unet-kl

November 9, 2022

0.1 prepare data

20 subjects in total, 18 will be used for training and validation, 2 will be used for independent testing raw images in nifti format, conver to png format, in order to use the existing augmentation solution.

[2]:
```
import os
import numpy as np
import nibabel as nib
import matplotlib.pyplot as plt
import torch.nn as nn
from PIL import Image
```

[3]:
```
from fastai.data.all import *
from fastai.vision.all import *
```

[4]:
```
#nii folder has orig/label images in nifti format, orig and label would have␣
 ↪corresponding images in png formats
train_path = Path('./data/train/')
test_path = Path('./data/test/')
```

[5]:
```
def nii2png(nii_path, png_path_orig, png_path_label):
    '''convert nii images to png files, and save original images to␣
 ↪png_path_orig, and labeled  images to png_path_label'''
    os.system('if [ ! -d {imgdir} ]; then mkdir -p {imgdir} ; fi;'.
 ↪format(imgdir = png_path_orig))
    os.system('if [ ! -d {imgdir} ]; then mkdir -p {imgdir} ; fi;'.
 ↪format(imgdir = png_path_label))

    nifti_images = sorted(get_files(nii_path,extensions='.gz')) #all nifti␣
 ↪images under folder: data/train/nii

    label_images = nifti_images[::2]
    raw_images = nifti_images[1::2]


    for (raw,label) in zip(raw_images, label_images):
        sub_name = raw.stem[:10] #substr, e.g., ircad_e01_
```

```
        raw_data = nib.load(raw,).get_fdata().astype(np.uint8) #intensity␣
 ↪within [0.255]
        label_data = nib.load(label).get_fdata().astype(np.uint8)

        assert raw_data.shape == label_data.shape

        print('working on subject : {}'.format(sub_name[:-1]))
        for idx in range(raw_data.shape[2]):
            orig_name = sub_name + '{:03}.png'.format(idx) #e.g., ircad_e01_000.
 ↪png
            label_name = sub_name + '{:03}L.png'.format(idx) #e.g.,␣
 ↪ircad_e01_000L.png
            Image.fromarray(raw_data[:,:,idx]).save(png_path_orig/orig_name)
            Image.fromarray(label_data[:,:,idx]).save(png_path_label/label_name)
```

[5]:
```
# for training and validation;
nii2png(nii_path = train_path/'nii',png_path_orig = train_path/'orig',␣
 ↪png_path_label=train_path/'label')
```

```
working on subject : ircad_e01
working on subject : ircad_e02
working on subject : ircad_e03
working on subject : ircad_e04
working on subject : ircad_e05
working on subject : ircad_e06
working on subject : ircad_e07
working on subject : ircad_e08
working on subject : ircad_e09
working on subject : ircad_e10
working on subject : ircad_e11
working on subject : ircad_e12
working on subject : ircad_e13
working on subject : ircad_e14
working on subject : ircad_e15
working on subject : ircad_e16
working on subject : ircad_e17
working on subject : ircad_e18
```

[6]:
```
# for independent testing;
nii2png(nii_path = test_path/'nii',png_path_orig = test_path/'orig',␣
 ↪png_path_label=test_path/'label')
```

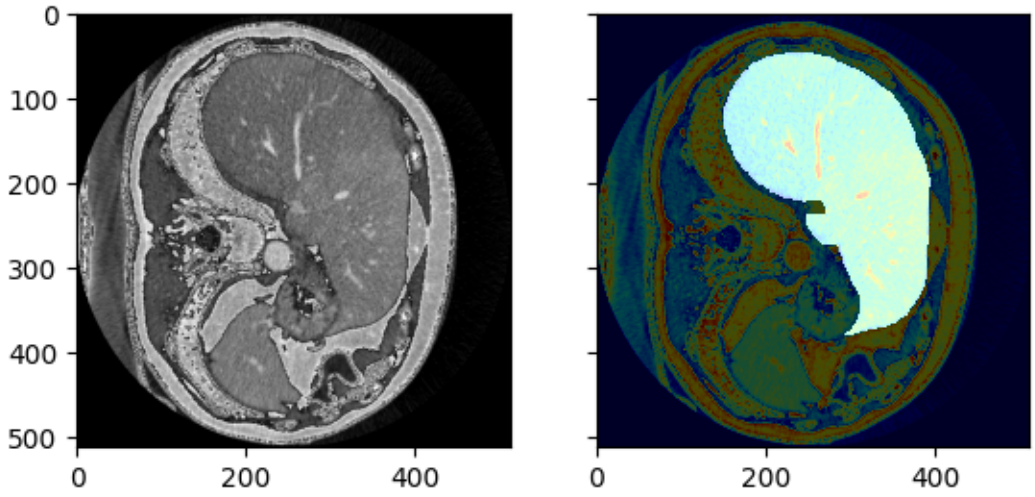
```
working on subject : ircad_e19
working on subject : ircad_e20
```

0.2 verify images

[7]:
```
def show_pair_overlay(seg, raw, alpha = 0.7):
    f, (ax1, ax2) = plt.subplots(1, 2, sharey=True)
    ax1.imshow(raw, cmap='gray')
    ax2.imshow(raw, cmap='jet')
    ax2.imshow(seg, cmap='gray', interpolation='none', alpha=alpha)
    return f, (ax1, ax2)
```

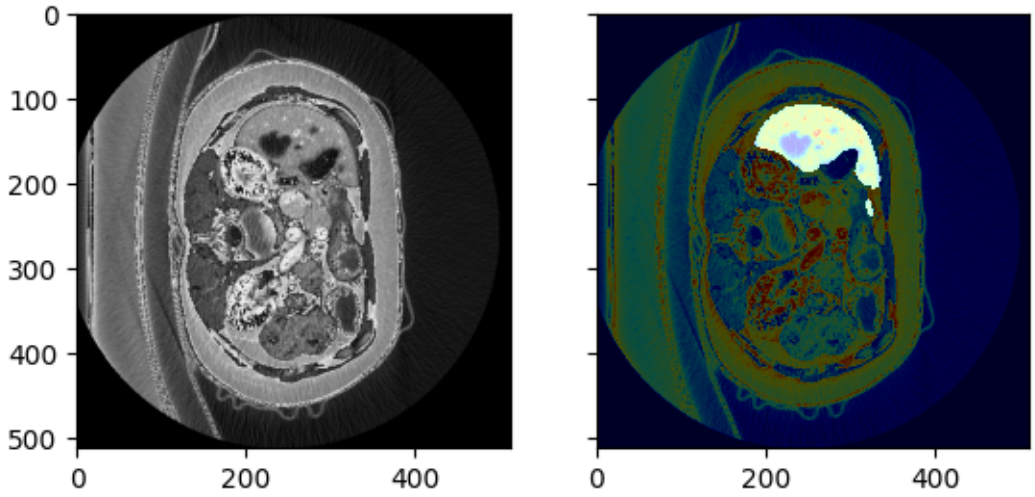
[8]:
```
#verify training dataset
orig = Image.open('data/train/orig/ircad_e01_104.png');
label = Image.open('data/train/label/ircad_e01_104L.png')
show_pair_overlay(label, orig, alpha = 0.7)
```

[8]: (<Figure size 640x480 with 2 Axes>, (<AxesSubplot: >, <AxesSubplot: >))



[9]:
```
#verify testing dataset
orig = Image.open('data/test/orig/ircad_e19_041.png');
label = Image.open('data/test/label/ircad_e19_041L.png')
show_pair_overlay(label, orig, alpha = 0.7)
```

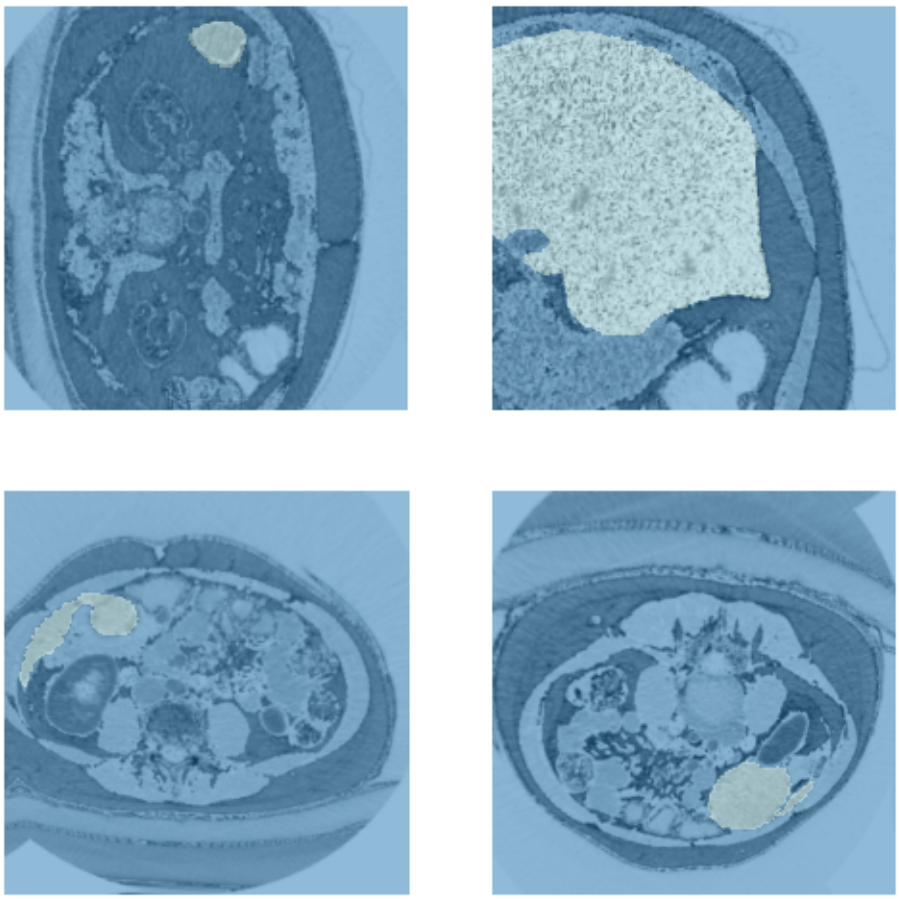
[9]: (<Figure size 640x480 with 2 Axes>, (<AxesSubplot: >, <AxesSubplot: >))



0.3 DataLoaders

[6]:
```
path = Path('./')
dls = SegmentationDataLoaders.from_label_func(
    path, bs=4, fnames = get_image_files(path/'data/train/orig'),
    label_func = lambda o: path/'data/train/label'/f'{o.stem}L{o.suffix}',␣
 ↪#liver images are put at data/label, with 'L' appended to the original name
    img_cls=PILImageBW,#only one channel, gray, not rgb;
    item_tfms=RandomResizedCrop(256, min_scale=0.3), # works on each pair of␣
 ↪(orig,label)
    batch_tfms=aug_transforms(flip_vert=True) # works on each batch
)
```

[6]:
```
dls.show_batch()
```



[35]:
```
#check batch dims
x,y = dls.train.one_batch()
x.shape, y.shape
```

[35]:
```
(torch.Size([4, 1, 256, 256]), torch.Size([4, 256, 256]))
```

0.4 unet with pretrained resnet

[8]:
```
loss_func = CrossEntropyLossFlat(axis=1) #softmax over the channel dim
learn = unet_learner(dls, resnet34, n_in = 1, n_out=2, opt_func = Adam,␣
 ↪loss_func = loss_func, metrics=Dice())
```

[16]:
```
learn.model
```

[16]:
```
DynamicUnet(
  (layers): ModuleList(
    (0): Sequential(
      (0): Conv2d(1, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3),
```

```
bias=False)
      (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (2): ReLU(inplace=True)
      (3): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1,
ceil_mode=False)
      (4): 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)
        )
        (2): 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)
        )
      )
      (5): 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)
        )
        (2): 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)
        )
        (3): 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)
        )
      )
      (6): 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)
        )
        (2): 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)
        )
        (3): 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)
```

```
        )
        (4): 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)
        )
        (5): 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)
        )
      )
      (7): 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)
        )
        (2): 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)
        )
      )
    )
    (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (2): ReLU()
    (3): Sequential(
      (0): ConvLayer(
        (0): Conv2d(512, 1024, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
        (1): ReLU()
      )
      (1): ConvLayer(
        (0): Conv2d(1024, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
        (1): ReLU()
      )
    )
    (4): UnetBlock(
      (shuf): PixelShuffle_ICNR(
        (0): ConvLayer(
          (0): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1))
          (1): ReLU()
        )
        (1): PixelShuffle(upscale_factor=2)
      )
      (bn): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv1): ConvLayer(
        (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
```

```
      (conv2): ConvLayer(
        (0): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (relu): ReLU()
    )
    (5): UnetBlock(
      (shuf): PixelShuffle_ICNR(
        (0): ConvLayer(
          (0): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1))
          (1): ReLU()
        )
        (1): PixelShuffle(upscale_factor=2)
      )
      (bn): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv1): ConvLayer(
        (0): Conv2d(384, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (conv2): ConvLayer(
        (0): Conv2d(384, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (relu): ReLU()
    )
    (6): UnetBlock(
      (shuf): PixelShuffle_ICNR(
        (0): ConvLayer(
          (0): Conv2d(384, 768, kernel_size=(1, 1), stride=(1, 1))
          (1): ReLU()
        )
        (1): PixelShuffle(upscale_factor=2)
      )
      (bn): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv1): ConvLayer(
        (0): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (conv2): ConvLayer(
        (0): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (relu): ReLU()
    )
    (7): UnetBlock(
```

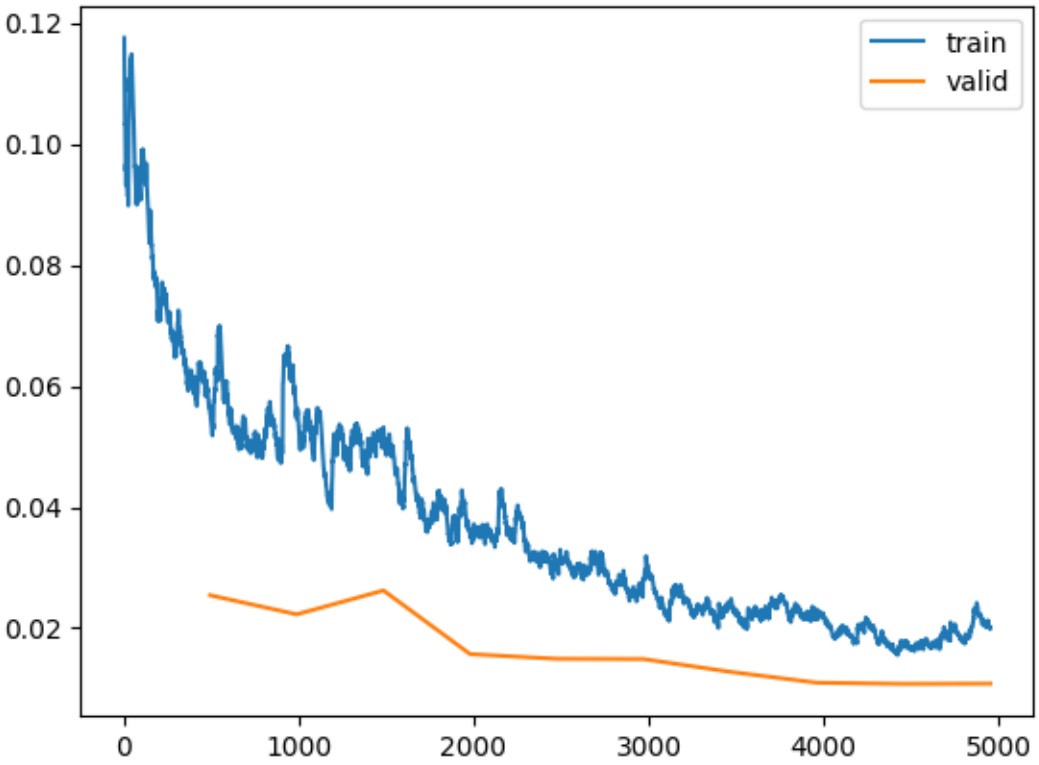
```
      (shuf): PixelShuffle_ICNR(
        (0): ConvLayer(
          (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1))
          (1): ReLU()
        )
        (1): PixelShuffle(upscale_factor=2)
      )
      (bn): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv1): ConvLayer(
        (0): Conv2d(192, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (conv2): ConvLayer(
        (0): Conv2d(96, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        (1): ReLU()
      )
      (relu): ReLU()
    )
    (8): PixelShuffle_ICNR(
      (0): ConvLayer(
        (0): Conv2d(96, 384, kernel_size=(1, 1), stride=(1, 1))
        (1): ReLU()
      )
      (1): PixelShuffle(upscale_factor=2)
    )
    (9): ResizeToOrig()
    (10): MergeLayer()
    (11): ResBlock(
      (convpath): Sequential(
        (0): ConvLayer(
          (0): Conv2d(97, 97, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
          (1): ReLU()
        )
        (1): ConvLayer(
          (0): Conv2d(97, 97, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
        )
      )
      (idpath): Sequential()
      (act): ReLU(inplace=True)
    )
    (12): ConvLayer(
      (0): Conv2d(97, 2, kernel_size=(1, 1), stride=(1, 1))
    )
    (13): fastai.layers.ToTensorBase(tensor_cls=<class
'fastai.torch_core.TensorBase'>)
  )
```

```
)
```

[9]:
```
learn.fine_tune(10)
```

```
<IPython.core.display.HTML object>
<IPython.core.display.HTML object>
<IPython.core.display.HTML object>
<IPython.core.display.HTML object>
```

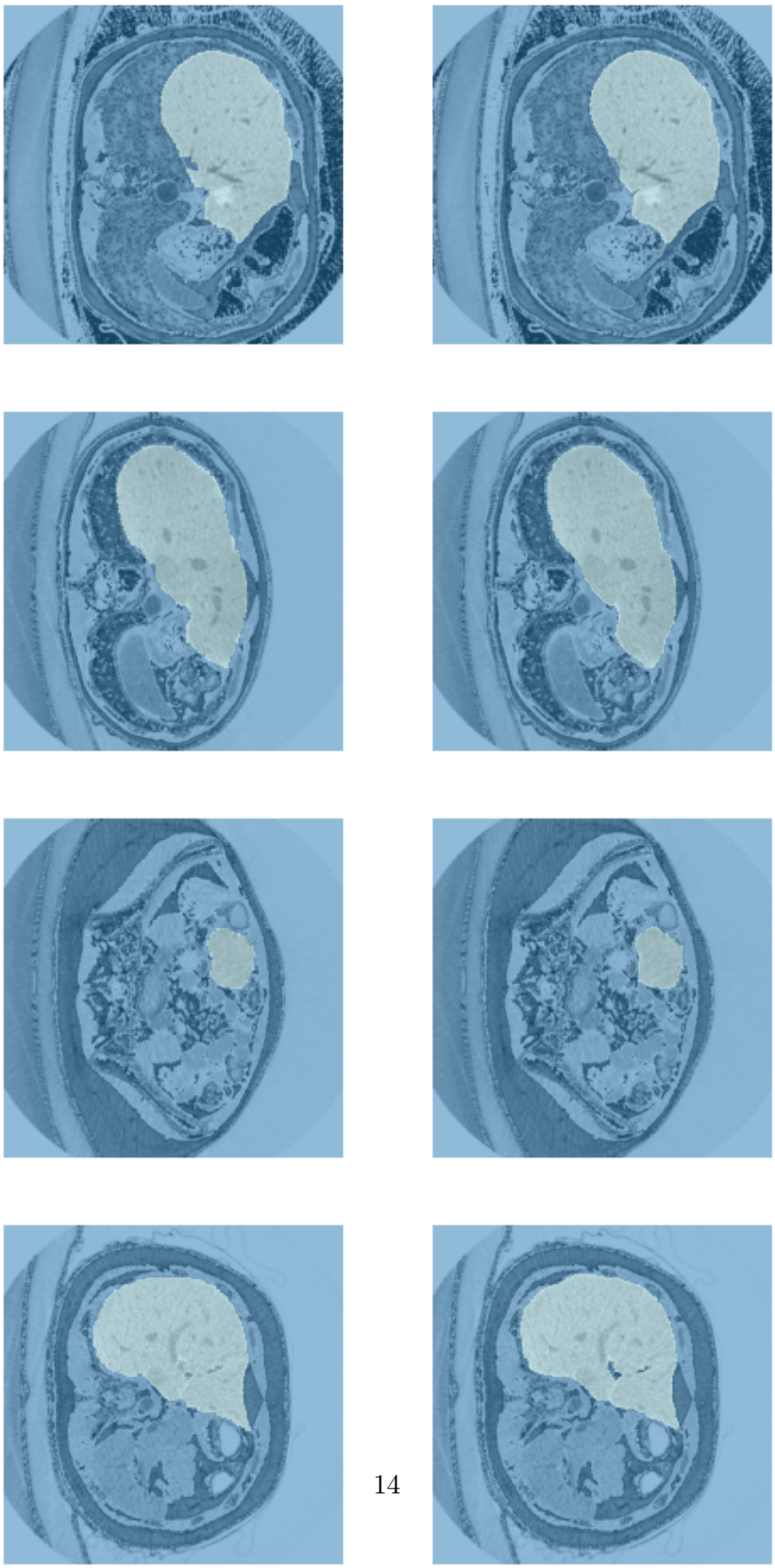
[145]:
```
learn.recorder.plot_loss() #seems to converge and a few more epochs would be
↪better.
```



[23]:
```
learn.show_results()
```

```
<IPython.core.display.HTML object>
<IPython.core.display.HTML object>
```

Target/Prediction



[12]:
```
mdl_name = 'unet-resnet34-liverseg'
```

[11]:
```
learn.save(mdl_name) # target: path/models/mdl_name
```

[11]:
```
Path('models/unet-resnet34-liverseg.pth')
```

0.5 predict on independent testing dataset

[24]:
```
def dice_coef(y_true, y_pred, eps=1e-8):
    y_true_f = torch.flatten(y_true)
    y_pred_f = torch.flatten(y_pred)
    intersection = torch.sum(y_true_f * y_pred_f)
    return ((2. * intersection + eps) / (torch.sum(y_true_f) + torch.
 ↪sum(y_pred_f) + eps)).item()
```

[10]:
```
path = Path('./')
dlsT = SegmentationDataLoaders.from_label_func(
    path, bs=4, fnames = get_image_files(path/'data/test/orig'),
    valid_pct = 0.99, #
    label_func = lambda o: path/'data/test/label'/f'{o.stem}L{o.suffix}',
    img_cls=PILImageBW,#only one channel, gray, not rgb;
    #item_tfms=Resize(256, method=ResizeMethod.Squish), # change to this resize␣
 ↪reduces the performance slightly
    item_tfms=RandomResizedCrop(256, min_scale=0.3), # works on each pair of␣
 ↪(orig,label)
)
```

[13]:
```
loss_func = CrossEntropyLossFlat(axis=1) #softmax over the channel dim
test = unet_learner(dlsT, resnet34, n_in = 1, n_out=2, opt_func = Adam,␣
 ↪loss_func = loss_func, metrics=Dice()) #
test.load(mdl_name)
```

[13]:
```
<fastai.learner.Learner at 0x7f9f82dda3d0>
```

[8]:
```
test.freeze()
```

[9]:
```
_, test_dice = test.validate()
print('independent testing subjects, dice: {:6f}'.format(test_dice))
```

```
<IPython.core.display.HTML object>
```

```
<IPython.core.display.HTML object>
```

```
independent testing subjects, dice: 0.951924
```

[38]:
```
test.show_results()
```

```
<IPython.core.display.HTML object>
```

```
<IPython.core.display.HTML object>
```

Target/Prediction