U-net image segmentation

In [1]:
```
import random
import sys
import os
import numpy as np
import matplotlib.pyplot as plt
import glob
import pickle
import cv2
import torch
import torch.nn as nn
import torch.nn.functional as F
from torch import optim
from torchvision import transforms
from torch.utils.data import Dataset
from torchsummary import summary

%matplotlib inline

device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print(device)
```

```
cuda:0
```

In [2]:
```
class BasicBlock(nn.Module):
    def __init__(self, in_ch, out_ch):
        super(BasicBlock, self).__init__()
        self.conv1 = nn.Conv2d(in_ch, out_ch, 3, padding=1) #in_channels, out_channels, kernel_size
        self.conv2 = nn.Conv2d(out_ch, out_ch, 3, padding=1)
        self.bn1 = nn.BatchNorm2d(out_ch)
        self.bn2 = nn.BatchNorm2d(out_ch)
        self.relu1 = nn.ReLU(inplace=True)
        self.relu2 = nn.ReLU(inplace=True)
    def forward(self, x):
        x = self.relu1(self.bn1(self.conv1(x)))
        x = self.relu2(self.bn2(self.conv2(x)))
        return x

class MaxPool(nn.Module):
    def __init__(self):
        super(MaxPool, self).__init__()
        self.down = nn.MaxPool2d(kernel_size=2, stride=2)
    def forward(self, x):
        return self.down(x)

class UpSample(nn.Module):
    def __init__(self):
        super(UpSample, self).__init__()
        self.up = nn.Upsample(scale_factor=2)
    def forward(self, x):
        return self.up(x)

class output_layer(nn.Module):
    def __init__(self, in_ch, out_ch):
        super(output_layer, self).__init__()
        self.conv = nn.Conv2d(16, 1, 3, padding=1)
    def forward(self, x):
        return torch.sigmoid(self.conv(x))
```

In [3]:
```
class UNet_3layer(nn.Module):
    def __init__(self):
        super(UNet_3layer, self).__init__()
        self.layer1 = BasicBlock(3, 16)
        self.layer2 = BasicBlock(16,32)
        self.layer3 = BasicBlock(32,32)
        self.layer2r = BasicBlock(64,16)
        self.layer1r = BasicBlock(32,16)

        self.output_layer = output_layer(16, 1)
        self.downlayer = MaxPool()
        self.uplayer = UpSample()

    def forward(self, x):
        x1 = self.layer1(x)
        x2 = self.layer2(self.downlayer(x1))
        out = self.layer3(self.downlayer(x2))

        out = self.uplayer(out)
        out = torch.cat((out,x2),1)
        out = self.layer2r(out) #64+32=96 => 32

        out = self.uplayer(out)
        out = torch.cat((out,x1),1)
        out = self.layer1r(out) #32+16=48 => 16

        out = self.output_layer(out)
        return out

net = UNet_3layer().to(device)
testmodelinputsize = torch.Size([3, 256, 256])
summary(net,testmodelinputsize)
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 16, 256, 256]             448
       BatchNorm2d-2         [-1, 16, 256, 256]              32
              ReLU-3         [-1, 16, 256, 256]               0
            Conv2d-4         [-1, 16, 256, 256]           2,320
       BatchNorm2d-5         [-1, 16, 256, 256]              32
              ReLU-6         [-1, 16, 256, 256]               0
        BasicBlock-7         [-1, 16, 256, 256]               0
         MaxPool2d-8         [-1, 16, 128, 128]               0
           MaxPool-9         [-1, 16, 128, 128]               0
           Conv2d-10         [-1, 32, 128, 128]           4,640
      BatchNorm2d-11         [-1, 32, 128, 128]              64
             ReLU-12         [-1, 32, 128, 128]               0
           Conv2d-13         [-1, 32, 128, 128]           9,248
      BatchNorm2d-14         [-1, 32, 128, 128]              64
             ReLU-15         [-1, 32, 128, 128]               0
       BasicBlock-16         [-1, 32, 128, 128]               0
```

In [4]:
```
class UNet_4layer(nn.Module):
    def __init__(self):
        super(UNet_4layer, self).__init__()
        self.layer1 = BasicBlock(3, 16)
        self.layer2 = BasicBlock(16,32)
        self.layer3 = BasicBlock(32,64)
        self.layer4 = BasicBlock(64,128)
        self.layer3r = BasicBlock(192,64)
        self.layer2r = BasicBlock(96,32)
        self.layer1r = BasicBlock(48,16)

        self.output_layer = output_layer(16, 1)
        self.downlayer = MaxPool()
        self.uplayer = UpSample()

    def forward(self, x):
        x1 = self.layer1(x)
        x2 = self.layer2(self.downlayer(x1))
        x3 = self.layer3(self.downlayer(x2))
        x4 = self.layer4(self.downlayer(x3))

        out = self.uplayer(x4)
        out = torch.cat((out,x3),1)
        out = self.layer3r(out) #128+64=192 => 64

        out = self.uplayer(out)
        out = torch.cat((out,x2),1)
        out = self.layer2r(out) #64+32=96 => 32

        out = self.uplayer(out)
        out = torch.cat((out,x1),1)
        out = self.layer1r(out) #32+16=48 => 16

        out = self.output_layer(out)
        return out

net = UNet_4layer().to(device)
testmodelinputsize = torch.Size([3, 256, 256])
summary(net,testmodelinputsize)
```

```
         MaxPool-27          [-1, 64, 32, 32]               0
          Conv2d-28         [-1, 128, 32, 32]          73,856
     BatchNorm2d-29         [-1, 128, 32, 32]             256
            ReLU-30         [-1, 128, 32, 32]               0
          Conv2d-31         [-1, 128, 32, 32]         147,584
     BatchNorm2d-32         [-1, 128, 32, 32]             256
            ReLU-33         [-1, 128, 32, 32]               0
      BasicBlock-34         [-1, 128, 32, 32]               0
        Upsample-35         [-1, 128, 64, 64]               0
        UpSample-36         [-1, 128, 64, 64]               0
          Conv2d-37          [-1, 64, 64, 64]         110,656
     BatchNorm2d-38          [-1, 64, 64, 64]             128
            ReLU-39          [-1, 64, 64, 64]               0
          Conv2d-40          [-1, 64, 64, 64]          36,928
     BatchNorm2d-41          [-1, 64, 64, 64]             128
            ReLU-42          [-1, 64, 64, 64]               0
      BasicBlock-43          [-1, 64, 64, 64]               0
        Upsample-44        [-1, 64, 128, 128]               0
        UpSample-45        [-1, 64, 128, 128]               0
          Conv2d-46        [-1, 32, 128, 128]          27,680
```

In [5]:
```
class PedDataset(Dataset):
    def __init__(self, img_path_list, label_path_list, res=(256,256), IF_TRAIN=False):
        self.img_path_list = img_path_list
        self.label_path_list = label_path_list
        self.res = res
        self.IF_TRAIN = IF_TRAIN
        self.scale_factor = 0.1
        self.img_list, self.mask_list = self.preprocess()

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

    def preprocess(self):
        img_list, mask_list = [], []
        for idx in range(len(self.label_path_list)):
            img = cv2.imread(self.img_path_list[idx])
            img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
            mask = cv2.imread(self.label_path_list[idx], cv2.IMREAD_GRAYSCALE)
            mask[mask>=1] = 255

            img = cv2.resize(img, self.res)
            mask = cv2.resize(mask, self.res)

            img_list.append(img)
            mask_list.append(mask)
        return img_list, mask_list


    def __getitem__(self, idx):
        img = self.img_list[idx]
        mask = self.mask_list[idx]
        if self.IF_TRAIN:
            if random.random()<0.7:
                scale = np.random.randn()*self.scale_factor+1
                new_res = (int(self.res[0]*scale), int(self.res[1]*scale))
                img_candidate = cv2.resize(img, new_res)
                mask_candidate = cv2.resize(mask, new_res)
                if scale >= 1:
                    x_begin = (new_res[0]-self.res[0])//2
                    y_begin = (new_res[1]-self.res[1])//2
                    img = img_candidate[x_begin:x_begin+self.res[0],y_begin:y_begin+self.res[1]]
                    mask = mask_candidate[x_begin:x_begin+self.res[0],y_begin:y_begin+self.res[1]]
                else:
                    img = np.zeros_like(img)
                    mask = np.zeros_like(mask)
                    x_begin = (self.res[0]-new_res[0])//2
                    y_begin = (self.res[1]-new_res[1])//2
                    img[x_begin:x_begin+new_res[0],y_begin:y_begin+new_res[1]] = img_candidate
                    mask[x_begin:x_begin+new_res[0],y_begin:y_begin+new_res[1]] = mask_candidate
            if random.random()<0.5:
                img = np.array(img[:,::-1,:])
                mask = np.array(mask[:,::-1])
        img = torch.Tensor(img).permute(2,0,1)
        label = torch.Tensor(mask).unsqueeze(0)
        return img/255., label/255.
```

In [6]:
```
img_list = sorted(glob.glob("./archive/PNGImages/*.png"))
label_list = sorted(glob.glob("./archive/PedMasks/*.png"))
assert len(img_list) == len(label_list)
print ("Total images size: ",len(img_list))

from random import shuffle
def shuffle_two_lists(listA, listB):
    temp = list(zip(listA, listB))
    shuffle(temp)
    return zip(*temp)

train_split_ratio = 0.8
test_split_ratio = 0.1

num_samples = len(img_list)
train_size = int(num_samples*train_split_ratio)
test_size = int(num_samples*test_split_ratio)
val_size = num_samples-train_size-test_size

img_list_shuffled, label_list_shuffled = shuffle_two_lists(img_list, label_list)

train_img_list, train_label_list = img_list_shuffled[:train_size], label_list_shuffled[:train_size]
valid_img_list, valid_label_list = img_list_shuffled[train_size:train_size+val_size], label_list_shuffled[train_size:train_size+va
tests_img_list, tests_label_list = img_list_shuffled[train_size+val_size:], label_list_shuffled[train_size+val_size:]

print ("Train set size: ",len(train_img_list))
print ("Valid set size: ",len(valid_img_list))
print ("Tests set size: ",len(tests_img_list))


train_dataset = PedDataset(train_img_list, train_label_list, IF_TRAIN=True)
valid_dataset = PedDataset(valid_img_list, valid_label_list, IF_TRAIN=True)
tests_dataset = PedDataset(tests_img_list, tests_label_list, IF_TRAIN=True)

BATCH_SIZE = 16
train_loader = torch.utils.data.DataLoader(train_dataset,batch_size=BATCH_SIZE,shuffle=True)
valid_loader = torch.utils.data.DataLoader(valid_dataset,batch_size=BATCH_SIZE,shuffle=False)
tests_loader = torch.utils.data.DataLoader(tests_dataset,batch_size=BATCH_SIZE,shuffle=False)
```

```
Total images size:  170
Train set size:  136
Valid set size:  17
Tests set size:  17
```

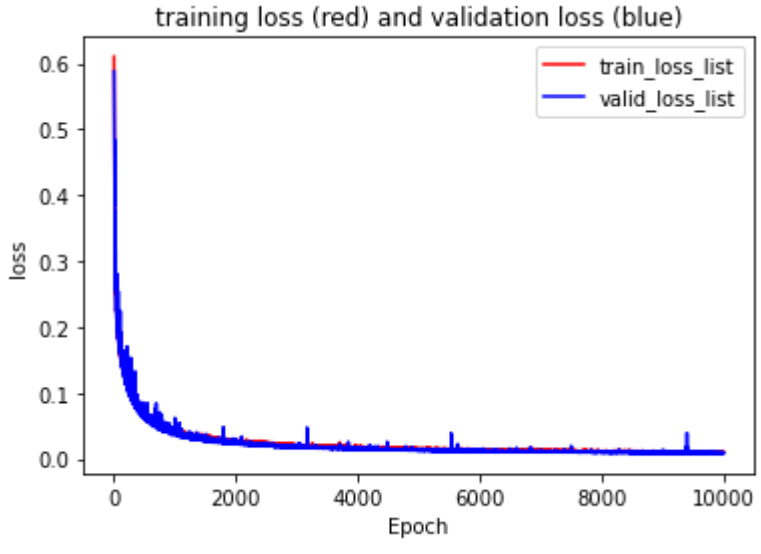
In [7]:
```
def dice_coeff(pred, target):
    smooth = 1
    num = pred.size(0)
    m1 = pred.view(num, -1).float()  # Flatten
    m2 = target.view(num, -1).float()  # Flatten
    intersection = 2 * torch.sum(m1*m2)
    cardinality = torch.sum(m1) + torch.sum(m2)
    if cardinality == 0:
        cardinality = cardinality + 0.001
    dice = intersection / cardinality
    return dice.mean()

class SoftDICELoss(nn.Module):
    def __init__(self, smooth = 1):
        super(SoftDICELoss, self).__init__()
        self.smooth = smooth
    def forward(self, pred, target):
        num = pred.size(0)
        m1 = pred.view(num, -1).float()  # Flatten
        m2 = target.view(num, -1).float()  # Flatten
        loss = 1 - 2 * torch.sum(m1*m2) / (torch.sum(m1**2)+torch.sum(m2**2))
        return loss.mean()
```

In [8]:
```
def train_epoch(net, data_loader, optimizer, criterion, epoch):
    net.train()
    loss_stat = []
    for i, (image, label) in enumerate(data_loader):
        image, label = image.to(device), label.to(device)
        optimizer.zero_grad()
        output = net(image)
        mask_pred_flat = output.view(output.shape[0], -1)
        mask_data_flat = label.view(label.shape[0], -1)
        loss = criterion(mask_pred_flat, mask_data_flat)
        loss.backward()
        optimizer.step()
        loss_stat += [loss.item()]*image.shape[0]
    #print ("Epoch {}: [{}/{}] Loss: {:.3f}".format(epoch, len(data_loader), len(data_loader),np.mean(loss_stat)))
    return np.mean(loss_stat)
def valid_epoch(net, data_loader, metric, criterion, epoch):
    net.eval() # set model in eval mode to avoid updating BN layer
    metric_stat = []
    val_loss_stat = []
    for i, (image, label) in enumerate(data_loader):
        image, label = image.to(device), label.to(device)
        with torch.no_grad():
            ypred = net(image)
            val_loss = criterion(ypred.view(1, -1),label.view(1, -1))
        ypred = ypred>0.5
        err = metric(ypred.view(1, -1).float(), label.view(1, -1).float())
        metric_stat += [err.item()]*image.shape[0]
        val_loss_stat += [val_loss.item()]*image.shape[0]
    #print ("Dice: {:.3f}  Val Loss: {:.3f} ".format(np.mean(metric_stat), np.mean(val_loss_stat)))
    return np.mean(val_loss_stat), np.mean(metric_stat)
```

In [9]:
```
NUM_EPOCH = 10000
LR = 0.001
SAVE_PATH = "./UNet_pth/"
optimizer = optim.SGD(net.parameters(), lr=LR, momentum=0.9, weight_decay=0.0005)
#criterion = nn.BCELoss()
criterion = SoftDICELoss()

best_train_loss = 1.0
train_loss_list = []
valid_loss_list = []
for epoch in range(NUM_EPOCH):
    train_loss = train_epoch(net, train_loader, optimizer, criterion, epoch)
    valid_loss, dice = valid_epoch(net, train_loader, dice_coeff, SoftDICELoss(), epoch)

    print("Epoch %d \t%0.3f\t%0.3f"%(epoch,train_loss,valid_loss))

    train_loss_list.append(train_loss)
    valid_loss_list.append(valid_loss)

    if train_loss<best_train_loss:
        best_train_loss = train_loss
        if not os.path.isdir(SAVE_PATH):
            os.makedirs(SAVE_PATH, exist_ok=True)
        torch.save(net.state_dict(),SAVE_PATH + 'UNetPedSegBestEpoch.pth')
        print('Checkpoint {} saved to {}'.format(epoch + 1, SAVE_PATH + 'UNetPedSegBestEpoch.pth'))
```

```
Epoch 9103      0.010   0.009
Epoch 9104      0.010   0.010
Epoch 9105      0.010   0.009
Epoch 9106      0.010   0.010
Epoch 9107      0.010   0.009
Epoch 9108      0.011   0.010
Epoch 9109      0.011   0.010
Epoch 9110      0.010   0.009
Epoch 9111      0.010   0.010
Epoch 9112      0.010   0.009
Epoch 9113      0.011   0.009
Epoch 9114      0.011   0.010
Epoch 9115      0.010   0.009
Epoch 9116      0.010   0.009
Epoch 9117      0.011   0.010
Epoch 9118      0.010   0.009
Epoch 9119      0.010   0.010
Epoch 9120      0.011   0.009
Epoch 9121      0.011   0.009
Epoch 9122      0.011   0.009
```

In [10]:
```
plt.plot(np.arange(len(train_loss_list)), train_loss_list, label = "train_loss_list", color='r')
plt.plot(np.arange(len(valid_loss_list)), valid_loss_list, label = "valid_loss_list", color='b')
plt.xlabel('Epoch')
plt.ylabel('loss')
plt.title('training loss (red) and validation loss (blue)')
plt.legend()
plt.show()
```



In [71]:
```
def predict_img(net, img, res, out_threshold=0.5):
    net.eval()
    img = cv2.resize(img, res)/255
    img = np.transpose(img, axes=[2, 0, 1])
    img = torch.from_numpy(np.array([img.tolist()])).type(torch.FloatTensor)   # Height*Width*Channel to Channel*Height*Width
    img = img.to(device)
    with torch.no_grad():
        pred = net(img)
        pred = pred.squeeze(0).squeeze(0)
        pred = torch.round(pred)
    return pred
def display(img):
    mask = predict_img(net=net,img=img,res=(256,256),out_threshold=0.5).cpu().numpy()
    mask = cv2.resize(mask,(img.shape[1],img.shape[0]))*255
    mask = cv2.normalize(mask, None, 0, 255, cv2.NORM_MINMAX, cv2.CV_8U)
    mask = np.repeat(mask[:, :, np.newaxis], 3, axis=2)
    mask_inv = cv2.bitwise_not(mask)
    mask[:,:,1] = 0
    mask_inv[:,:,0] = 0
    img_seg = cv2.addWeighted(img,0.5,mask_inv,0.5,0)
    img_seg = cv2.addWeighted(img_seg,0.7,mask,0.3,0)
    return img_seg

img_path_displays = ['./archive/PNGImages/FudanPed00012.png','./archive/PNGImages/FudanPed00014.png',
                     './archive/PNGImages/FudanPed00016.png', './archive/PNGImages/FudanPed00059.png',
                     './archive/PNGImages/FudanPed00020.png', './archive/PNGImages/FudanPed00028.png',
                     './archive/PNGImages/FudanPed00031.png', './archive/PNGImages/FudanPed00039.png',
                     './archive/PNGImages/FudanPed00045.png']

plt.figure(figsize = (16,13))
plt.title('Image Segmentation Result')
for i, img_path_display in enumerate(img_path_displays):
    img = cv2.imread(img_path_display)
    img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
    img_seg = display(img)
    plt.subplot(3,3,i+1)
    plt.imshow(img_seg)
```

In [ ]:

In [ ]: