

```
Automated_Nerves_Quantification (/github/IA92/Automated_Nerves_Quantification/tree/main)
/
Nerves Segmentation Demo.ipynb (/github/IA92/Automated_Nerves_Quantification/tree/main/Nerves Segmentation Demo.ipynb)
```

Nerves Segmentation

Importing libraries

Importing libraries to access directory, to load image, to use array, to plot, to process image, and generate random variables

In [1]:

```
import os, cv2, csv, random, time
from pathlib import Path
from os import listdir
from os.path import isfile, join
import openslide
import numpy as np
import matplotlib.pyplot as plt
from skimage.morphology import binary_closing, binary_opening, binary_dilation, binary_
from skimage.color import rgb2hsv
from skimage.transform import resize
from PIL import Image, ImageDraw
import scipy.misc
from itertools import combinations, permutations

import keras
from keras import backend as K
from keras.utils.data_utils import get_file
from keras.models import Sequential, Model
from keras.layers.core import Flatten, Dense, Dropout, Lambda, Reshape
from keras.layers import Input, LeakyReLU, Dense, Layer, LocallyConnected1D, Activation
from keras.layers.convolutional import Convolution2D, MaxPooling2D, ZeroPadding2D, Average
from keras.layers import Conv1D, Conv2D, Conv3D, Conv2DTranspose, ConvLSTM2D, SimpleRNN,
from keras.layers import UpSampling2D, merge, Reshape
from keras.optimizers import SGD, RMSprop, Adam
from keras.preprocessing import image
from keras.layers.normalization import BatchNormalization
from keras import optimizers
from keras import regularizers
from keras.engine import InputLayer
from keras.callbacks import ModelCheckpoint
```

```
C:\Users\Indri92\Anaconda3\envs\tfgpu\lib\site-packages\h5py\__init__.py:36: FutureWarning
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

Importing Functions

In [2]:

```
from utils import getRowsFromCSV,extractBBWithSizeTh,paddedMorphologicalOperation,boxOv
from utils import filterColourRange,drawPredBoxOnImage
from utils import scoringRoiWrtAnnot,combineBoxes,processCC
from utils import saveImageToJpg, savingCSVFile,boundingBoxOnWSI,saveImageFromRoiPatche

from preprocessing import preprocessListWSI
from model import get_dLB
from predict import roiListToSetPatchesWithLabel,buildingImageFromRoiPatchesSet,predPat

```

Listing Training, Validation and Testing Files

In [3]:

```
demoFiles=['10039','10097','10114']
print("Number of demo files is "+str(len(demoFiles)))

testingFiles=['10012', '10023', '10029', '10036','10039', '10049', '10064', '10067',
              '10071', '10072', '10073', '10078', '10087', '10088', '10093',
              '10096', '10097', '10102', '10113', '10114', '10116', '10121']
print("Number of testing files is "+str(len(testingFiles)))
```

Number of demo files is 3
 Number of testing files is 22

Defining Path for Source Files

In [4]:

```
fileDir=os.path.join(os.getcwd(),"dataFiles")
slicePath=os.path.join(fileDir,"svs files")

#annotFile.csv consists of fileName and bounding box coordinate [x, y, w, h] of the ann
annotPath=os.path.join(fileDir,"annot csv")

#sArea.csv consists of fileName and bounding box coordinate [x, y, w, h] of the slide a
sArea=getRowsFromCSV(os.path.join(fileDir,"sArea.csv"),'Dict')
```

Defining Mean and Std

In [5]:

```
pxlToUm=0.5036
xTrainMean=np.array([2.13762123e+02, 2.07595257e+02, 2.03273641e+02])
xTrainStd=np.array([36.67175097, 39.33090933, 42.27675675])
```

Loading model DL-B

In [6]:

```
#input pretrained model path
pretrainedModelPath=os.path.join(fileDir,"pretrained models","pretrained_DL-B.h5")
#Load model
model=get_dLB((160,160), chN=3, lr = 1e-4, loss='binary_crossentropy', metrics=['accuracy'])

#Displaying model architecture summary
model.summary()

```

D:\UniData\Projects\NervesSegmentationProject\model.py:151: UserWarning: Update your `Model` call
model = Model(input = inputs, output = [finalLayer,fc1c])

Model loaded: D:\UniData\Projects\NervesSegmentationProject\dataFiles\pretrained models

Layer (type)	Output Shape	Param #	Connected to
input_1 (InputLayer)	(None, 160, 160, 3)	0	
batch_normalization_1 (BatchNormalization)	(None, 160, 160, 3)	12	input_1[0][0]
conv2d_1 (Conv2D)	(None, 160, 160, 16)	448	batch_normalization_1[0][0]
batch_normalization_2 (BatchNormalization)	(None, 160, 160, 16)	64	conv2d_1[0][0]
activation_1 (Activation)	(None, 160, 160, 16)	0	batch_normalization_2[0][0]
conv2d_2 (Conv2D)	(None, 160, 160, 16)	2320	activation_1[0][0]
batch_normalization_3 (BatchNormalization)	(None, 160, 160, 16)	64	conv2d_2[0][0]
activation_2 (Activation)	(None, 160, 160, 16)	0	batch_normalization_3[0][0]
concatenate_1 (Concatenate)	(None, 160, 160, 32)	0	activation_1[0][0] activation_2[0][0]
average_pooling2d_1 (AveragePooling2D)	(None, 80, 80, 32)	0	concatenate_1[0][0]
conv2d_3 (Conv2D)	(None, 80, 80, 32)	9248	average_pooling2d_1[0][0]
batch_normalization_4 (BatchNormalization)	(None, 80, 80, 32)	128	conv2d_3[0][0]
activation_3 (Activation)	(None, 80, 80, 32)	0	batch_normalization_4[0][0]
conv2d_4 (Conv2D)	(None, 80, 80, 32)	9248	activation_3[0][0]
batch_normalization_5 (BatchNormalization)	(None, 80, 80, 32)	128	conv2d_4[0][0]
activation_4 (Activation)	(None, 80, 80, 32)	0	batch_normalization_5[0][0]
concatenate_2 (Concatenate)	(None, 80, 80, 64)	0	activation_3[0][0] activation_4[0][0]
average_pooling2d_2 (AveragePooling2D)	(None, 40, 40, 64)	0	concatenate_2[0][0]
conv2d_5 (Conv2D)	(None, 40, 40, 64)	36928	average_pooling2d_2[0][0]
batch_normalization_6 (BatchNormalization)	(None, 40, 40, 64)	256	conv2d_5[0][0]
activation_5 (Activation)	(None, 40, 40, 64)	0	batch_normalization_6[0][0]
conv2d_6 (Conv2D)	(None, 40, 40, 64)	36928	activation_5[0][0]
batch_normalization_7 (BatchNormalization)	(None, 40, 40, 64)	256	conv2d_6[0][0]

activation_6 (Activation)	(None, 40, 40, 64)	0	batch_normalization_7[0][0]
concatenate_3 (Concatenate)	(None, 40, 40, 128)	0	activation_5[0][0] activation_6[0][0]
average_pooling2d_3 (AveragePooling2D)	(None, 20, 20, 128)	0	concatenate_3[0][0]
conv2d_7 (Conv2D)	(None, 20, 20, 128)	147584	average_pooling2d_3[0][0]
batch_normalization_8 (BatchNormalization)	(None, 20, 20, 128)	512	conv2d_7[0][0]
activation_7 (Activation)	(None, 20, 20, 128)	0	batch_normalization_8[0][0]
conv2d_8 (Conv2D)	(None, 20, 20, 128)	147584	activation_7[0][0]
batch_normalization_9 (BatchNormalization)	(None, 20, 20, 128)	512	conv2d_8[0][0]
activation_8 (Activation)	(None, 20, 20, 128)	0	batch_normalization_9[0][0]
concatenate_4 (Concatenate)	(None, 20, 20, 256)	0	activation_7[0][0] activation_8[0][0]
dropout_1 (Dropout)	(None, 20, 20, 256)	0	concatenate_4[0][0]
average_pooling2d_4 (AveragePooling2D)	(None, 10, 10, 256)	0	dropout_1[0][0]
conv2d_9 (Conv2D)	(None, 10, 10, 256)	590080	average_pooling2d_4[0][0]
batch_normalization_10 (BatchNormalization)	(None, 10, 10, 256)	1024	conv2d_9[0][0]
activation_9 (Activation)	(None, 10, 10, 256)	0	batch_normalization_10[0][0]
conv2d_10 (Conv2D)	(None, 10, 10, 256)	590080	activation_9[0][0]
batch_normalization_11 (BatchNormalization)	(None, 10, 10, 256)	1024	conv2d_10[0][0]
activation_10 (Activation)	(None, 10, 10, 256)	0	batch_normalization_11[0][0]
concatenate_5 (Concatenate)	(None, 10, 10, 512)	0	activation_9[0][0] activation_10[0][0]
dropout_2 (Dropout)	(None, 10, 10, 512)	0	concatenate_5[0][0]
up_sampling2d_1 (UpSampling2D)	(None, 20, 20, 512)	0	dropout_2[0][0]
conv2d_12 (Conv2D)	(None, 20, 20, 128)	262272	up_sampling2d_1[0][0]
batch_normalization_13 (BatchNormalization)	(None, 20, 20, 128)	512	conv2d_12[0][0]
activation_12 (Activation)	(None, 20, 20, 128)	0	batch_normalization_13[0][0]
concatenate_6 (Concatenate)	(None, 20, 20, 384)	0	concatenate_4[0][0] activation_12[0][0]
conv2d_13 (Conv2D)	(None, 20, 20, 128)	442496	concatenate_6[0][0]
batch_normalization_14 (BatchNormalization)	(None, 20, 20, 128)	512	conv2d_13[0][0]
activation_13 (Activation)	(None, 20, 20, 128)	0	batch_normalization_14[0][0]
conv2d_14 (Conv2D)	(None, 20, 20, 128)	147584	activation_13[0][0]
batch_normalization_15 (BatchNormalization)	(None, 20, 20, 128)	512	conv2d_14[0][0]

activation_14 (Activation)	(None, 20, 20, 128) 0	batch_normalization_15[0][0]
concatenate_7 (Concatenate)	(None, 20, 20, 256) 0	activation_13[0][0] activation_14[0][0]
up_sampling2d_2 (UpSampling2D)	(None, 40, 40, 256) 0	concatenate_7[0][0]
conv2d_15 (Conv2D)	(None, 40, 40, 64) 65600	up_sampling2d_2[0][0]
batch_normalization_16 (BatchNormalisation2D)	(None, 40, 40, 64) 256	conv2d_15[0][0]
activation_15 (Activation)	(None, 40, 40, 64) 0	batch_normalization_16[0][0]
concatenate_8 (Concatenate)	(None, 40, 40, 192) 0	concatenate_3[0][0] activation_15[0][0]
conv2d_16 (Conv2D)	(None, 40, 40, 64) 110656	concatenate_8[0][0]
batch_normalization_17 (BatchNormalisation2D)	(None, 40, 40, 64) 256	conv2d_16[0][0]
activation_16 (Activation)	(None, 40, 40, 64) 0	batch_normalization_17[0][0]
conv2d_17 (Conv2D)	(None, 40, 40, 64) 36928	activation_16[0][0]
batch_normalization_18 (BatchNormalisation2D)	(None, 40, 40, 64) 256	conv2d_17[0][0]
activation_17 (Activation)	(None, 40, 40, 64) 0	batch_normalization_18[0][0]
concatenate_9 (Concatenate)	(None, 40, 40, 128) 0	activation_16[0][0] activation_17[0][0]
up_sampling2d_3 (UpSampling2D)	(None, 80, 80, 128) 0	concatenate_9[0][0]
conv2d_18 (Conv2D)	(None, 80, 80, 32) 16416	up_sampling2d_3[0][0]
batch_normalization_19 (BatchNormalisation2D)	(None, 80, 80, 32) 128	conv2d_18[0][0]
activation_18 (Activation)	(None, 80, 80, 32) 0	batch_normalization_19[0][0]
concatenate_10 (Concatenate)	(None, 80, 80, 96) 0	concatenate_2[0][0] activation_18[0][0]
conv2d_19 (Conv2D)	(None, 80, 80, 32) 27680	concatenate_10[0][0]
batch_normalization_20 (BatchNormalisation2D)	(None, 80, 80, 32) 128	conv2d_19[0][0]
activation_19 (Activation)	(None, 80, 80, 32) 0	batch_normalization_20[0][0]
conv2d_20 (Conv2D)	(None, 80, 80, 32) 9248	activation_19[0][0]
batch_normalization_21 (BatchNormalisation2D)	(None, 80, 80, 32) 128	conv2d_20[0][0]
activation_20 (Activation)	(None, 80, 80, 32) 0	batch_normalization_21[0][0]
concatenate_11 (Concatenate)	(None, 80, 80, 64) 0	activation_19[0][0] activation_20[0][0]
up_sampling2d_4 (UpSampling2D)	(None, 160, 160, 64) 0	concatenate_11[0][0]
conv2d_21 (Conv2D)	(None, 160, 160, 16) 4112	up_sampling2d_4[0][0]
batch_normalization_22 (BatchNormalisation2D)	(None, 160, 160, 16) 64	conv2d_21[0][0]

activation_21 (Activation)	(None, 160, 160, 16) 0	batch_normalization_2[0]
concatenate_12 (Concatenate)	(None, 160, 160, 48) 0	concatenate_1[0][0] activation_21[0][0]
conv2d_22 (Conv2D)	(None, 160, 160, 16) 6928	concatenate_12[0][0]
batch_normalization_23 (BatchNormalisation)	(None, 160, 160, 16) 64	conv2d_22[0][0]
activation_22 (Activation)	(None, 160, 160, 16) 0	batch_normalization_23[0]
conv2d_23 (Conv2D)	(None, 160, 160, 16) 2320	activation_22[0][0]
conv2d_11 (Conv2D)	(None, 10, 10, 8) 4104	dropout_2[0][0]
batch_normalization_24 (BatchNormalisation)	(None, 160, 160, 16) 64	conv2d_23[0][0]
batch_normalization_12 (BatchNormalisation)	(None, 10, 10, 8) 32	conv2d_11[0][0]
activation_23 (Activation)	(None, 160, 160, 16) 0	batch_normalization_24[0]
activation_11 (Activation)	(None, 10, 10, 8) 0	batch_normalization_12[0]
concatenate_13 (Concatenate)	(None, 160, 160, 32) 0	activation_22[0][0] activation_23[0][0]
dropout_3 (Dropout)	(None, 10, 10, 8) 0	activation_11[0][0]
conv2d_24 (Conv2D)	(None, 160, 160, 2) 578	concatenate_13[0][0]
flatten_1 (Flatten)	(None, 800) 0	dropout_3[0][0]
batch_normalization_25 (BatchNormalisation)	(None, 160, 160, 2) 8	conv2d_24[0][0]
dense_1 (Dense)	(None, 256) 205056	flatten_1[0][0]
activation_24 (Activation)	(None, 160, 160, 2) 0	batch_normalization_25[0]
dropout_4 (Dropout)	(None, 256) 0	dense_1[0][0]
conv2d_25 (Conv2D)	(None, 160, 160, 1) 3	activation_24[0][0]
dense_2 (Dense)	(None, 1) 257	dropout_4[0][0]
batch_normalization_26 (BatchNormalisation)	(None, 160, 160, 1) 4	conv2d_25[0][0]
reshape_1 (Reshape)	(None, 1, 1, 1) 0	dense_2[0][0]
activation_25 (Activation)	(None, 160, 160, 1) 0	batch_normalization_26[0]
conv2d_transpose_1 (Conv2DTranspose)	(None, 160, 160, 1) 25601	reshape_1[0][0]
multiply_1 (Multiply)	(None, 160, 160, 1) 0	activation_25[0][0] conv2d_transpose_1[0]
<hr/>		
Total params:	2,945,191	
Trainable params:	2,916,138	
Non-trainable params:	29,053	

Implementation

In [7]:

```
#Assign file list with a list of file to be processed
fileList=testingFiles.copy()

#Extract ROIs
fileROIs,fileScores=preprocessListWSI(slicePath,fileList, annotPath=annotPath, sArea=sA
#Getting the scores and saves the prediction images and coordinate
testingScores=predictListWSI(slicePath, fileList, fileROIs, model, xTrainMean, xTrainSt

#print testing scores
print(scoresDict(testingScores)
```

```
12 images saved successfully to AnnotDetected\10012
14 images saved successfully to NonAnnotDetected\10012
26 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
16 images saved successfully to AnnotDetected\10023
11 images saved successfully to NonAnnotDetected\10023
27 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
16 images saved successfully to AnnotDetected\10029
7 images saved successfully to NonAnnotDetected\10029
23 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
9 images saved successfully to AnnotDetected\10036
159 images saved successfully to NonAnnotDetected\10036
168 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
56 images saved successfully to AnnotDetected\10039
274 images saved successfully to NonAnnotDetected\10039
330 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
16 images saved successfully to AnnotDetected\10049
20 images saved successfully to NonAnnotDetected\10049
36 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
35 images saved successfully to AnnotDetected\10064
21 images saved successfully to NonAnnotDetected\10064
56 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
29 images saved successfully to AnnotDetected\10067
61 images saved successfully to NonAnnotDetected\10067
90 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
20 images saved successfully to AnnotDetected\10071
28 images saved successfully to NonAnnotDetected\10071
48 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
21 images saved successfully to AnnotDetected\10072
12 images saved successfully to NonAnnotDetected\10072
33 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
1 images saved successfully to AnnotDetected\10073
9 images saved successfully to NonAnnotDetected\10073
10 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
20 images saved successfully to AnnotDetected\10078
102 images saved successfully to NonAnnotDetected\10078
122 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
0 images saved successfully to AnnotDetected\10087
6 images saved successfully to NonAnnotDetected\10087
6 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
9 images saved successfully to AnnotDetected\10088
47 images saved successfully to NonAnnotDetected\10088
56 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
14 images saved successfully to AnnotDetected\10093
5 images saved successfully to NonAnnotDetected\10093
19 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
1 images saved successfully to AnnotDetected\10096
10 images saved successfully to NonAnnotDetected\10096
11 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
24 images saved successfully to AnnotDetected\10097
203 images saved successfully to NonAnnotDetected\10097
227 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
```

```
30 images saved successfully to AnnotDetected\10102
167 images saved successfully to NonAnnotDetected\10102
197 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
17 images saved successfully to AnnotDetected\10113
38 images saved successfully to NonAnnotDetected\10113
55 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
16 images saved successfully to AnnotDetected\10114
507 images saved successfully to NonAnnotDetected\10114
523 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
17 images saved successfully to AnnotDetected\10116
74 images saved successfully to NonAnnotDetected\10116
91 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
11 images saved successfully to AnnotDetected\10121
159 images saved successfully to NonAnnotDetected\10121
170 rows stored successfully to D:\UniData\Projects\NervesSegmentationProject\dataFiles\
Testing results :
10012 : Identified annotations [9, 10] and Additional 14
10023 : Identified annotations [11, 12] and Additional 11
10029 : Identified annotations [8, 11] and Additional 7
10036 : Identified annotations [8, 9] and Additional 159
10039 : Identified annotations [34, 35] and Additional 274
10049 : Identified annotations [13, 15] and Additional 20
10064 : Identified annotations [28, 28] and Additional 21
10067 : Identified annotations [25, 27] and Additional 61
10071 : Identified annotations [17, 21] and Additional 28
10072 : Identified annotations [13, 15] and Additional 12
10073 : Identified annotations [1, 2] and Additional 9
10078 : Identified annotations [12, 15] and Additional 102
10087 : Identified annotations [0.0, 0] and Additional 6
10088 : Identified annotations [8, 8] and Additional 47
10093 : Identified annotations [10, 11] and Additional 5
10096 : Identified annotations [1, 1] and Additional 10
10097 : Identified annotations [18, 19] and Additional 203
10102 : Identified annotations [24, 25] and Additional 167
10113 : Identified annotations [13, 16] and Additional 38
10114 : Identified annotations [14, 14] and Additional 507
10116 : Identified annotations [15, 16] and Additional 74
10121 : Identified annotations [8, 8] and Additional 159
```

Demo

In [2]:

```
from demo import demoFile

fileList=demoFiles.copy()

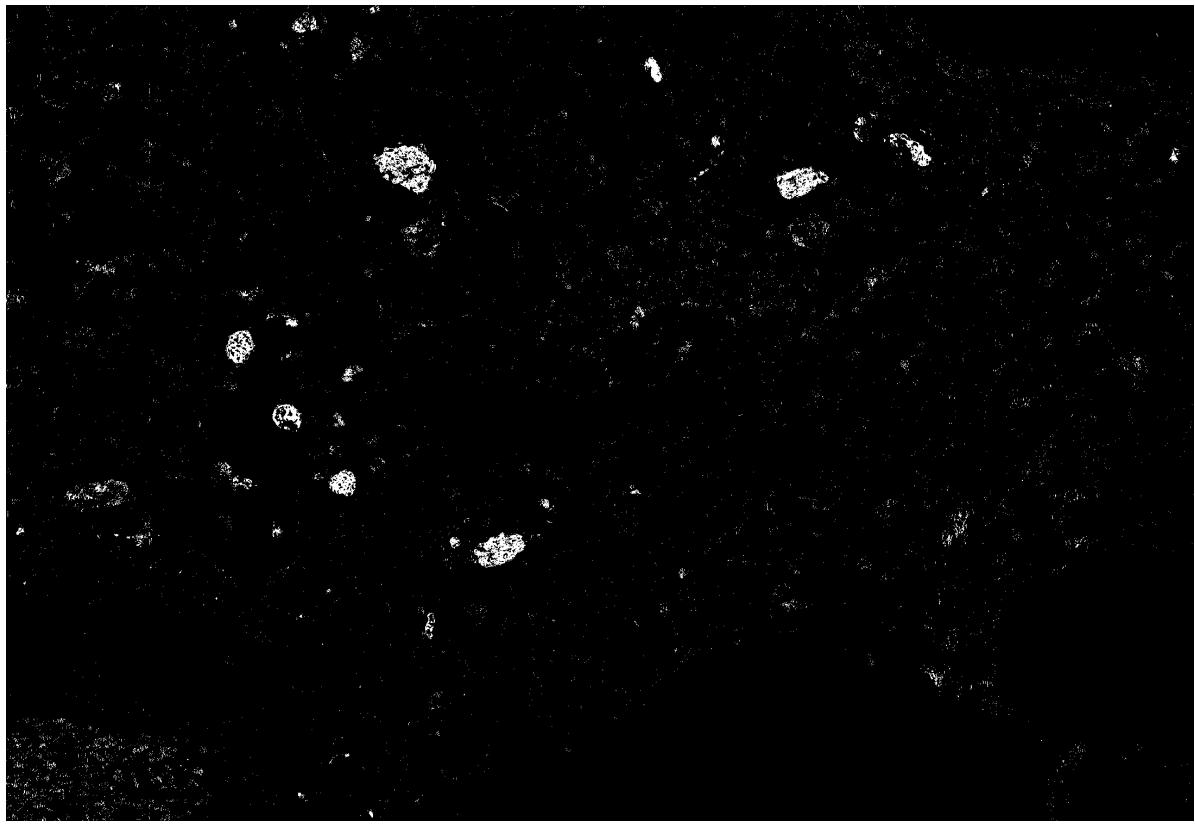
#Get the area of the slide to be processed for demo as size of the whole slide is too b
dArea=getBytesFromCSV(os.path.join(fileDir,"sArea_Demo.csv"),'Dict')
```

Draw and visualise prediction on demo file 1 (Scroll for complete results)

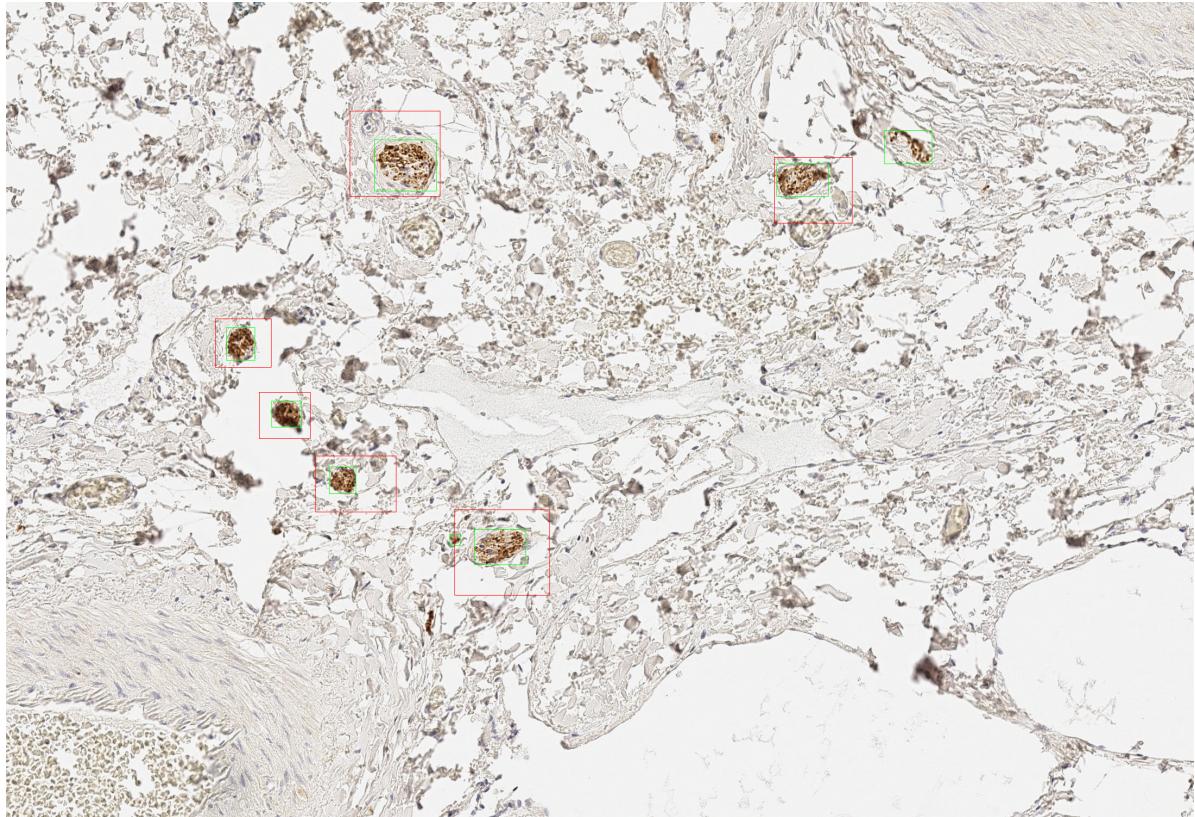
In [3]:

```
print("Processing file: "+str(fileList[0]))  
demoFile(fileList[0], dArea, fileDir, slicePath, annotPath)
```

Processing file: 10039
Colour filter output



Drawing manual annotation (red) and predictions by model (green)

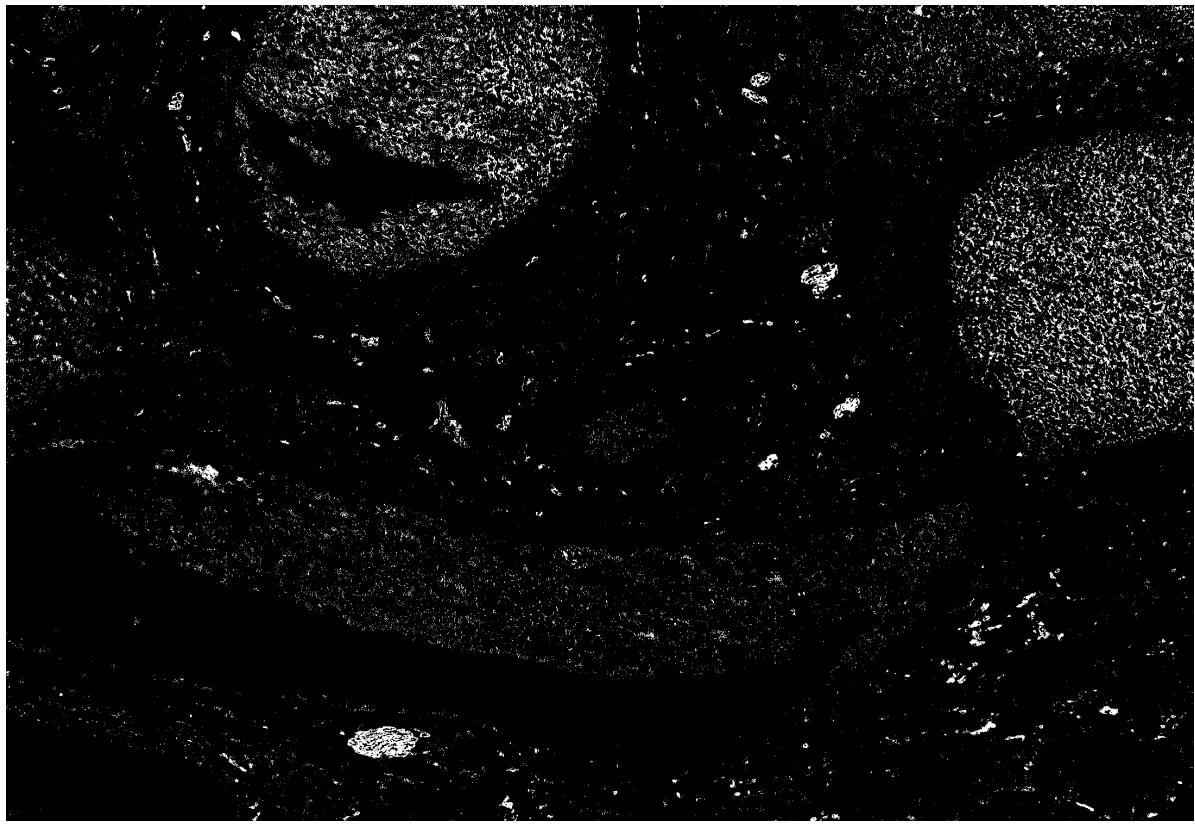


Draw and visualise prediction on demo file 2 (Scroll for complete results)

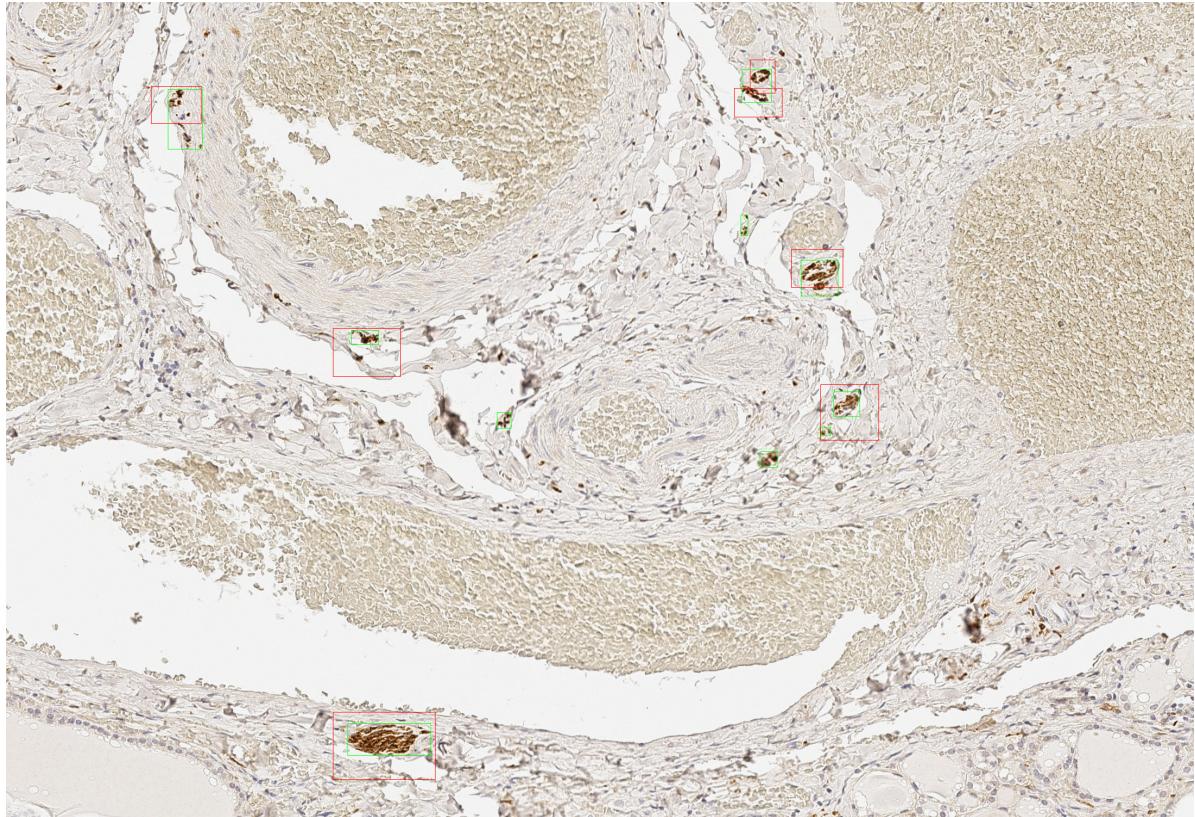
In [4]:

```
print("Processing file: "+str(fileList[1]))  
demoFile(fileList[1], dArea, fileDir, slicePath, annotPath)
```

Processing file: 10097
Colour filter output



Drawing manual annotation (red) and predictions by model (green)

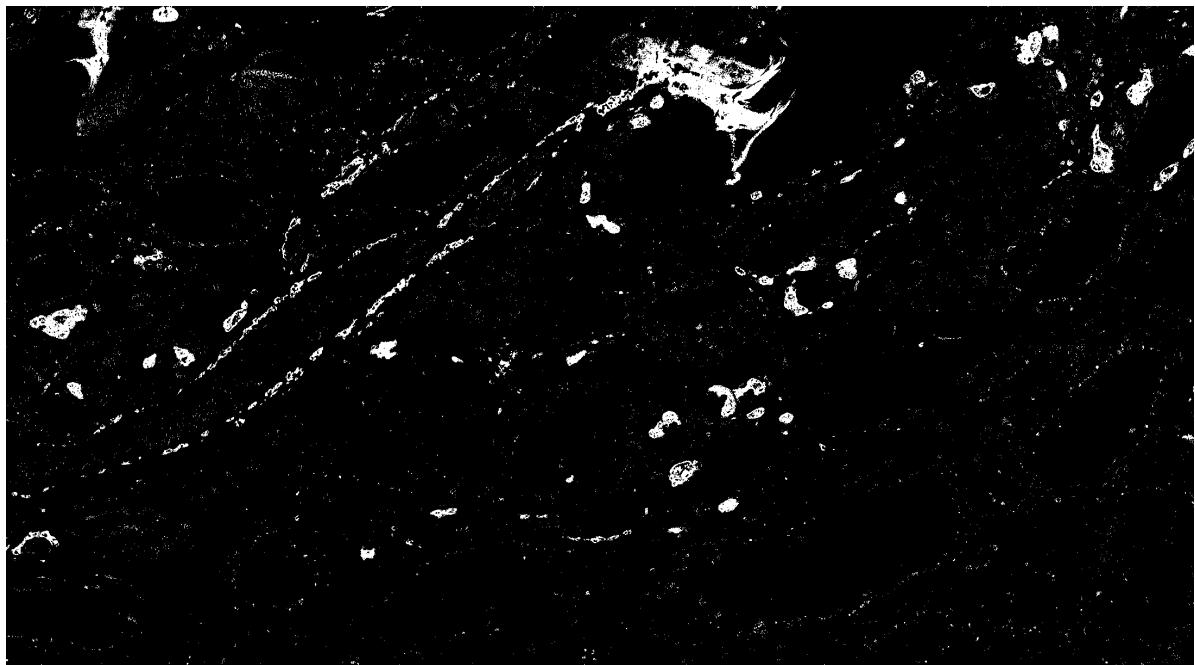


Draw and visualise prediction on demo file 3 (Scroll for complete results)

In [5]:

```
print("Processing file: "+str(fileList[2]))  
demoFile(fileList[2], dArea, fileDir, slicePath, annotPath)
```

Processing file: 10114
Colour filter output



Drawing manual annotation (red) and predictions by model (green)

