(
                label_encoder.idx2char[char_idx] if char_idx != 0 else '-')
        masked_tokens.append(chars)

    preds = []
    for label_encoded in masked_tokens:
        pred = []
        for idx, char in enumerate(label_encoded):
            if char != label_encoded[idx-1] and char != '-':
                pred.append(char)
        preds.append(''.join(pred))
    return preds
```

```python
def get_loss(logits, text, label_encoder, criterion):
    """Calculate CTC-loss"""
    input_len, batch_size, vocab_size = logits.size()
    logits = logits.log_softmax(2)
    enc_text, text_lens = label_encoder.encode(text)
    logits_lens = torch.full(
        size=(batch_size,), fill_value=input_len, dtype=torch.int32).to(DEVICE)
    loss = criterion(logits, enc_text, logits_lens, text_lens)
    return loss
```

```python
def train_loop(model, data_loader, label_encoder, criterion, optimizer, clip_norm):
    model.train()
    losses = []
    for img, text in tqdm(data_loader):
        optimizer.zero_grad()
        logits = model(img.to(DEVICE))
        loss = get_loss(logits, text, label_encoder, criterion)
        loss.backward()
        nn.utils.clip_grad_norm_(model.parameters(), clip_norm)
        optimizer.step()

        preds = decode_preds(logits, label_encoder)
        acc = accuracy(preds, text)

        losses.append(loss.item())

    return losses, acc
```

```python
def val_loop(model, data_loader, label_encoder, criterion):
    model.eval()
    losses = []
    with torch.inference_mode():
        for img, text in tqdm(data_loader):
            logits = model(img.to(DEVICE))
            loss = get_loss(logits, text, label_encoder, criterion)

            preds = decode_preds(logits, label_encoder)
            acc = accuracy(preds, text)

            losses.append(loss.item())

    return losses, acc
```

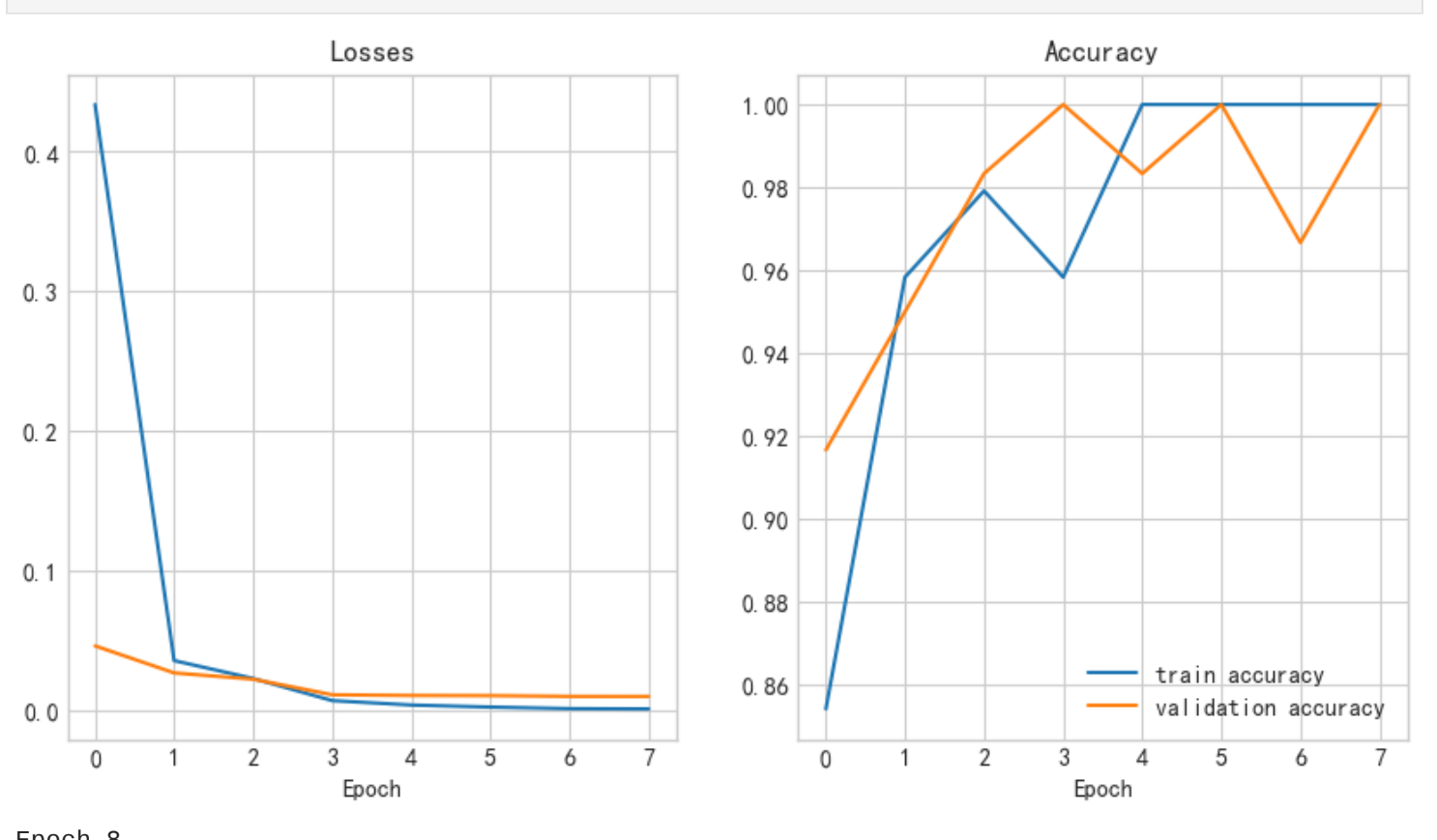
```python
def evaluate(test_dataloader, label_encoder):
    model.eval()
    losses = []
    predictions = []
    texts = []

    with torch.inference_mode():
        for img, text in tqdm(test_dataloader):
            logits = model(img.to(DEVICE))
            preds = decode_preds(logits, label_encoder)

            predictions.extend(preds)
            texts.extend(text)

    acc = accuracy(predictions, texts)
    cer = char_error_rate(predictions, texts)

    print(f'Test accuracy -- {acc}')
    print(f'Test CER -- {cer}')

    return predictions, texts
```

```python
def train(model, optimizer, criterion, scheduler, epochs, train_dataloader, val_dataloader, l
    train_losses = []
    val_losses = []
    train_acc_history = []
    val_acc_history = []

    for epoch in range(epochs):
        train_loss, train_acc = train_loop(model, train_dataloader, label_encoder,
                                           criterion, optimizer, clip_norm)
        val_loss, val_acc = val_loop(
            model, val_dataloader, label_encoder, criterion)
        scheduler.step()

        train_losses.append(np.mean(train_loss))
        val_losses.append(np.mean(val_loss))
        train_acc_history.append(train_acc)
        val_acc_history.append(val_acc)

        clear_output(True)
        fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(10, 5))
        ax[0].plot(train_losses, label='train loss')
        ax[0].plot(val_losses, label='val loss')
        ax[0].set_xlabel('Epoch')
        ax[0].set_title('Losses')
        ax[1].plot(train_acc_history, label='train accuracy')
        ax[1].plot(val_acc_history, label='validation accuracy')
        ax[1].set_xlabel('Epoch')
        ax[1].set_title('Accuracy')
        plt.legend()
        plt.show()

        print(f'Epoch {epoch + 1}')
        print(
            f'Losses: train -- {np.mean(train_loss)}, val -- {np.mean(val_loss)}')
        print(f'Accuracy: train -- {train_acc}, val -- {val_acc}')
```

4. Train model

```python
model = CRNN(len(characters) + 1).to(DEVICE)     # length of chars + 1 for CTC token
optimizer = torch.optim.AdamW(model.parameters(), lr=0.001)
criterion = nn.CTCLoss(blank=0, zero_infinity=True)
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, step_size=3, gamma=0.1)
epochs = 8
label_encoder = LabelEncoder(''.join(characters))
clip_norm = 5
```

```python
train(model, optimizer, criterion, scheduler, epochs,
      train_dataloader, val_dataloader, label_encoder, clip_norm)
```




```
Epoch 8
Losses: train -- 0.0010650644053341238, val -- 0.010003448391897837
Accuracy: train -- 1.0, val -- 1.0
```

5. Test model

5.1. Metrics

Now we good to test our model

```python
preds, texts = evaluate(test_dataloader, label_encoder)
```

```
  0%|          | 0/157 [00:00<?, ?it/s]
Test accuracy -- 0.943994399439944
Test CER -- 0.010186732746660071
```

We have nice and solid scores on both metrics

Best Test accuracy -- 0.95 Best Test CER -- 0.009

```python
draw_samples(test_dataset, preds)
```

5.2. Get errors

Let's see where our model has the worst CER score

```python
error_inxs = []

for ind, (pred, text) in enumerate(zip(preds, texts)):
    CER = char_error_rate(pred, text).numpy()
    if CER > 0.5:   # empirically selected threshold
        error_inxs.append(ind)
```

```python
draw_samples(test_dataset, preds, error_inxs)
```

6. Conclusion

It is clearly seen that model mispredicts in case of really fuzzy samples even I could not always recognize. There is snow on the characters that covers the half of hieroglyphs

To conculde, I have built an OCR model on CCPD dataset with CRNN architecture. Various optimizers, shedulers and hyperparameters were tested to achieve an excellent accuracy and CER scores, but not ideal though. To improve model understanding of low-poly or distorted images i think we need to work on DATA. So I believe it's feature-extraction problem and maybe we can add augmentation (my approach with augmentation gave lower scores than without) and detect problematic pictures for upsampling before passing them into model. Also I think we can generate more images with defects by adding noise to original and train model on them