10027693_raney

February 9, 2022

[47]:
```
# CISC 881
# Assignment 3
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import numpy as np
import pandas as pd
import SimpleITK as sitk
import os
import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap
from scipy import stats
from collections import OrderedDict
from tqdm import tqdm
from sklearn.preprocessing import scale as Normalize
from sklearn.model_selection import train_test_split

# PyTorch
import torch
import torch.utils.data
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
cuda = torch.device('cuda')

# PyTorchSummary
from torchsummary import summary
```

[2]:
```
# readMhd method
# SimpleITK ReadImage wrapper from utils.py from the LNDb Challenge
# Reference: https://lndb.grand-challenge.org/
def readMhd(filename):
    # read mhd/raw image
    itkimage = sitk.ReadImage(filename)
    scan = sitk.GetArrayFromImage(itkimage) #3D image
    spacing = itkimage.GetSpacing() #voxelsize
    origin = itkimage.GetOrigin() #world coordinates of origin
```

```
    transfmat = itkimage.GetDirection() #3D rotation matrix
    return scan,spacing,origin,transfmat
```

[3]:
```
# resample method
# returns resampled itk image with reference spacing (0.625, 0.625, 3.6)
# Reference: https://github.com/SimpleITK/SimpleITK/issues/561
def resample(filename, interpolator):
    itkImage = sitk.ReadImage(filename)
    refSpacing = np.array([0.625,0.625,3.6])
    resampler = sitk.ResampleImageFilter()

    # Set interpolator
    resampler.SetInterpolator(interpolator)
    #resampler.SetTransform(sitk.Transform(3,sitk.sitkIdentity))

    resampler.SetTransform(sitk.Transform())
    # Set out direction
    resampler.SetOutputDirection(itkImage.GetDirection())
    # Set out origin
    resampler.SetOutputOrigin(itkImage.GetOrigin())
    # Set out spacing
    resampler.SetOutputSpacing(refSpacing)
    # Calculate new size
    newSize = np.array(itkImage.GetSize()*(itkImage.GetSpacing()/refSpacing),␣
 ↪dtype=np.uint).tolist()
    # Set out size
    resampler.SetSize(newSize)

    return resampler.Execute(itkImage)
```

[4]:
```
# centerCrop method
# returns the center 224x224 crop of an SimpleITK image with all depth
def centerCrop(itkImage):
    # First pad the image to make sure its width x height is at least 224 x 224.
    padding = np.tile(0, 3)
    padding[0] = np.max([0, 224-itkImage.GetWidth()])
    padding[1] = np.max([0, 224-itkImage.GetHeight()])

    padder = sitk.MirrorPadImageFilter()
    padder.SetPadLowerBound(padding.tolist())
    padder.SetPadUpperBound(np.tile(0,3).tolist())
    paddedImage = padder.Execute(itkImage)

    # Slice out the center 224 x 224 region and include all depth
    wCenter = paddedImage.GetHeight() // 2
    hCenter = paddedImage.GetHeight() // 2
```

```
    return paddedImage[wCenter - 112: wCenter + 112, hCenter - 112: hCenter +␣
↪112, :]
```

[5]:
```
# saveSlices method
# saves the top 5 slices with the most label region
def saveSlices(itkImage, itkLabel, case):
    def findMaxAxialIndices(label):
        sumIntensities = sitk.GetArrayFromImage(label).sum(axis=1).sum(axis=1)
        dic = OrderedDict(zip(range(len(sumIntensities)), sumIntensities))
        oDic = sorted(dic.items(), key= lambda x: x[1])
        return list(dict(oDic[-5:]).keys())

    def saveSlice(index):
        np.save(os.path.join(imagesTr, case.split('.')[0] + ("_z%d"%index).
↪zfill(3)),
                sitk.GetArrayFromImage(itkImage)[index, :, :])
        np.save(os.path.join(labelsTr, case.split('.')[0] + ("_z%d"%index).
↪zfill(3)),
               sitk.GetArrayFromImage(itkLabel)[index, :, :])

    [saveSlice(z) for z in findMaxAxialIndices(itkLabel)]
```

[6]:
```
# preprocess_and_save method
# runs preprocessing for all the labels and images for resampling,
# cropping and slicing to save npy arrays
def preprocess_and_save(imgList, lblList):
    print("Preprocessing ...")
    imgList.sort()
    lblList.sort()
    with tqdm(total=50) as pbar:
        for lbl,img in zip(lblList, imgList):
            # a) Resample to a reference spacing of (0.625, 0.625, 3.6)
            pbar.set_description(("Resampling " + img.split('.')[0] + " ...").
↪ljust(30, ' '))
            pbar.update(1)
            pbar.refresh
            resLbl = resample(os.path.join(RAW_DIR, lbl), sitk.
↪sitkNearestNeighbor)
            resImg = resample(os.path.join(RAW_DIR, img), sitk.sitkLinear)

            # b) Crop to a central volume, 224 x 224, ignoring depth
            pbar.set_description(("Cropping " + img.split('.')[0] + " ...").
↪ljust(30, ' '))
            pbar.refresh
            croppedImg = centerCrop(resImg)
            croppedLbl = centerCrop(resLbl)
```

```
            # c) save the five axial slices with the most label region
            pbar.set_description(("Saving " + img.split('.')[0] + " ...").
 ↪ljust(30, ' '))
            pbar.refresh
            saveSlices(croppedImg, croppedLbl, img)
```

[7]:
```
# flip_and_save method
# doubles the number of slices by flipping the image and label arrays along the␣
 ↪y-axis
def flip_and_save(npyList):
    print("Flipping y-axis ...")
    def flipSave(npyName):
        imgA = np.load(os.path.join(imagesTr, npyName))
        lblA = np.load(os.path.join(labelsTr, npyName))
        pbar.set_description(("Saving " + npyName.split('.')[0] + " ...").
 ↪ljust(30, ' '))
        pbar.update(1)
        pbar.refresh
        np.save(os.path.join(imagesTr, npyName.split('.')[0] + '_my'), np.
 ↪fliplr(imgA))
        np.save(os.path.join(labelsTr, npyName.split('.')[0] + '_my'), np.
 ↪fliplr(lblA))

    with tqdm(total=250) as pbar:
        [flipSave(npyFilename) for npyFilename in npyList]
```

[8]:
```
# normalize_and_save method
# normalize the image arrays to zero-mean and unit-variance and save them again
def normalize_and_save(npyList):
    print("Normalizing axial slices ...")
    def normalizeSave(npyFilename):
        imgA = np.load(os.path.join(imagesTr, npyFilename))
        pbar.set_description(("Saving " + npyFilename.split('.')[0] + " ...").
 ↪ljust(30, ' '))
        pbar.update(1)
        pbar.refresh
        np.save(os.path.join(imagesTr, npyFilename), Normalize(imgA))

    with tqdm(total=500) as pbar:
        [normalizeSave(npyName) for npyName in npyList]
```

[9]:
```
# maybeMakeDir method
# wrapper for os.mkdir
def maybeMakeDir(dirName):
    if os.path.exists(dirName) and os.path.isdir(dirName):
```

```
        return
    else:
        os.mkdir(dirName)
```

[10]:
```
# trainValTest method
# split into train, validation and test sets keeping case numbers together
def trainValTest(caseNos):
    train, valTest = train_test_split(caseNos, train_size=0.6,␣
↪random_state=12345)
    validation, test = train_test_split(valTest, train_size=0.5,␣
↪random_state=12345)

    # Make sure the Case number from part A is in the test set
    def switch(case, fromSet, toSet):
        fromSet.remove(case)
        toSet.append(case)
        switch = toSet[0]
        toSet = toSet[1:]
        fromSet.append(switch)

    if 'Case43' not in test:
        if 'Case43' in validation:
            switch('Case43', validation, test)
        else:
            switch('Case43', train, test)

    def fetchNpyNames(caseNos):
        return np.array(list(filter(lambda filename: filename.split('.')[-1] \
                                    == 'npy' and filename.split('_')[0] in␣
↪caseNos,
                                    os.listdir(imagesTr))))
    return [fetchNpyNames(caseList) for caseList in [train, validation, test,␣
↪['Case43']]]
```

[11]:
```
# Location of the raw data
RAW_DIR = './/data//train//'

# Preprocessing output folders
imagesTr = 'imagesTr'
labelsTr = 'labelsTr'

maybeMakeDir(imagesTr)
maybeMakeDir(labelsTr)

# Get the filenames for the images and the labels into arrays
imgFilenamesTr = np.array(list(filter(lambda filename: filename.split('.')[-1]␣
↪== 'mhd' \
```

```
                                        and 'segmentation' not in filename.
↪split('.')[0], os.listdir('data/train'))))

lblFilenamesTr = np.array(list(filter(lambda filename: filename.split('.')[-1]␣
↪== 'mhd' \
                                        and 'segmentation' in filename.split('.
↪')[0], os.listdir('data/train'))))

# a)-c): Preprocess and save
preprocess_and_save(imgFilenamesTr, lblFilenamesTr)

# Get the filenames for the saved npy arrays (n=250)
npyFileList = np.array(list(filter(lambda filename: filename.split('.')[-1] ==␣
↪'npy', os.listdir('imagesTr'))))

# d) Double the number of slices by flipping along the y-axis
flip_and_save(npyFileList)

# Get the filenames for the saved npy arrays (n=500)
npyFileList = np.array(list(filter(lambda filename: filename.split('.')[-1] ==␣
↪'npy', os.listdir('imagesTr'))))

# e) Normalize the intensity values of the images
normalize_and_save(npyFileList)

# Get the case identifiers
caseIds = [fname.split('.')[0] for fname in imgFilenamesTr]

# f) Split into train, validation and test sets keeping cases together
train, validation, test, case43 = trainValTest(caseIds)
```

```
Cropping Case03 …           :   8%|          | 4/50 [00:00<00:01, 27.22it/s]

Preprocessing …

Saving Case49 …             : 100%|      | 50/50 [00:02<00:00, 22.57it/s]
Saving Case10_z10 …         :  27%|         | 68/250 [00:00<00:00,
338.16it/s]

Flipping y-axis …

Saving Case35_z12 …         : 100%|      | 250/250 [00:00<00:00,
342.37it/s]
Saving Case43_z12_my …      :  21%|         | 105/500 [00:00<00:00,
529.47it/s]

Normalizing axial slices …

Saving Case05_z14_my …      : 100%|      | 500/500 [00:00<00:00,
536.57it/s]
```

[12]:
```
# Promise12Dataset class
# PyTorch Dataset
class Promise12Dataset(torch.utils.data.Dataset):
    def __init__(self, listOfFiles):
        self.filenames = listOfFiles
    def __getitem__(self, index):
        img = np.load(os.path.join(imagesTr, self.filenames[index]))[np.
 ↪newaxis, ...]
        target = np.load(os.path.join(labelsTr, self.filenames[index]))[np.
 ↪newaxis, ...]
        return img, target
    def __len__(self):
        return len(self.filenames)
```

[13]:
```
# g) UNet class
# PyTorch model
# Reference: https://github.com/milesial/Pytorch-UNet/blob/master/unet/
 ↪unet_parts.py
class DoubleConv(nn.Module):
    """(convolution => [BN] => ReLU) * 2"""

    def __init__(self, in_channels, out_channels):
        super().__init__()
        self.double_conv = nn.Sequential(
            nn.Conv2d(in_channels, out_channels, kernel_size=3, padding=1),
            nn.BatchNorm2d(out_channels),
            nn.ReLU(inplace=True),
            nn.Conv2d(out_channels, out_channels, kernel_size=3, padding=1),
            nn.BatchNorm2d(out_channels),
            nn.ReLU(inplace=True)
        )

    def forward(self, x):
        return self.double_conv(x)

# Reference: https://github.com/milesial/Pytorch-UNet/blob/master/unet/
 ↪unet_parts.py
class Down(nn.Module):
    """Downscaling with maxpool then double conv"""

    def __init__(self, in_channels, out_channels):
        super().__init__()
        self.maxpool_conv = nn.Sequential(
            nn.MaxPool2d(2),
            DoubleConv(in_channels, out_channels)
        )
```

```
    def forward(self, x):
        return self.maxpool_conv(x)

#n Reference: https://github.com/milesial/Pytorch-UNet/blob/master/unet/
 ↪unet_parts.py
class Up(nn.Module):
    """Upscaling then double conv"""

    def __init__(self, in_channels, out_channels, bilinear=True):
        super().__init__()

        # if bilinear, use the normal convolutions to reduce the number of␣
 ↪channels
        if bilinear:
            self.up = nn.Upsample(scale_factor=2, mode='bilinear',␣
 ↪align_corners=True)
        else:
            self.up = nn.ConvTranspose2d(in_channels // 2, in_channels // 2,␣
 ↪kernel_size=2, stride=2)

        self.conv = DoubleConv(in_channels, out_channels)

    def forward(self, x1, x2):
        x1 = self.up(x1)
        # input is CHW
        diffY = torch.tensor([x2.size()[2] - x1.size()[2]])
        diffX = torch.tensor([x2.size()[3] - x1.size()[3]])

        x1 = F.pad(x1, [diffX // 2, diffX - diffX // 2,
                        diffY // 2, diffY - diffY // 2])
        # if you have padding issues, see
        # https://github.com/HaiyongJiang/U-Net-Pytorch-Unstructured-Buggy/
 ↪commit/0e854509c2cea854e247a9c615f175f76fbb2e3a
        # https://github.com/xiaopeng-liao/Pytorch-UNet/commit/
 ↪8ebac70e633bac59fc22bb5195e513d5832fb3bd
        x = torch.cat([x2, x1], dim=1)
        return self.conv(x)

# Reference: https://github.com/milesial/Pytorch-UNet/blob/master/unet/
 ↪unet_parts.py
class OutConv(nn.Module):
    def __init__(self, in_channels, out_channels):
        super(OutConv, self).__init__()
        self.conv = nn.Conv2d(in_channels, out_channels, kernel_size=1)

    def forward(self, x):
```

```
        return F.sigmoid(self.conv(x))

# Reference: https://github.com/milesial/Pytorch-UNet/blob/master/unet/
 ↪unet_model.py
class UNet(nn.Module):
    def __init__(self, n_channels=1, n_classes=1, bilinear=True):
        super(UNet, self).__init__()
        self.n_channels = n_channels
        self.n_classes = n_classes
        self.bilinear = bilinear

        self.inc = DoubleConv(n_channels, 64)
        self.down1 = Down(64, 128)
        self.down2 = Down(128, 256)
        self.down3 = Down(256, 512)
        self.down4 = Down(512, 512)
        self.up1 = Up(1024, 256, bilinear)
        self.up2 = Up(512, 128, bilinear)
        self.up3 = Up(256, 64, bilinear)
        self.up4 = Up(128, 64, bilinear)
        self.outc = OutConv(64, n_classes)

    def forward(self, x):
        x1 = self.inc(x)
        x2 = self.down1(x1)
        x3 = self.down2(x2)
        x4 = self.down3(x3)
        x5 = self.down4(x4)
        x = self.up1(x5, x4)
        x = self.up2(x, x3)
        x = self.up3(x, x2)
        x = self.up4(x, x1)
        logits = self.outc(x)
        return logits

# Initialize
net = UNet().float().to(torch.device('cuda'))

summary(net, (1, 224, 224))
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 224, 224]             640
       BatchNorm2d-2         [-1, 64, 224, 224]             128
              ReLU-3         [-1, 64, 224, 224]               0
            Conv2d-4         [-1, 64, 224, 224]          36,928
```

BatchNorm2d-5	[-1, 64, 224, 224]	128
ReLU-6	[-1, 64, 224, 224]	0
DoubleConv-7	[-1, 64, 224, 224]	0
MaxPool2d-8	[-1, 64, 112, 112]	0
Conv2d-9	[-1, 128, 112, 112]	73,856
BatchNorm2d-10	[-1, 128, 112, 112]	256
ReLU-11	[-1, 128, 112, 112]	0
Conv2d-12	[-1, 128, 112, 112]	147,584
BatchNorm2d-13	[-1, 128, 112, 112]	256
ReLU-14	[-1, 128, 112, 112]	0
DoubleConv-15	[-1, 128, 112, 112]	0
Down-16	[-1, 128, 112, 112]	0
MaxPool2d-17	[-1, 128, 56, 56]	0
Conv2d-18	[-1, 256, 56, 56]	295,168
BatchNorm2d-19	[-1, 256, 56, 56]	512
ReLU-20	[-1, 256, 56, 56]	0
Conv2d-21	[-1, 256, 56, 56]	590,080
BatchNorm2d-22	[-1, 256, 56, 56]	512
ReLU-23	[-1, 256, 56, 56]	0
DoubleConv-24	[-1, 256, 56, 56]	0
Down-25	[-1, 256, 56, 56]	0
MaxPool2d-26	[-1, 256, 28, 28]	0
Conv2d-27	[-1, 512, 28, 28]	1,180,160
BatchNorm2d-28	[-1, 512, 28, 28]	1,024
ReLU-29	[-1, 512, 28, 28]	0
Conv2d-30	[-1, 512, 28, 28]	2,359,808
BatchNorm2d-31	[-1, 512, 28, 28]	1,024
ReLU-32	[-1, 512, 28, 28]	0
DoubleConv-33	[-1, 512, 28, 28]	0
Down-34	[-1, 512, 28, 28]	0
MaxPool2d-35	[-1, 512, 14, 14]	0
Conv2d-36	[-1, 512, 14, 14]	2,359,808
BatchNorm2d-37	[-1, 512, 14, 14]	1,024
ReLU-38	[-1, 512, 14, 14]	0
Conv2d-39	[-1, 512, 14, 14]	2,359,808
BatchNorm2d-40	[-1, 512, 14, 14]	1,024
ReLU-41	[-1, 512, 14, 14]	0
DoubleConv-42	[-1, 512, 14, 14]	0
Down-43	[-1, 512, 14, 14]	0
Upsample-44	[-1, 512, 28, 28]	0
Conv2d-45	[-1, 256, 28, 28]	2,359,552
BatchNorm2d-46	[-1, 256, 28, 28]	512
ReLU-47	[-1, 256, 28, 28]	0
Conv2d-48	[-1, 256, 28, 28]	590,080
BatchNorm2d-49	[-1, 256, 28, 28]	512
ReLU-50	[-1, 256, 28, 28]	0
DoubleConv-51	[-1, 256, 28, 28]	0
Up-52	[-1, 256, 28, 28]	0

```
          Upsample-53          [-1, 256, 56, 56]               0
            Conv2d-54          [-1, 128, 56, 56]         589,952
       BatchNorm2d-55          [-1, 128, 56, 56]             256
              ReLU-56          [-1, 128, 56, 56]               0
            Conv2d-57          [-1, 128, 56, 56]         147,584
       BatchNorm2d-58          [-1, 128, 56, 56]             256
              ReLU-59          [-1, 128, 56, 56]               0
        DoubleConv-60          [-1, 128, 56, 56]               0
                Up-61          [-1, 128, 56, 56]               0
          Upsample-62        [-1, 128, 112, 112]               0
            Conv2d-63         [-1, 64, 112, 112]         147,520
       BatchNorm2d-64         [-1, 64, 112, 112]             128
              ReLU-65         [-1, 64, 112, 112]               0
            Conv2d-66         [-1, 64, 112, 112]          36,928
       BatchNorm2d-67         [-1, 64, 112, 112]             128
              ReLU-68         [-1, 64, 112, 112]               0
        DoubleConv-69         [-1, 64, 112, 112]               0
                Up-70         [-1, 64, 112, 112]               0
          Upsample-71         [-1, 64, 224, 224]               0
            Conv2d-72         [-1, 64, 224, 224]          73,792
       BatchNorm2d-73         [-1, 64, 224, 224]             128
              ReLU-74         [-1, 64, 224, 224]               0
            Conv2d-75         [-1, 64, 224, 224]          36,928
       BatchNorm2d-76         [-1, 64, 224, 224]             128
              ReLU-77         [-1, 64, 224, 224]               0
        DoubleConv-78         [-1, 64, 224, 224]               0
                Up-79         [-1, 64, 224, 224]               0
            Conv2d-80          [-1, 1, 224, 224]              65
           OutConv-81          [-1, 1, 224, 224]               0
================================================================
Total params: 13,394,177
Trainable params: 13,394,177
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.19
Forward/backward pass size (MB): 689.06
Params size (MB): 51.09
Estimated Total Size (MB): 740.35
----------------------------------------------------------------

/home/fraser/environment_directory/pytorch_workspace/lib/python3.7/site-
packages/torch/nn/functional.py:1350: UserWarning: nn.functional.sigmoid is
deprecated. Use torch.sigmoid instead.
  warnings.warn("nn.functional.sigmoid is deprecated. Use torch.sigmoid
instead.")
```

[14]:
```
# h) Dice Score (DSC) and Dice loss
```

```
# dice_loss method
# returns 1 - DSC
# Reference: https://github.com/pytorch/pytorch/issues/1249
def dice_loss(inputs, target):

    smooth = 1.
    iflat = inputs.float().view(-1)
    tflat = target.float().view(-1)
    intersection = (iflat * tflat).sum()

    return 1 - ((2. * intersection + smooth) /
              (iflat.sum() + tflat.sum() + smooth))

# dice_metric
# returns the DSC
# Reference: https://github.com/pytorch/pytorch/issues/1249
def dice_metric(inputs, target):

    smooth = 1.
    iflat = inputs.float().view(-1)
    tflat = target.float().view(-1)
    intersection = (iflat * tflat).sum()

    return ((2. * intersection + smooth) /
              (iflat.sum() + tflat.sum() + smooth))
```

[17]:
```
# datasetEval method
# prints the mean DSC loss and DSC for a dataloader
def datasetEval(loader):
    with torch.no_grad():
        running_loss = 0.
        running_dice = 0.
        for i, data in enumerate(loader, 0):
            # get the inputs; data is a list of [inputs, labels]
            inputs, labels = data

            outputs = net(inputs.float().to(torch.device('cuda')))
            running_loss += dice_loss(outputs, labels.to(torch.device('cuda')))
            running_dice += dice_metric(outputs, labels.to(torch.
 ↪device('cuda')))

    loss = running_loss / len(loader)
    dice = running_dice / len(loader)
    print(('loss: %.3f dice: %.3f' % (loss, dice)))
```

[15]:
```
# Make the dataloaders
trainset = Promise12Dataset(train)
```

```
trainloader = torch.utils.data.DataLoader(trainset, batch_size=1,
                                          shuffle=True, num_workers=2)
validationset = Promise12Dataset(validation)
validationloader = torch.utils.data.DataLoader(validationset, batch_size=1,
                                          shuffle=True, num_workers=2)
testset = Promise12Dataset(test)
testloader = torch.utils.data.DataLoader(testset, batch_size=1,
                                          shuffle=True, num_workers=2)
# Gradient optimizers
optimizer = optim.Adam(net.parameters())
scheduler = optim.lr_scheduler.ReduceLROnPlateau(optimizer, mode='min')

print("Training ...")

# Metric variables
statsTr = []
val_dice = 0.
prev_val_dice = 0.
running_val_loss = 0.
running_val_dice = 0.
running_dice = 0.
running_loss = 0.

# Main training loop
for epoch in range(100):  # loop over the dataset multiple times

    # Train
    for i, data in enumerate(trainloader, 0):
        # get the inputs; data is a list of [inputs, labels]
        inputs, labels = data

        # zero the parameter gradients
        optimizer.zero_grad()

        # forward + backward + optimize
        outputs = net(inputs.float().to(torch.device('cuda')))
        loss = dice_loss(outputs, labels.to(torch.device('cuda')))
        loss.backward()
        optimizer.step()
        running_loss += loss.item()
        running_dice += dice_metric(outputs, labels.to(torch.device('cuda')))

    train_loss = running_loss / len(trainloader)
    train_dice = running_dice / len(trainloader)
    print(('[epoch %d] train_loss: %.3f ' % (epoch + 1, train_loss)).ljust(30,␣
↪' '), end='')
    running_loss = 0.
```

```
    running_dice = 0.

    # Validation
    with torch.no_grad():
        for i, data in enumerate(validationloader, 0):
            # get the inputs; data is a list of [inputs, labels]
            inputs, labels = data
            # forward + backward + optimize
            outputs = net(inputs.float().to(torch.device('cuda')))
            running_val_loss += dice_loss(outputs, labels.to(torch.
↪device('cuda')))
            running_val_dice += dice_metric(outputs, labels.to(torch.
↪device('cuda')))

    val_loss = running_val_loss / len(validationloader)
    val_dice = running_val_dice / len(validationloader)
    print(('val_loss: %.3f val_dice: %.3f' % (val_loss, val_dice)).rjust(30, '␣
↪'))
    running_val_loss = 0.
    running_val_dice = 0.

    # Learning rate reduction
    scheduler.step(val_loss)

    # Record metrics
    statsTr.append({'epoch': (epoch + 1), 'lossTr': train_loss,
                    'diceTr': train_dice, 'lossVa': val_loss, 'diceVa':␣
↪val_dice})

    # i) Early stopping
    if np.abs(val_dice.item() - prev_val_dice) < 0.00001:
        print("Early stopping")
        break

    prev_val_dice = val_dice.item()

print('Finished Training')
```

```
Training …
[epoch 1] train_loss: 0.485   val_loss: 0.266 val_dice: 0.734
[epoch 2] train_loss: 0.191   val_loss: 0.178 val_dice: 0.822
[epoch 3] train_loss: 0.152   val_loss: 0.199 val_dice: 0.801
[epoch 4] train_loss: 0.124   val_loss: 0.196 val_dice: 0.804
[epoch 5] train_loss: 0.116   val_loss: 0.153 val_dice: 0.847
[epoch 6] train_loss: 0.105   val_loss: 0.164 val_dice: 0.836
[epoch 7] train_loss: 0.107   val_loss: 0.164 val_dice: 0.836
[epoch 8] train_loss: 0.100   val_loss: 0.160 val_dice: 0.840
```

```
[epoch 9] train_loss: 0.091   val_loss: 0.126 val_dice: 0.874
[epoch 10] train_loss: 0.081  val_loss: 0.125 val_dice: 0.875
[epoch 11] train_loss: 0.080  val_loss: 0.127 val_dice: 0.873
[epoch 12] train_loss: 0.072  val_loss: 0.161 val_dice: 0.839
[epoch 13] train_loss: 0.069  val_loss: 0.118 val_dice: 0.882
[epoch 14] train_loss: 0.062  val_loss: 0.124 val_dice: 0.876
[epoch 15] train_loss: 0.057  val_loss: 0.135 val_dice: 0.865
[epoch 16] train_loss: 0.078  val_loss: 0.120 val_dice: 0.880
[epoch 17] train_loss: 0.060  val_loss: 0.119 val_dice: 0.881
[epoch 18] train_loss: 0.054  val_loss: 0.116 val_dice: 0.884
[epoch 19] train_loss: 0.076  val_loss: 0.118 val_dice: 0.882
[epoch 20] train_loss: 0.051  val_loss: 0.117 val_dice: 0.883
[epoch 21] train_loss: 0.046  val_loss: 0.113 val_dice: 0.887
[epoch 22] train_loss: 0.046  val_loss: 0.110 val_dice: 0.890
[epoch 23] train_loss: 0.048  val_loss: 0.130 val_dice: 0.870
[epoch 24] train_loss: 0.048  val_loss: 0.112 val_dice: 0.888
[epoch 25] train_loss: 0.042  val_loss: 0.118 val_dice: 0.882
[epoch 26] train_loss: 0.048  val_loss: 0.097 val_dice: 0.903
[epoch 27] train_loss: 0.041  val_loss: 0.107 val_dice: 0.893
[epoch 28] train_loss: 0.049  val_loss: 0.113 val_dice: 0.887
[epoch 29] train_loss: 0.040  val_loss: 0.099 val_dice: 0.901
[epoch 30] train_loss: 0.038  val_loss: 0.109 val_dice: 0.891
[epoch 31] train_loss: 0.040  val_loss: 0.100 val_dice: 0.900
[epoch 32] train_loss: 0.037  val_loss: 0.090 val_dice: 0.910
[epoch 33] train_loss: 0.035  val_loss: 0.105 val_dice: 0.895
[epoch 34] train_loss: 0.036  val_loss: 0.103 val_dice: 0.897
[epoch 35] train_loss: 0.034  val_loss: 0.107 val_dice: 0.893
[epoch 36] train_loss: 0.033  val_loss: 0.106 val_dice: 0.894
[epoch 37] train_loss: 0.031  val_loss: 0.107 val_dice: 0.893
[epoch 38] train_loss: 0.034  val_loss: 0.132 val_dice: 0.868
[epoch 39] train_loss: 0.051  val_loss: 0.113 val_dice: 0.887
[epoch 40] train_loss: 0.034  val_loss: 0.096 val_dice: 0.904
[epoch 41] train_loss: 0.029  val_loss: 0.093 val_dice: 0.907
[epoch 42] train_loss: 0.028  val_loss: 0.095 val_dice: 0.905
[epoch 43] train_loss: 0.029  val_loss: 0.096 val_dice: 0.904
[epoch 44] train_loss: 0.024  val_loss: 0.091 val_dice: 0.909
[epoch 45] train_loss: 0.022  val_loss: 0.093 val_dice: 0.907
[epoch 46] train_loss: 0.021  val_loss: 0.092 val_dice: 0.908
[epoch 47] train_loss: 0.020  val_loss: 0.094 val_dice: 0.906
[epoch 48] train_loss: 0.020  val_loss: 0.093 val_dice: 0.907
[epoch 49] train_loss: 0.019  val_loss: 0.095 val_dice: 0.905
[epoch 50] train_loss: 0.019  val_loss: 0.094 val_dice: 0.906
[epoch 51] train_loss: 0.018  val_loss: 0.094 val_dice: 0.906
[epoch 52] train_loss: 0.018  val_loss: 0.096 val_dice: 0.904
[epoch 53] train_loss: 0.018  val_loss: 0.094 val_dice: 0.906
[epoch 54] train_loss: 0.017  val_loss: 0.096 val_dice: 0.904
[epoch 55] train_loss: 0.017  val_loss: 0.096 val_dice: 0.904
[epoch 56] train_loss: 0.017  val_loss: 0.095 val_dice: 0.905
```

```
[epoch 57] train_loss: 0.016  val_loss: 0.095 val_dice: 0.905
[epoch 58] train_loss: 0.016  val_loss: 0.095 val_dice: 0.905
[epoch 59] train_loss: 0.016  val_loss: 0.096 val_dice: 0.904
[epoch 60] train_loss: 0.016  val_loss: 0.096 val_dice: 0.904
[epoch 61] train_loss: 0.016  val_loss: 0.096 val_dice: 0.904
[epoch 62] train_loss: 0.016  val_loss: 0.096 val_dice: 0.904
[epoch 63] train_loss: 0.016  val_loss: 0.096 val_dice: 0.904
Early stopping
Finished Training
```

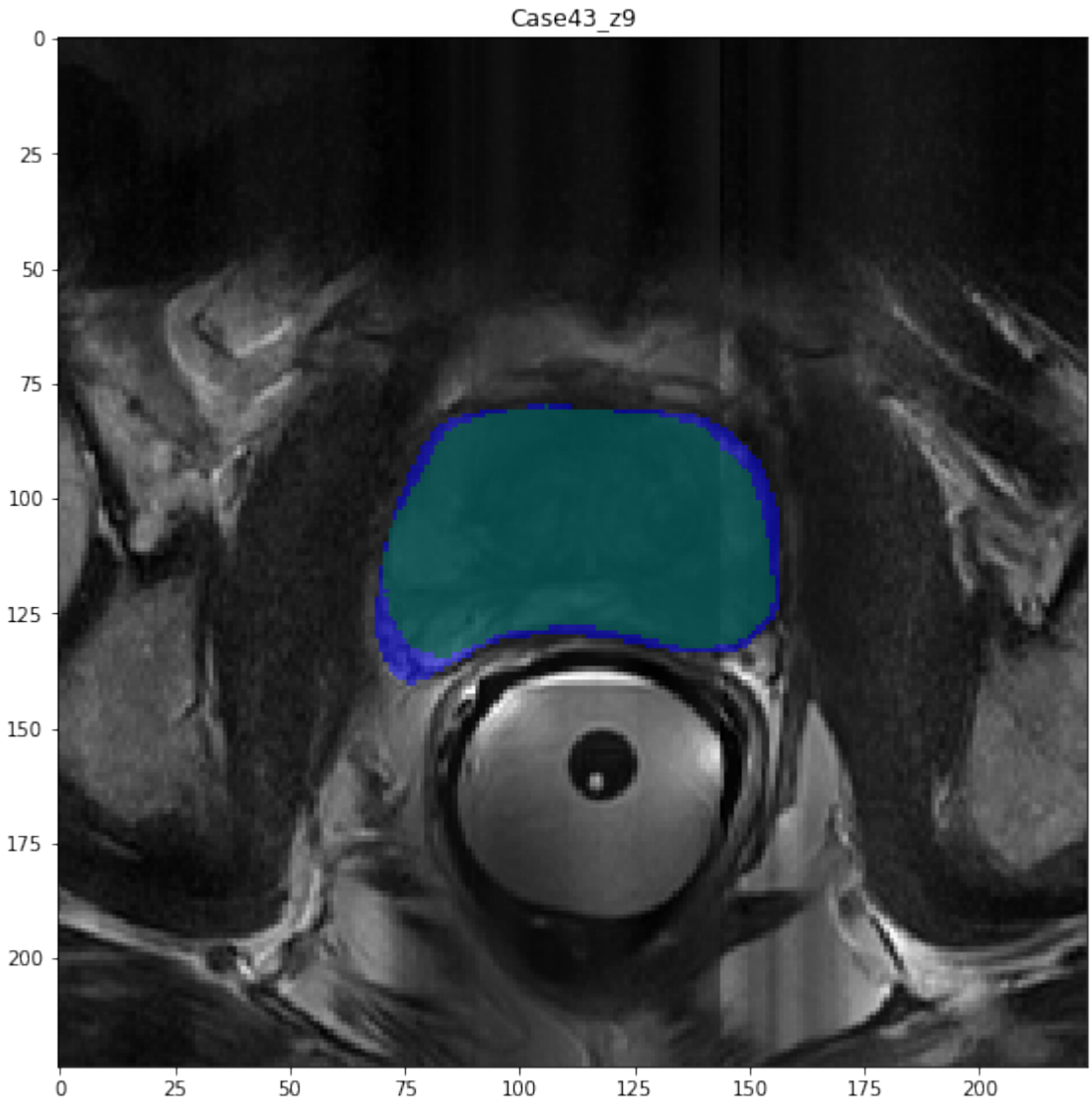
[18]:
```
# Write the metric table to file
statsDf = pd.DataFrame(statsTr)
statsDf['diceTr'] = statsDf['diceTr'].apply(lambda x: x.to(torch.
 ↪device('cuda')).item())
statsDf['lossVa'] = statsDf['lossVa'].apply(lambda x: x.to(torch.
 ↪device('cuda')).item())
statsDf['diceVa'] = statsDf['diceVa'].apply(lambda x: x.to(torch.
 ↪device('cuda')).item())
statsDf.to_csv('metricsTr.csv')

# j) Get mean metrics for train, validation and test sets
# Train
print("Train mean:")
datasetEval(trainloader)
# Val
print("Validation mean:")
datasetEval(validationloader)
# Test
print("Test mean:")
datasetEval(testloader)
```

```
Train mean:
loss: 0.016 dice: 0.984
Validation mean:
loss: 0.096 dice: 0.904
Test mean:
loss: 0.091 dice: 0.909
```

[52]:
```
# k) Largest label area of the case from part A
sumIntensities = [np.load(os.path.join(labelsTr,fname)).sum() for fname in␣
 ↪case43]
filen = case43[np.argmax(sumIntensities)]
print(filen)

with torch.no_grad():
    case43_out = net(torch.tensor([np.load(os.path.join(imagesTr, filen))[np.
 ↪newaxis, ...]],
```

```
                                    device=torch.device('cuda')).float())

green = ListedColormap(['green'])
blue = ListedColormap(['blue'])
def getLabelMask(npyA):
    labelA = npyA.astype(int)
    return np.ma.masked_where(labelA == 0., labelA)

plt.figure(figsize=(9.6,9.6))
plt.subplot(111)
plt.imshow(np.load(os.path.join(imagesTr, filen)), cmap='gray')
plt.imshow(getLabelMask(np.load(os.path.join(labelsTr, filen))), cmap=blue,␣
 ↪alpha=0.5)
plt.imshow(getLabelMask(case43_out.squeeze().cpu().numpy()), cmap=green,␣
 ↪alpha=0.5)
plt.title(filen.split('.')[0])
plt.savefig("case43", format='png')
```

Case43_z9.npy


Case43_z9
0
25
50
75
100
125
150
175
200
0
25
50
75
100
125
150
175
200