In [ ]:
```
!unzip -qq CCPD2019-dl1.zip
```

In [12]:
```
!pip install torchmetrics pybind11 fastwer scikit-learn matplotlib
```

```
Requirement already satisfied: torchmetrics in /opt/conda/lib/python3.10/site-pack
ages (0.11.0)
Requirement already satisfied: pybind11 in /opt/conda/lib/python3.10/site-packages
(2.10.3)
Requirement already satisfied: fastwer in /opt/conda/lib/python3.10/site-packages
(0.1.3)
Requirement already satisfied: scikit-learn in /opt/conda/lib/python3.10/site-pack
ages (1.2.0)
Collecting matplotlib
  Downloading matplotlib-3.6.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl (11.8 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 11.8/11.8 MB 9.4 MB/s eta 0:00:00:0
0:0100:01
Requirement already satisfied: numpy>=1.17.2 in /opt/conda/lib/python3.10/site-pac
kages (from torchmetrics) (1.24.1)
Requirement already satisfied: packaging in /opt/conda/lib/python3.10/site-package
s (from torchmetrics) (21.3)
Requirement already satisfied: torch>=1.8.1 in /opt/conda/lib/python3.10/site-pack
ages (from torchmetrics) (1.13.1+cu116)
Requirement already satisfied: joblib>=1.1.1 in /opt/conda/lib/python3.10/site-pac
kages (from scikit-learn) (1.2.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /opt/conda/lib/python3.10/s
ite-packages (from scikit-learn) (3.1.0)
Requirement already satisfied: scipy>=1.3.2 in /opt/conda/lib/python3.10/site-pack
ages (from scikit-learn) (1.10.0)
Collecting kiwisolver>=1.0.1
  Downloading kiwisolver-1.4.4-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86
_64.whl (1.6 MB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.6/1.6 MB 5.6 MB/s eta 0:00:0000:01
00:01
Requirement already satisfied: pillow>=6.2.0 in /opt/conda/lib/python3.10/site-pac
kages (from matplotlib) (9.4.0)
Requirement already satisfied: pyparsing>=2.2.1 in /opt/conda/lib/python3.10/site-
packages (from matplotlib) (3.0.9)
Collecting cycler>=0.10
  Downloading cycler-0.11.0-py3-none-any.whl (6.4 kB)
Requirement already satisfied: python-dateutil>=2.7 in /opt/conda/lib/python3.10/s
ite-packages (from matplotlib) (2.8.2)
Collecting fonttools>=4.22.0
  Downloading fonttools-4.38.0-py3-none-any.whl (965 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 965.4/965.4 kB 6.6 MB/s eta 0:00:000
0:0100:01
Collecting contourpy>=1.0.1
  Downloading contourpy-1.0.6-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_
64.whl (296 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 296.1/296.1 kB 5.3 MB/s eta 0:00:00a
0:00:01
Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.10/site-packages
(from python-dateutil>=2.7->matplotlib) (1.16.0)
Requirement already satisfied: typing-extensions in /opt/conda/lib/python3.10/site
-packages (from torch>=1.8.1->torchmetrics) (4.3.0)
Installing collected packages: kiwisolver, fonttools, cycler, contourpy, matplotli
b
Successfully installed contourpy-1.0.6 cycler-0.11.0 fonttools-4.38.0 kiwisolver-
1.4.4 matplotlib-3.6.2
```

In [13]:
```
import torch
import torchvision
import fastwer
import torchmetrics
import os
import gc

import numpy as np
import matplotlib.pyplot as plt

from torch import nn
from torchvision import transforms
from PIL import Image

from tqdm.notebook import tqdm
from sklearn.metrics import accuracy_score
```

In [2]:
```
path = 'CCPD2019-dl1/'

dictionary = ["皖", "沪", "津", "渝", "冀", "晋", "蒙", "辽",
              "吉", "黑", "苏", "浙", "京", "闽", "赣", "鲁",
              "豫", "鄂", "湘", "粤", "桂", "琼", "川", "贵",
              "云", "藏", "陕", "甘", "青", "宁", "新", "警",
              "学", "O", 'A', 'B', 'C', 'D', 'E', 'F', 'G', 'H',
       'J', 'K', 'L', 'M', 'N', 'P', 'Q', 'R',
       'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z',
       '0', '1', '2', '3', '4', '5', '6', '7',
       '8', '9', 'O']
unknown = '<U>'
blank = '<B>'
```

In [3]:
```
class Tokenizer:
    def __init__(self, labels):
        self.char2id = {}
        self.char2id[unknown] = 0
        self.char2id[blank] = 1
        for i, label in enumerate(labels):
                self.char2id[label] = i + 2
        self.id2char = {v:k for k, v in self.char2id.items()}

    def encode(self, label):
        enc_label = [self.char2id[char] if char in self.char2id else self.char2id[u
        return enc_label

    def __len__(self):
        return len(self.char2id)

    def decode(self, enc_list):
        decoded_list = ''
        for i, char in enumerate(enc_list):
            if (char != self.char2id[unknown] and char != self.char2id[blank] and r
                decoded_list += self.id2char[char]
        return decoded_list
```

In [4]:
```
class Dataset(torch.utils.data.Dataset):
    def __init__(self, path, transform, tokenizer):
        super().__init__()
        self.files = [file for file in os.listdir(path) if file[0] != '.']
        self.t = transform
        self.labels = [file.split('-')[-1].split('.')[0] for file in self.files]
```

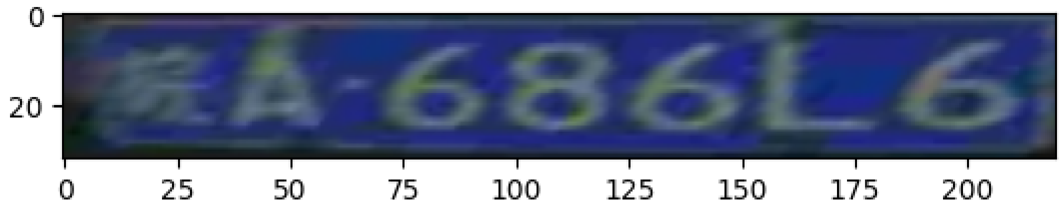
```
        self.path = path
        self.alphabet = {}
        self.tokenizer = tokenizer
        self.encoded_labels = [self.tokenizer.encode(label) for label in self.label

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

    def __getitem__(self, ind):
        image = Image.open(f'{self.path}{self.files[ind]}')
        img = self.t(image)
        label = self.labels[ind]
        return img, label, self.encoded_labels[ind]
```

In [5]:
```
tokenizer = Tokenizer(dictionary)

transform = transforms.Compose([
    transforms.Resize((32, 220)),
    transforms.ToTensor(),
])

train_dataset = Dataset(os.path.join(path,'train/'), transform, tokenizer)
test_dataset = Dataset(os.path.join(path,'test/'), transform, tokenizer)
```

In [7]:
```
len(train_dataset), len(test_dataset)
```

Out[7]: (199980, 9999)

In [18]:
```
plt.imshow(test_dataset[3][0].permute(1, 2, 0))
plt.show()
```



In [6]:
```
class Downsample(nn.Module):
  def __init__(self, in_channels, out_channels, kernel_size, stride, padding=1,use_
    super().__init__()
    if use_batchnorm:
      self.core=nn.Sequential(
          nn.Conv2d(in_channels=in_channels, out_channels=out_channels, kernel_size
          nn.BatchNorm2d(out_channels),
          nn.ReLU()
      )
    else:
      self.core=nn.Sequential(
        nn.Conv2d(in_channels=in_channels, out_channels=out_channels, kernel_size=k
        nn.ReLU()
    )
  def forward(self, x):
    return self.core(x)
```

In [7]:
```
class Encoder(nn.Module):
    def __init__(self):
        super().__init__()
        self.layers = nn.Sequential(
```

```
        Downsample(in_channels=3, out_channels=64, kernel_size=3, stride=1, use_bat
        nn.MaxPool2d(kernel_size = 2, stride = 2),
        Downsample(in_channels=64, out_channels=128, kernel_size=3, stride=1),
        nn.MaxPool2d(kernel_size = (1,2), stride = 2),
        Downsample(in_channels=128, out_channels=256, kernel_size=3, stride=1),
        nn.MaxPool2d(kernel_size = (1,2), stride = 2),
        Downsample(in_channels=256, out_channels=128, kernel_size=3, stride=1),
        )
    def forward(self, inputs):
        x = self.layers(inputs)
        return x
```

In [8]:
```
class BiLSTM(nn.Module):
    def __init__(self, input_dim, hidden_dim, num_layers, dropout = 0.1):
        super().__init__()
        self.rnn = nn.LSTM(input_dim, hidden_dim, num_layers, dropout = dropout, ba

    def forward(self, inputs):
        outputs, _ = self.rnn(inputs)
        return outputs

class CRNN(nn.Module):



    def __init__(self, output_dim,  hidden_dim, max_len = 15, num_layers = 2):
        super().__init__()
        self.encoder = Encoder()
        self.avg_pool = nn.AdaptiveAvgPool2d((max_len, max_len))
        self.rnn = BiLSTM(max_len, hidden_dim, num_layers)
        self.classify_layer = nn.Sequential(
            nn.Linear(hidden_dim * 2, max_len),
            nn.GELU(),
            nn.Dropout(0.1),
            nn.Linear(max_len, output_dim)
        )

    def forward(self, inputs):
        outp = self.encoder(inputs)
        b, c, h, w = outp.shape
        outp = outp.view(b, c * h, w)
        outp = self.avg_pool(outp)
        outp = outp.transpose(1,2)
        outp = self.rnn(outp)
        outp = self.classify_layer(outp)
        outp = outp.permute(1, 0, 2)
        outp = nn.functional.log_softmax(outp, dim=2)
        return outp
```

In [9]:
```
def collate_fn(batch):
    images, labels, encoded_labels = zip(*batch)
    images = torch.stack(images, 0)
    encoded_labels = torch.nn.utils.rnn.pad_sequence(torch.tensor(encoded_labels),
    return images, labels, encoded_labels
```

In [10]:
```
def train_epoch(model,
                dataset,
                loss,
                optimizer,
                scheduler,
```

```
                 device):
    model.train()
    epoch_loss = 0
    model = model.to(device)
    for img, label, encoded_label in tqdm(dataset):

        batch = img.shape[0]

        img = img.to(device)

        optimizer.zero_grad()

        preds = model(img)

        p_labels = torch.full(size = (batch,), fill_value = preds.size(0), dtype =
        t_labels = torch.full(size = (batch,), fill_value = encoded_label.size(1),

        b_loss = loss(preds, encoded_label, p_labels, t_labels)

        epoch_loss += b_loss.item()

        b_loss.backward()
        optimizer.step()


    return epoch_loss / len(dataset)
```

In [11]:

```
def eval_epoch(model,
               dataset,
               loss,
               device):
    model.eval()
    epoch_loss = 0
    model = model.to(device)
    for img, label, encoded_label in tqdm(dataset):

        with torch.no_grad():
            batch = img.shape[0]

            img = img.to(device)
            encoded_label = encoded_label.to(device)

            preds = model(img)

            p_labels = torch.full(size = (batch,), fill_value = preds.size(0), dtyp
            t_labels = torch.full(size = (batch,), fill_value = encoded_label.size(

            b_loss = loss(preds, encoded_label, p_labels, t_labels)

            epoch_loss += b_loss.item()

    return epoch_loss / len(dataset)
```

In [12]:

```
def train_model(model,
                train_dataset,
                test_dataset,
                batch_size,
                epochs,
                loss,
                optimizer,
```

```
                  scheduler,
                  device):

    model.cuda()
    loss.to(device)

    test_dataloader = torch.utils.data.DataLoader(test_dataset,
                                                  batch_size = batch_size,
                                                  shuffle = False,
                                                  collate_fn = collate_fn)

    train_dataloader = torch.utils.data.DataLoader(train_dataset,
                                                   batch_size = batch_size,
                                                   shuffle = True,
                                                   collate_fn = collate_fn)
    for epoch_i in range(epochs):
        print(f'Epoch {epoch_i+1}')
        train_loss = train_epoch(model, train_dataloader, loss, optimizer, schedule
        eval_loss = eval_epoch(model, test_dataloader, loss, device)
        scheduler.step(eval_loss)
        print(f'Train CTC: {train_loss}')
        print(f'Eval CTC: {eval_loss}')
        print()
    torch.save(model, f'model_ep{epoch_i+1}.pt')
```

In [13]:

```
model = CRNN(max_len = 15, hidden_dim = 200, output_dim = len(train_dataset.tokeni

CTC =  nn.CTCLoss(blank = 1, reduction = 'mean', zero_infinity = True)
optimizer = torch.optim.Adam(model.parameters(), lr = 1e-4)

scheduler = torch.optim.lr_scheduler.ReduceLROnPlateau(optimizer, factor=0.8, patie

gc.collect()
torch.cuda.empty_cache()

train_model(
    model = model,
    train_dataset = train_dataset,
    test_dataset = test_dataset,
    batch_size = 128,
    loss = CTC,
    optimizer = optimizer,
    scheduler = scheduler,
    epochs = 10,
    device = 'cuda'
)
```

```
Epoch 1
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 3.0028658341842815
Eval CTC: 2.0103080891355685

Epoch 2
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.9231137104013069
Eval CTC: 0.2196903477741193

Epoch 3
```

```
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.20089744116755837
Eval CTC: 0.10001567105137849

Epoch 4
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.10375405463818473
Eval CTC: 0.07591616317535503

Epoch 5
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.06926006894089133
Eval CTC: 0.0693979582431007

Epoch 6
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.05219624730772074
Eval CTC: 0.06486983366216285

Epoch 7
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.04214400670807558
Eval CTC: 0.07545892772252989

Epoch 8
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.035413823933033745
Eval CTC: 0.06186418796563816

Epoch 9
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.03099549728221071
Eval CTC: 0.05557966011663298

Epoch 10
  0%|          | 0/1563 [00:00<?, ?it/s]
  0%|          | 0/79 [00:00<?, ?it/s]
Train CTC: 0.027535500582867682
Eval CTC: 0.0651401086055373
```

In [14]:
```
def predict(model, dataset, tokenizer, device = 'cuda'):
    model.eval()
    preds = []
    real = []
    epoch_loss = 0
    model = model.to(device)
    test_dataloader = torch.utils.data.DataLoader(dataset, batch_size = 1, shuffle
    for img, label, encoded_label in tqdm(test_dataloader):
        with torch.no_grad():
            batch = img.shape[0]
            img = img.to(device)
            encoded_label = encoded_label.to(device)
            pred = model(img)
```

```
            preds.append(tokenizer.decode(pred.argmax(2).squeeze(1).tolist()))
            real.append(label)

    return preds, real
```

In [15]:

```
accuracy = torchmetrics.CharErrorRate()

preds, real_labels = predict(model, test_dataset, tokenizer)

print('CER:', accuracy(preds, real_labels).item())
print('Accuracy:', accuracy_score(preds, real_labels))
```

```
  0%|          | 0/9999 [00:00<?, ?it/s]
CER: 6.995199680328369
Accuracy: 0.9487948794879488
```