naczynia-oka

May 10, 2022

[4]:
```
import cv2
import numpy as np
import math
import matplotlib.pyplot as plt
import os
import re
```

1 1. Przetwarzanie obrazów

1.0.1 Wczytanie obrazów

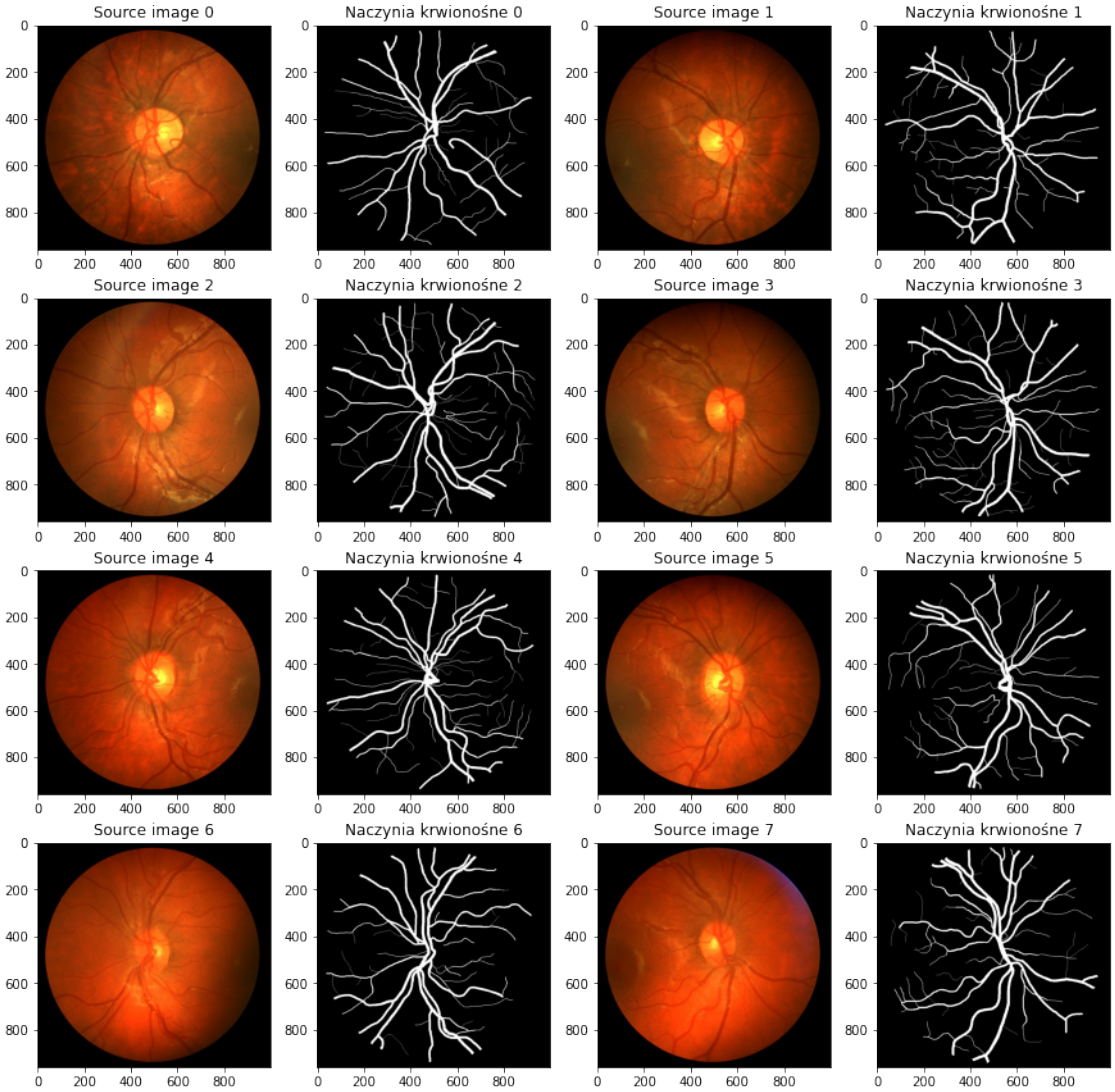
[5]:
```
# source: https://blogs.kingston.ac.uk/retinal/chasedb1/

imageFolder = "images"
imageNames = os.listdir(imageFolder)
imageNames.sort()
images = {}
for filename in imageNames:
    img = cv2.imread(imageFolder + "/" +  filename)
    images[filename] = img

manualLabeledImageFolder = "manual1"
labeledImageNames = os.listdir(manualLabeledImageFolder)
labeledImageNames.sort()
manualVessels = {}
for filename in labeledImageNames:
    img  = cv2.imread(manualLabeledImageFolder + "/" + filename)
    manualVessels[filename] = img
print(images.keys())
print(manualVessels.keys())
```

```
dict_keys(['01_h.jpg', '02_h.jpg', '03_h.jpg', '04_h.jpg', '05_h.jpg',
'06_h.jpg', '07_h.jpg', '08_h.jpg', '09_h.jpg', '10_h.jpg', '11_h.jpg',
'12_h.jpg', '13_h.jpg', '14_h.jpg', '15_h.jpg'])
```

```
dict_keys(['01_h.jpg', '02_h.jpg', '03_h.jpg', '04_h.jpg', '05_h.jpg',
'06_h.jpg', '07_h.jpg', '08_h.jpg', '09_h.jpg', '10_h.jpg', '11_h.jpg',
'12_h.jpg', '13_h.jpg', '14_h.jpg', '15_h.jpg'])
```

1.0.2 Przykładowe obrazy

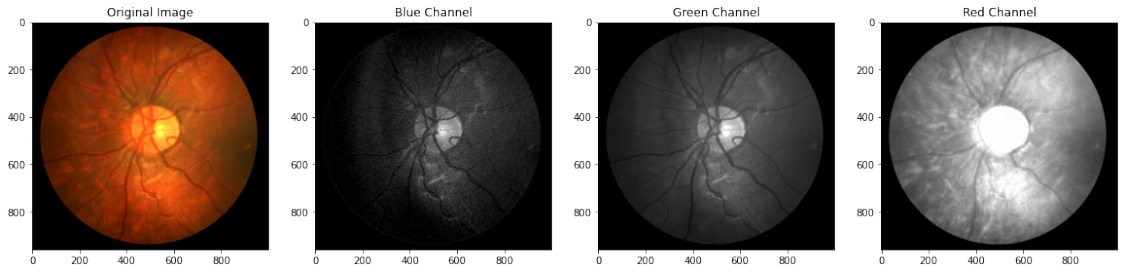
[6]:
```
figure = plt.figure(figsize=(15, 15))
columns = 4
rows = 4
for i in range(0, columns*rows):
    figure.add_subplot(rows, columns, i+1)
    if (i+1)%2:
        img = list(images.values())[int(i/2)]
        plt.title(f"Source image {int(i/2)}")
        plt.imshow(img[:,:,::-1])
    else:
        img = list(manualVessels.values())[int(i/2)]
        plt.title(f"Naczynia krwionośne {int(i/2)}")
        plt.imshow(img, cmap='gray')
plt.show()
```



1.0.3 Wybór najlepszego kanału koloru

[7]:
```
img = images['01_h.jpg']
imgBlueChannel = img[:,:,0]
imgGreenChannel = img[:,:,1]
imgRedChannel = img[:,:,2]

plt.figure(figsize=(20,12))
plt.subplot(141)
plt.imshow(img[:,:,::-1]);
plt.title("Original Image")
plt.subplot(142)
plt.imshow(imgBlueChannel, cmap='gray');
```

```
plt.title("Blue Channel")
plt.subplot(143)
plt.imshow(imgGreenChannel, cmap='gray');
plt.title("Green Channel")
plt.subplot(144)
plt.imshow(imgRedChannel, cmap='gray');
plt.title("Red Channel");
```

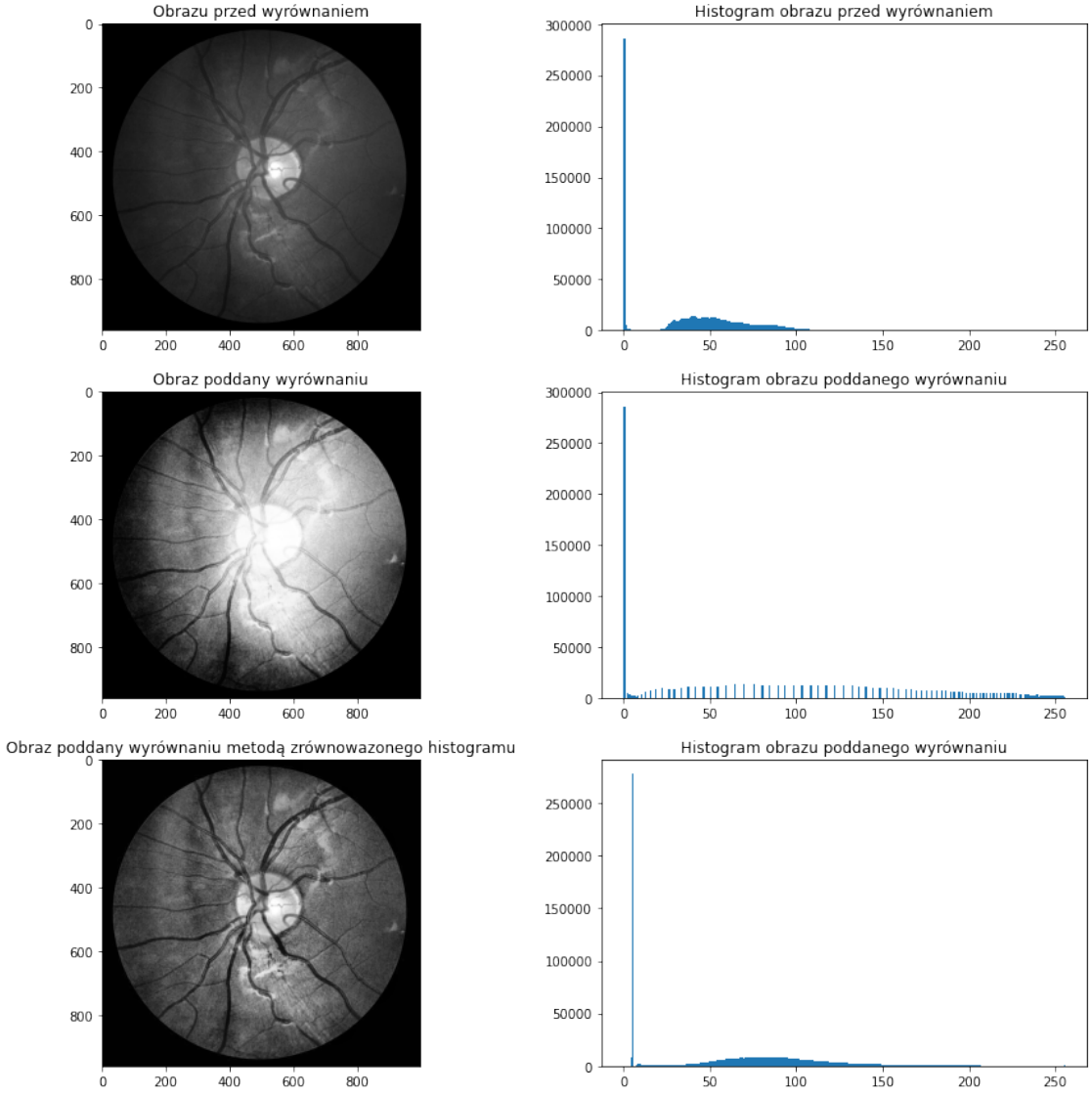


1.0.4 Zwiększenie kontrastu metodą wyrównania histogramu

- od tego momentu przetwarzamy już tylko kanał zielony

[8]:
```
imgEqualized = cv2.equalizeHist(imgGreenChannel)
clahe = cv2.createCLAHE(clipLimit=4.0, tileGridSize=(8,8))
imgEqualizedCLAHE = clahe.apply(imgGreenChannel)

fig = plt.figure(figsize=(15, 15))

plt.subplot(321)
plt.imshow(imgGreenChannel, cmap='gray')
plt.title("Obrazu przed wyrównaniem")
plt.subplot(322)
plt.hist(imgGreenChannel.ravel(),256,[0,256])
plt.title("Histogram obrazu przed wyrównaniem")

plt.subplot(323)
plt.imshow(imgEqualized, cmap='gray')
plt.title("Obraz poddany wyrównaniu")
plt.subplot(324)
plt.hist(imgEqualized.ravel(),256,[0,256])
plt.title("Histogram obrazu poddanego wyrównaniu")

plt.subplot(325)
plt.imshow(imgEqualizedCLAHE, cmap='gray')
plt.title("Obraz poddany wyrównaniu metodą zrównowazonego histogramu")
plt.subplot(326)
```

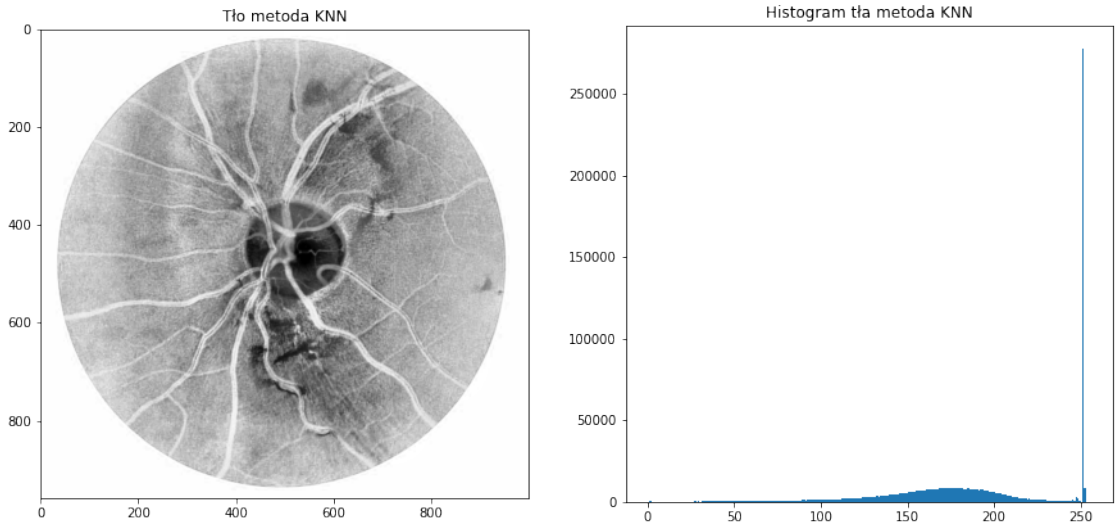
```
plt.hist(imgEqualizedCLAHE.ravel(),256,[0,256])
plt.title("Histogram obrazu poddanego wyrównaniu")

plt.show()
```



[9]:
```
backgroundSubstractorKNN = cv2.createBackgroundSubtractorKNN()
backgroundSubstractorMOG2 = cv2.createBackgroundSubtractorMOG2(0,␣
 ↪varThreshold=0, detectShadows=False)
imgBackgroundKNN = backgroundSubstractorKNN.apply(imgEqualizedCLAHE)
imgBackgroundMOG2 = backgroundSubstractorMOG2.apply(imgEqualizedCLAHE)
```

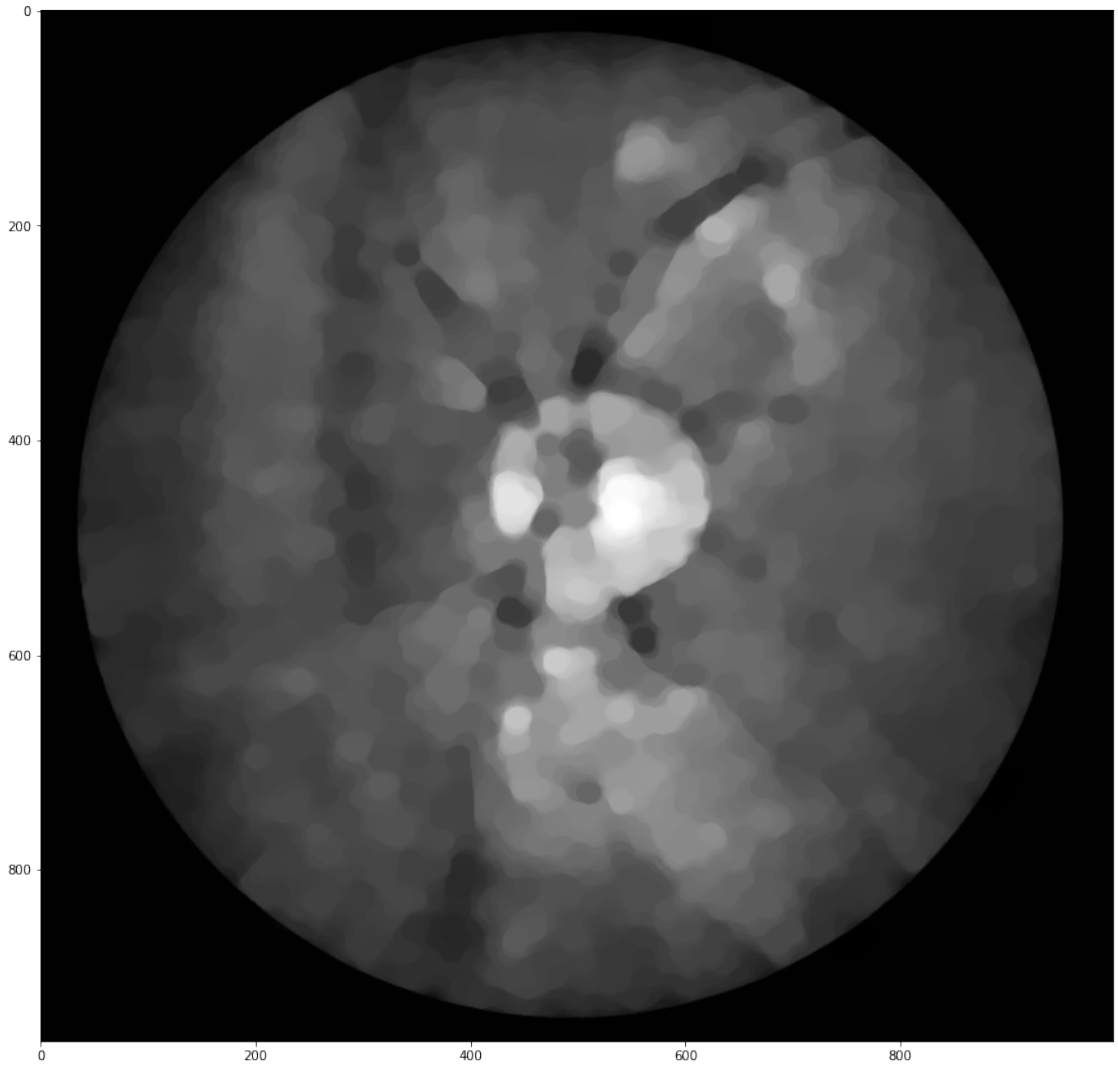
```
imgBackgroundKNN = backgroundSubstractorKNN.apply(imgEqualizedCLAHE.copy())
imgKNNSubtracted = imgEqualizedCLAHE * imgBackgroundKNN
fig = plt.figure(figsize=(15, 15))

plt.subplot(221)
plt.imshow(imgKNNSubtracted, cmap='gray')
plt.title("Tło metoda KNN")
plt.subplot(222)
plt.hist(imgKNNSubtracted.ravel(),256,[0,256])
plt.title("Histogram tła metoda KNN")
```

[9]:
```
Text(0.5, 1.0, 'Histogram tła metoda KNN')
```

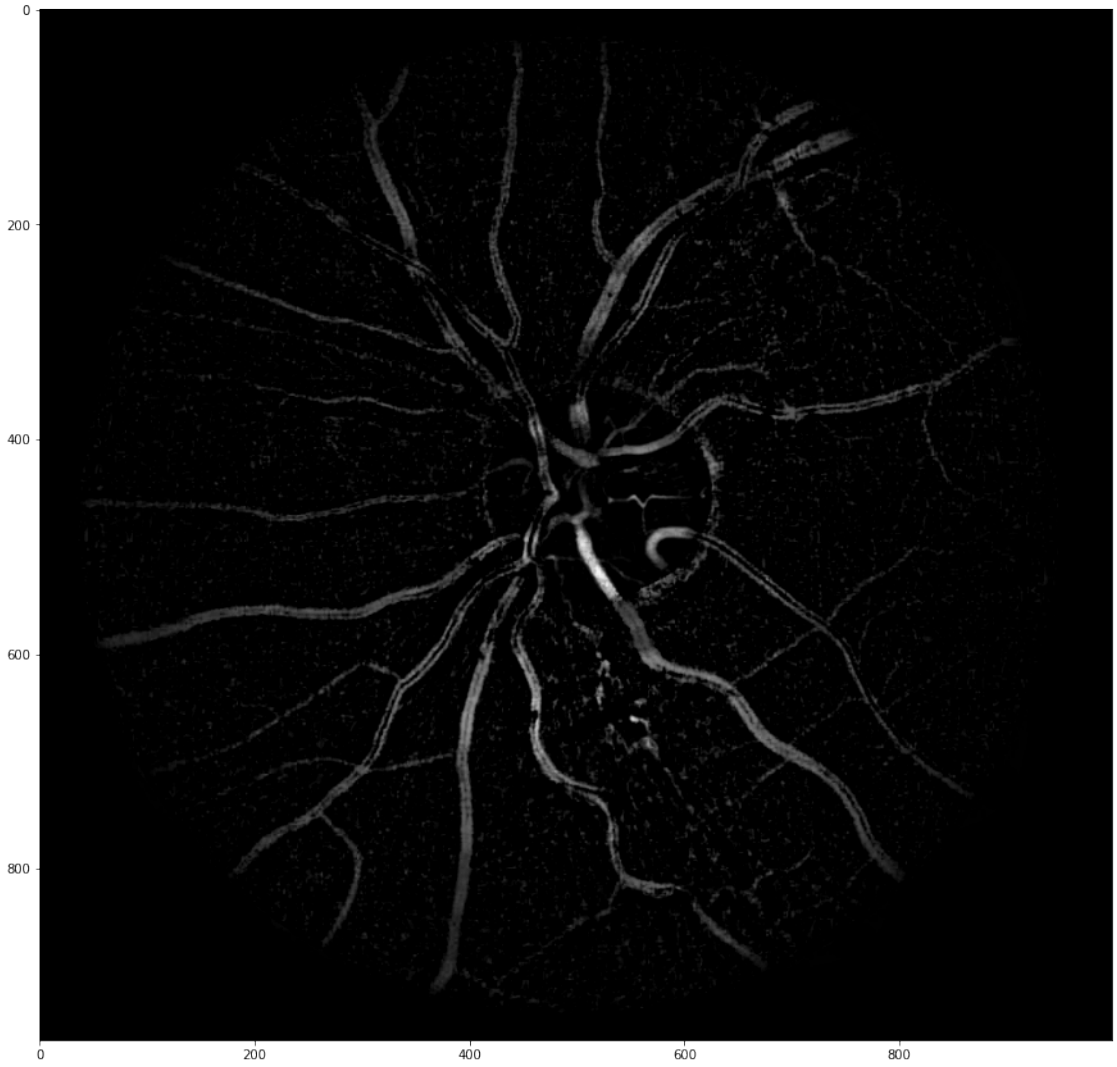


[10]:
```
kernelSizes = [7, 11, 13, 21]
kernels = [cv2.getStructuringElement(cv2.MORPH_ELLIPSE,(size, size)) for size␣
 ↪in kernelSizes]

morphology_steps = [imgEqualizedCLAHE.copy()]
for kernel in kernels:
    imageOpened = cv2.morphologyEx(morphology_steps[-1], cv2.MORPH_OPEN,␣
 ↪kernel, iterations = 1)
    imageClosed = cv2.morphologyEx(imageOpened, cv2.MORPH_CLOSE, kernel,␣
 ↪iterations = 1)
    morphology_steps.extend([imageOpened, imageClosed])

img = morphology_steps[-1]

fig = plt.figure(figsize=(15, 15))
plt.imshow(img, cmap='gray')
```

```
plt.show()
```



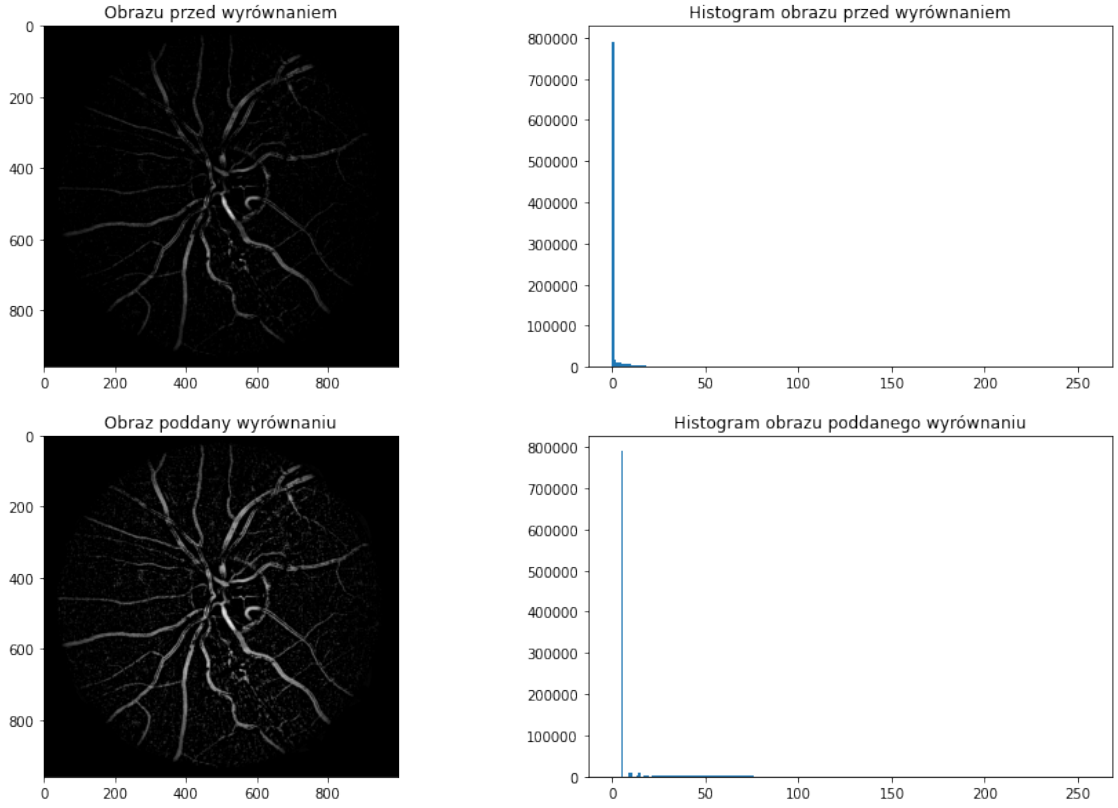
[11]:
```
vessels = cv2.subtract(morphology_steps[-1],imgEqualizedCLAHE)

fig = plt.figure(figsize=(15, 15))
plt.imshow(vessels, cmap='gray')
plt.show()
```



[16]:
```
vesselsCLAHE = clahe.apply(vessels)
fig = plt.figure(figsize=(15, 10))

plt.subplot(221)
plt.imshow(vessels, cmap='gray')
plt.title("Obrazu przed wyrównaniem")
plt.subplot(222)
plt.hist(vessels.ravel(),256,[0,256])
plt.title("Histogram obrazu przed wyrównaniem")

plt.subplot(223)
plt.imshow(vesselsCLAHE, cmap='gray')
plt.title("Obraz poddany wyrównaniu")
plt.subplot(224)
```

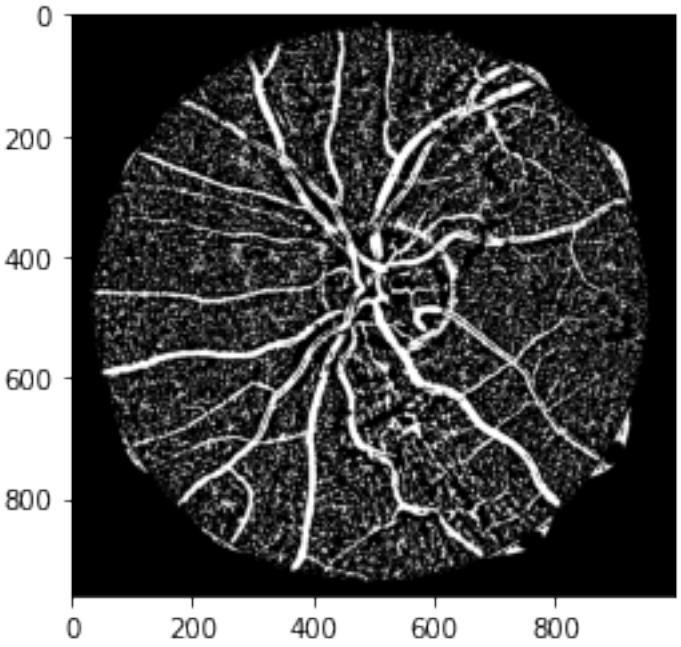
```
plt.hist(vesselsCLAHE.ravel(),256,[0,256])
plt.title("Histogram obrazu poddanego wyrównaniu")
```

[16]: Text(0.5, 1.0, 'Histogram obrazu poddanego wyrównaniu')



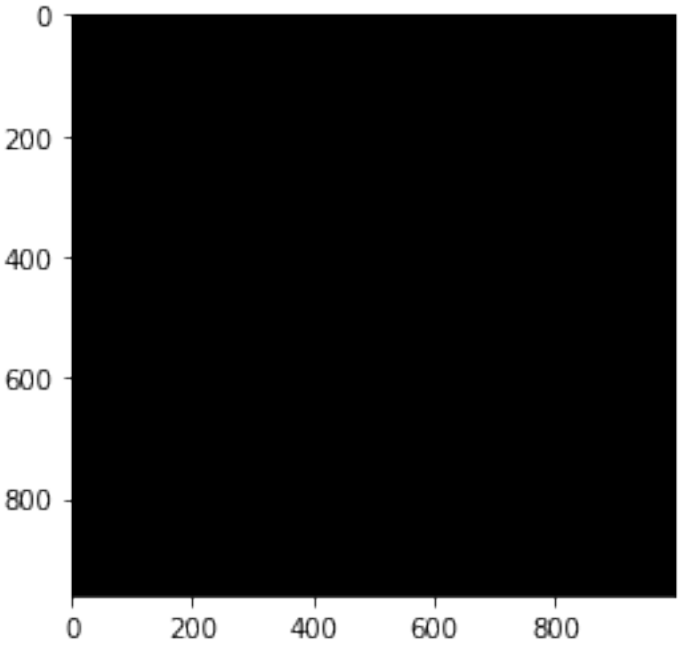
[30]:
```
ret,vesselsThreshold = cv2.threshold(vesselsCLAHE,5,255,cv2.THRESH_BINARY)
plt.imshow(vesselsThreshold,cmap='gray')
```

[30]: <matplotlib.image.AxesImage at 0x7fc956b7d180>



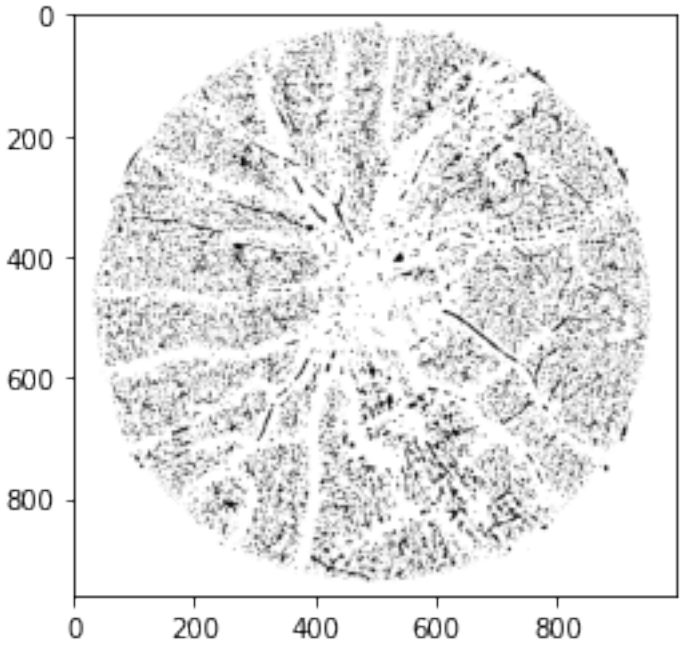
[31]:
```
noise_mask = np.ones(vesselsThreshold.shape[:2], dtype="uint8") * 255
plt.imshow(noise_mask,cmap='gray')
print(np.shape(noise_mask))
```

```
(960, 999)
```



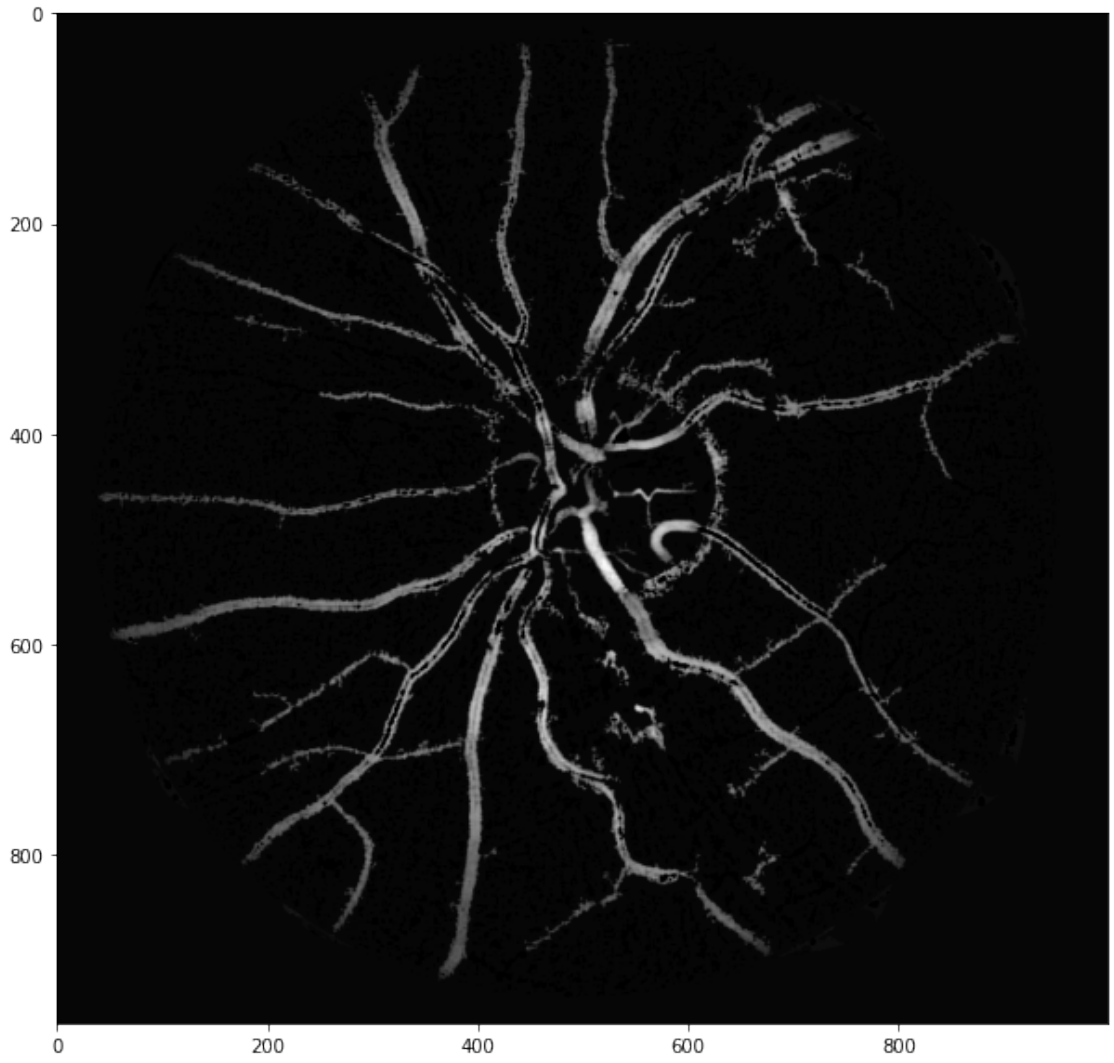
[32]:
```
contours, hierarchy = cv2.findContours(vesselsThreshold.copy(),cv2.
 ↪RETR_LIST,cv2.CHAIN_APPROX_SIMPLE)
for contour in contours:
    if cv2.contourArea(contour) <= 200:
        cv2.drawContours(noise_mask, [contour], -1, 0, -1)
plt.imshow(noise_mask, cmap='gray')
```

[32]:
```
<matplotlib.image.AxesImage at 0x7fc956da0f40>
```



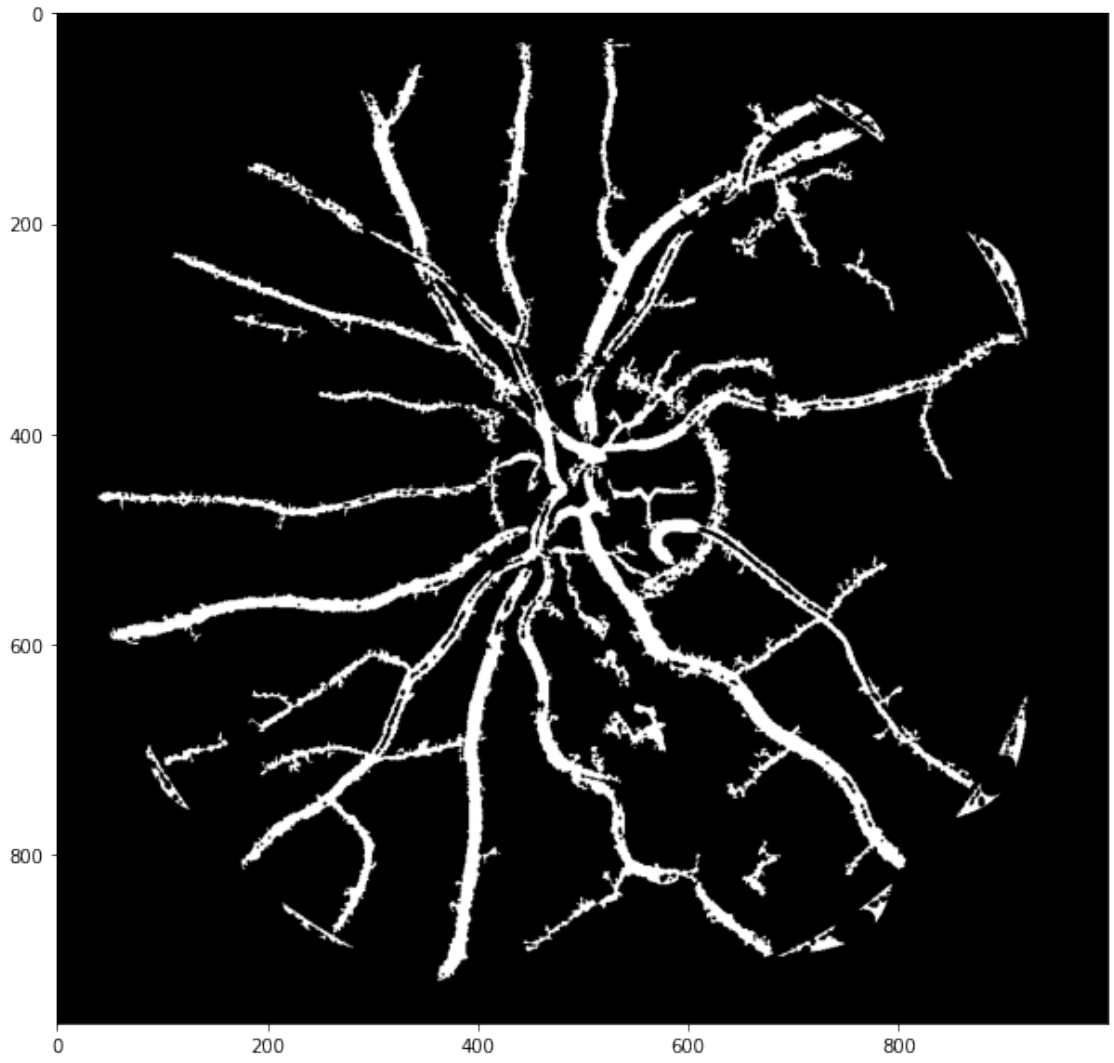
[33]:
```
vesselsNoiseReducted = cv2.bitwise_and(vesselsCLAHE, vesselsCLAHE,␣
 ↪mask=noise_mask)
fig = plt.figure(figsize=(15, 10))
plt.imshow(vesselsNoiseReducted, cmap='gray')
```

[33]:
```
<matplotlib.image.AxesImage at 0x7fc91459a2c0>
```



[34]:
```
ret,vesselsThresholded = cv2.threshold(vesselsNoiseReducted,5,255,cv2.
  ↪THRESH_BINARY)
fig = plt.figure(figsize=(15, 10))
plt.imshow(vesselsThresholded, cmap='gray')
```

[34]: <matplotlib.image.AxesImage at 0x7fc9145cd330>



1.1 Now all of this steps for each img

[35]:
```
def extractVessels(image, kernelSizes = [37, 49, 55, 73], threshold = 5,␣
↪noiseContour = 1000):
    # extract green channel
    imageGreenChannel = image[:,:,1]

    # CLAHE
    clahe = cv2.createCLAHE(clipLimit=4.0, tileGridSize=(8,8))
    imageEqualizedCLAHE = clahe.apply(imageGreenChannel)

    # open-close to get background
    kernels = [cv2.getStructuringElement(cv2.MORPH_ELLIPSE,(size, size)) for␣
↪size in kernelSizes]
```

```
    morphology_steps = [imageEqualizedCLAHE.copy()]
    for kernel in kernels:
        imageOpened = cv2.morphologyEx(morphology_steps[-1], cv2.MORPH_OPEN,␣
↪kernel, iterations = 1)
        imageClosed = cv2.morphologyEx(imageOpened, cv2.MORPH_CLOSE, kernel,␣
↪iterations = 1)
        morphology_steps.extend([imageOpened, imageClosed])

    # subtract vessels from background
    vessels = cv2.subtract(morphology_steps[-1],imageEqualizedCLAHE)

    # first threshold for contours
    _, vesselsThreshold = cv2.threshold(vessels,threshold,255,cv2.THRESH_BINARY)
    # get image noise

    noiseMask = np.ones(vesselsThreshold.shape[:2], dtype="uint8") * 255

    # delete noise in small contours
    contours, _ = cv2.findContours(vesselsThreshold.copy(),cv2.RETR_LIST,cv2.
↪CHAIN_APPROX_SIMPLE)
    for contour in contours:
        if cv2.contourArea(contour) <= noiseContour:
            cv2.drawContours(noiseMask, [contour], -1, 0, -1)
    vesselsNoiseReducted = cv2.bitwise_and(vessels, vessels, mask=noiseMask)

    # second threshold for result
    _, vesselsThresholded = cv2.
↪threshold(vesselsNoiseReducted,threshold,255,cv2.THRESH_BINARY)
    return vesselsThresholded
```

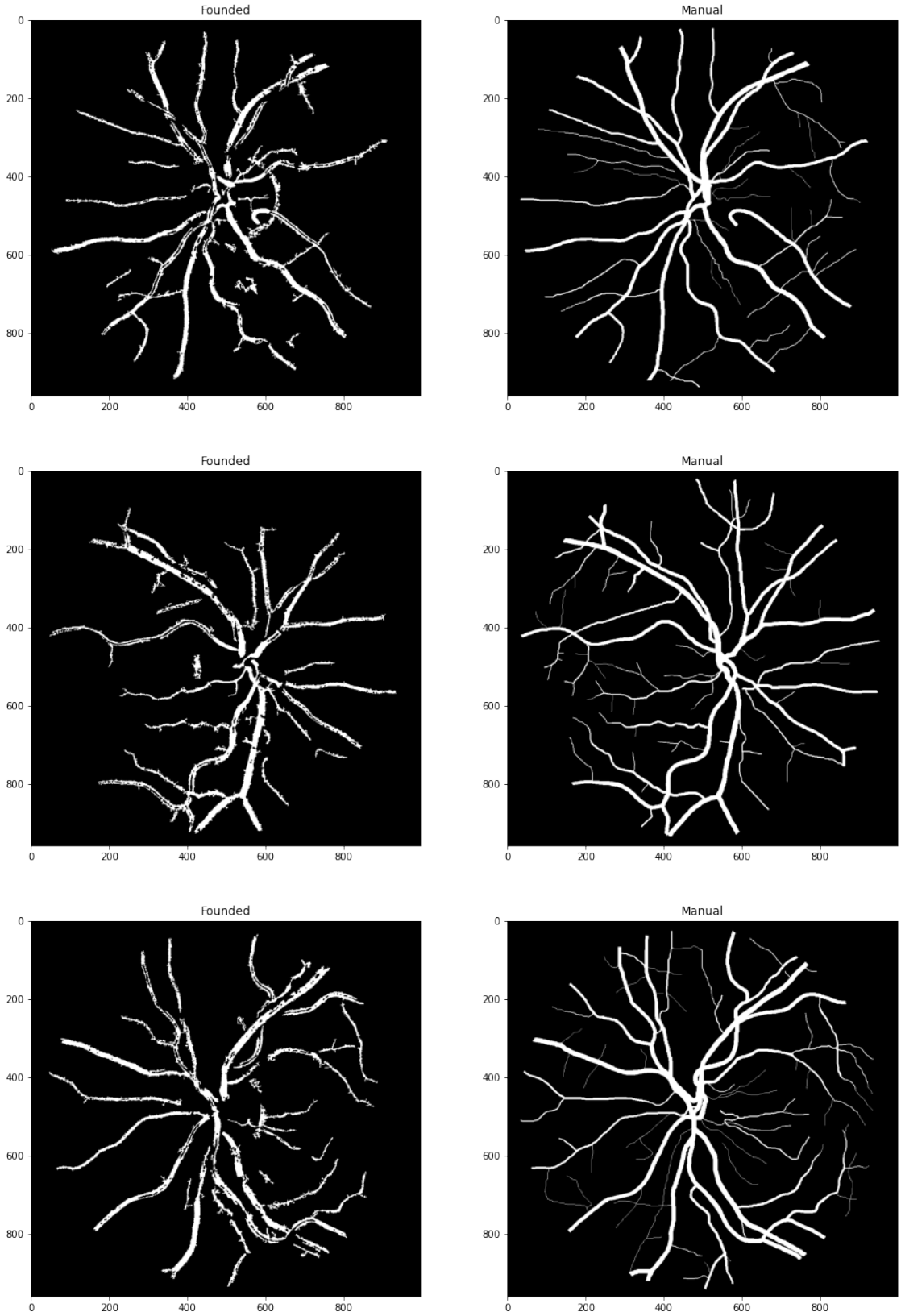
[36]:
```
imagesVessels = {}
for name, img in list(images.items())[0:6]:
    print(name)
    # imagesVessels[name] = extractVessels(img, kernelSizes = [37, 49, 55, 73],␣
↪threshold = 5, noiseContour = 1000)
    imagesVessels[name] = extractVessels(img, kernelSizes =[7, 11, 13, 21],␣
↪threshold = 5, noiseContour = 200)
```

```
01_h.jpg
02_h.jpg
03_h.jpg
04_h.jpg
05_h.jpg
06_h.jpg
```

[37]:
```
figure = plt.figure(figsize=(16,24))

name = '01_h.jpg'
plt.subplot(321)
plt.imshow(imagesVessels[name], cmap='gray')
print(np.shape(imagesVessels[name]))
plt.title("Founded")
plt.subplot(322)
plt.imshow(manualVessels[name], cmap='gray')
print(np.shape(manualVessels[name]))
plt.title("Manual")

name = '02_h.jpg'
plt.subplot(323)
plt.imshow(imagesVessels[name], cmap='gray')
plt.title("Founded")
plt.subplot(324)
plt.imshow(manualVessels[name], cmap='gray')
plt.title("Manual")

name = '03_h.jpg'
plt.subplot(325)
plt.imshow(imagesVessels[name], cmap='gray')
plt.title("Founded")
plt.subplot(326)
plt.imshow(manualVessels[name], cmap='gray')
plt.title("Manual")
```

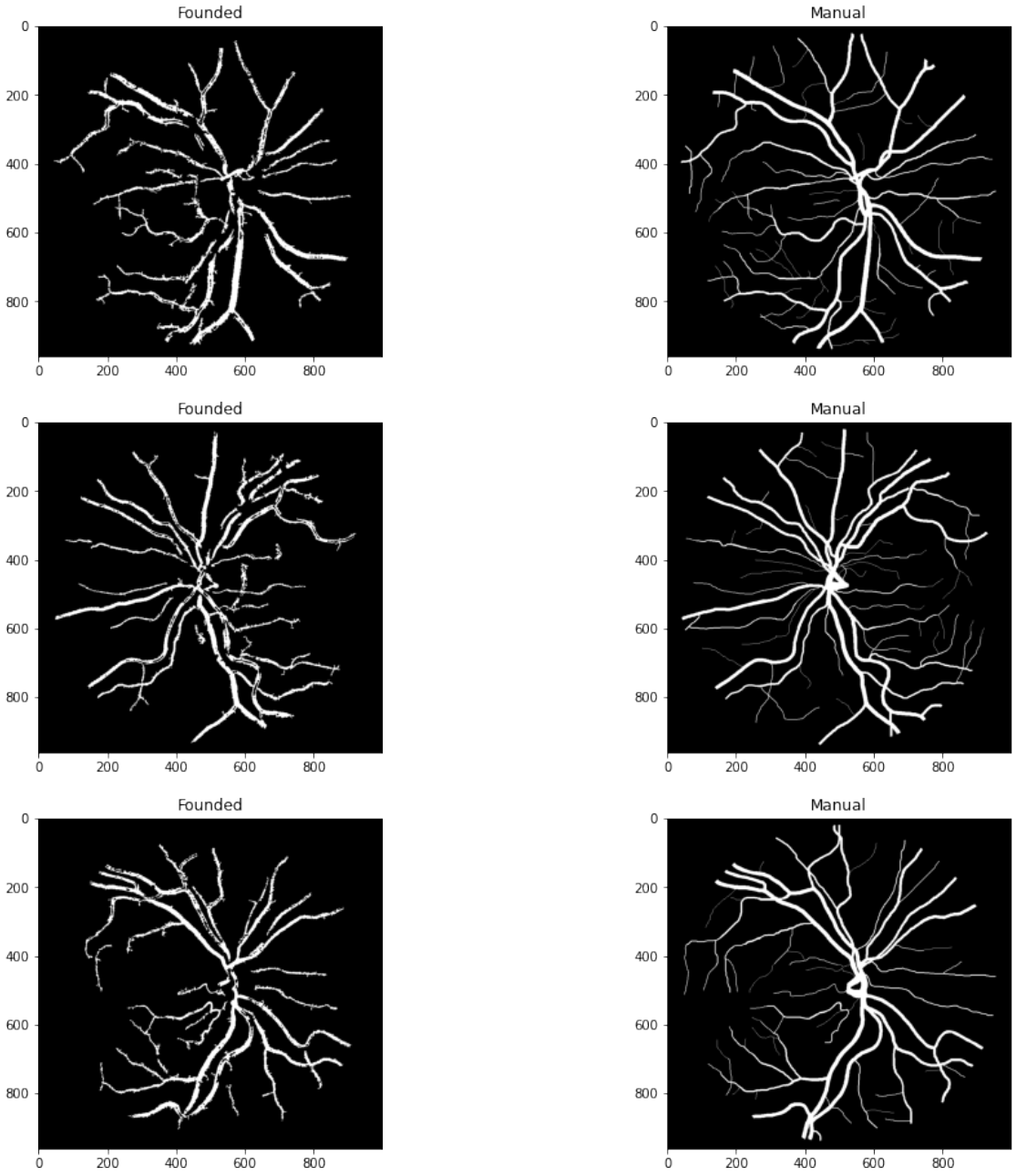
```
(960, 999)
(960, 999, 3)
```

[37]:
```
Text(0.5, 1.0, 'Manual')
```


Founded
Manual
Founded
Manual
Founded
Manual

[38]:
```
figure = plt.figure(figsize=(16,16))

name = '04_h.jpg'
plt.subplot(321)
plt.imshow(imagesVessels[name], cmap='gray')
plt.title("Founded")
plt.subplot(322)
plt.imshow(manualVessels[name], cmap='gray')
plt.title("Manual")

name = '05_h.jpg'
plt.subplot(323)
plt.imshow(imagesVessels[name], cmap='gray')
plt.title("Founded")
plt.subplot(324)
plt.imshow(manualVessels[name], cmap='gray')
plt.title("Manual")

name = '06_h.jpg'
plt.subplot(325)
plt.imshow(imagesVessels[name], cmap='gray')
plt.title("Founded")
plt.subplot(326)
plt.imshow(manualVessels[name], cmap='gray')
plt.title("Manual")
```

[38]:
```
Text(0.5, 1.0, 'Manual')
```



[39]:
```
from sklearn.metrics import confusion_matrix


def summary(vesselsManual, vesselsFounded):
    conf = confusion_matrix(vesselsManual.flatten(), vesselsFounded.flatten())
    TrueNeg, FalsePos, FalseNeg, TruePos = conf.ravel()
```

```
    accuracy = (float (TruePos+TrueNeg) / float(TruePos + TrueNeg + FalsePos +␣
↪FalseNeg))
    sensitivity = (TruePos / float(TruePos + FalseNeg))
    specificity = (TrueNeg / float(TrueNeg + FalsePos))
    geoMean = (sensitivity * specificity)**(1.0/2)

    return (accuracy, sensitivity, specificity, geoMean)
```

[40]:
```
for name in imagesVessels.keys():
    print(name)
    vesselsFound = imagesVessels[name]
    vesselsManual = manualVessels[name][:,:,1]
    _, vesselsManual = cv2.threshold(vesselsManual,10,255,cv2.THRESH_BINARY)

    results = summary(vesselsManual,vesselsFound)
    print(f"accuracy: {round(results[0], 5)} sensitivity: {round(results[1],␣
↪5)} specificity: {round(results[2], 5)} geoMean: {round(results[3], 5)}")
```

```
01_h.jpg
accuracy: 0.9582 sensitivity: 0.65767 specificity: 0.98074 geoMean: 0.80312
02_h.jpg
accuracy: 0.9558 sensitivity: 0.60714 specificity: 0.98446 geoMean: 0.77311
03_h.jpg
accuracy: 0.95125 sensitivity: 0.60677 specificity: 0.98167 geoMean: 0.77178
04_h.jpg
accuracy: 0.94936 sensitivity: 0.6229 specificity: 0.97702 geoMean: 0.78012
05_h.jpg
accuracy: 0.95666 sensitivity: 0.68751 specificity: 0.97956 geoMean: 0.82065
06_h.jpg
accuracy: 0.95836 sensitivity: 0.67177 specificity: 0.98177 geoMean: 0.81211
```

2 2. Uczenie maszynowe

[2]:
```
from skimage.util import view_as_windows
import cv2
import numpy as np
import math
import matplotlib.pyplot as plt
import os
import re
import pandas as pd
from sklearn.ensemble import RandomForestClassifier
from imblearn.under_sampling import RandomUnderSampler
from multiprocessing import Pool
```

[111]:
```
imageFolder = "images"
imageNames = os.listdir(imageFolder)
imageNames.sort()
images = {}
for filename in imageNames:
    img = cv2.imread(imageFolder + "/" +  filename)
    images[filename] = img

manualLabeledImageFolder = "manual1"
labeledImageNames = os.listdir(manualLabeledImageFolder)
labeledImageNames.sort()
manualVessels = {}
for filename in labeledImageNames:
    img  = cv2.imread(manualLabeledImageFolder + "/" + filename)
    manualVessels[filename] = img
```

[23]:
```
IMAGE_SHAPE = (999, 960, 3)
TILE_SHAPE = (5, 5, 3)


def imageFeatures(img, img_id):
    return np.array([tileFeatures(tile, img_id) for tile in imageToTiles(img)])

def imageTrainingValues(img):
    return np.array([tileTrainingValue(tile) for tile in imageToTiles(img)])

def tileFeatures(tile, img_id):
    channels = tile.reshape(-1,3)

    mean = np.mean(channels, axis=0)
    std = np.std(channels, axis=0)

    greenChannel = tile[:,:,1]
    centralMomentsKeys = ['mu20', 'mu11', 'mu02', 'mu30', 'mu21', 'mu12',␣
 ↪'mu03']

    moments = cv2.moments(greenChannel)
    centralMoments = [moments[x] for x in centralMomentsKeys]
    huMoments = cv2.HuMoments(moments)[:,0]

    return np.hstack([img_id, mean, std, centralMoments, huMoments])

def tileTrainingValue(tile):
    tileMiddlePointIndex = len(tile)//2
    tileMiddlePoint = tile[tileMiddlePointIndex, tileMiddlePointIndex]
    if any(x > 0 for x in tileMiddlePoint):
        return True
```

```
    else:
        return False

def imageToTiles(img):
    tiles = []
    for i in range(0, IMAGE_SHAPE[1]-5):
        for j in range(0, IMAGE_SHAPE[0]-5):
            tiles.append(img[i:i+5, j:j+5])

    return tiles


# print(splitImage(images['01_h.jpg'], (5,5,3)))
# print(imageFeatures(images['01_h.jpg'])[0])
# print(imageTrainingValues(manualVessels['01_h.jpg']))

allImagesData = []

# for i, image in enumerate(images.values()):
#     allImagesData.append(imageFeatures(image, i))

with Pool() as pool:
    allImagesData = pool.starmap(imageFeatures, zip(images.values(),␣
 ↪[0,1,2,3,4,5,6,7,8,9,10,11,12,13,14]))

with Pool() as pool:
    allImagesTrainingValues = pool.map(imageTrainingValues, manualVessels.
 ↪values())

# allImagesTrainingValues = []
# for image in manualVessels.values():
#     allImagesTrainingValues.append(imageTrainingValues(image))

print("Done")
```

```
Done
```

[24]:
```
allImagesData = np.array(allImagesData).reshape(-1, 21)
allImagesTrainingValues = np.array(allImagesTrainingValues).reshape(-1)


print("Done")
```

```
Done
```

[25]:
```
features = ['img_id', 'avg_r', 'avg_g', 'avg_b', 'std_r', 'std_g', 'std_b',
            'cm_1','cm_2','cm_3','cm_4','cm_5','cm_6',
            'cm_7','hm_1','hm_2','hm_3','hm_4','hm_5',
```

```
            'hm_6','hm_7']

df = pd.DataFrame(allImagesData, columns = features)
df['is_vessel'] = allImagesTrainingValues
df.head(5000000)
```

[25]:

	img_id	avg_r	avg_g	avg_b	std_r	std_g	std_b	\
0	0.0	0.00	0.00	0.00	0.000000	0.000000	0.000000	
1	0.0	0.00	0.00	0.00	0.000000	0.000000	0.000000	
2	0.0	0.00	0.00	0.00	0.000000	0.000000	0.000000	
3	0.0	0.00	0.00	0.00	0.000000	0.000000	0.000000	
4	0.0	0.00	0.00	0.00	0.000000	0.000000	0.000000	
…	…	…	…	…	…	…		
4999995	5.0	2.52	39.24	142.04	1.472956	1.175755	1.708333	
4999996	5.0	2.96	39.40	142.64	1.038460	1.131371	1.162067	
4999997	5.0	3.00	39.56	142.92	0.894427	1.267438	1.197330	
4999998	5.0	2.88	39.88	143.60	0.765245	1.394848	1.697056	
4999999	5.0	3.04	40.32	144.40	0.823650	1.406272	1.939072	

	cm_1	cm_2	cm_3	…	cm_6	cm_7	\
0	0.000000	0.000000	0.000000	…	0.000000	0.000000	
1	0.000000	0.000000	0.000000	…	0.000000	0.000000	
2	0.000000	0.000000	0.000000	…	0.000000	0.000000	
3	0.000000	0.000000	0.000000	…	0.000000	0.000000	
4	0.000000	0.000000	0.000000	…	0.000000	0.000000	
…	…	…	…	…	…	…	
4999995	1957.983690	-27.032620	1991.934760	…	21.318575	-34.732881	
4999996	1976.998985	-13.995939	2003.983756	…	23.851810	-3.585919	
4999997	1985.801820	-5.900910	2018.950455	…	3.336084	-0.130125	
4999998	1998.557673	6.147442	2038.950853	…	-4.861520	-0.052847	
4999999	2017.329365	12.128968	2056.975198	…	-12.937213	-4.390127	

	hm_1	hm_2	hm_3	hm_4	hm_5	\
0	0.000000	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1	0.000000	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00	
2	0.000000	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00	
3	0.000000	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00	
4	0.000000	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00	
…	…	…	…	…	…	
4999995	0.004104	4.400772e-09	9.079326e-12	1.127439e-12	1.513383e-24	
4999996	0.004103	1.605933e-09	6.426963e-12	3.849430e-13	-6.013833e-25	
4999997	0.004094	1.294124e-09	3.080712e-12	1.123190e-12	1.971613e-24	
4999998	0.004062	1.804328e-09	2.728317e-12	4.018175e-12	1.317953e-23	
4999999	0.004010	2.092473e-09	9.481519e-13	6.653168e-12	1.614154e-23	

	hm_6	hm_7	is_vessel
0	0.000000e+00	0.000000e+00	False

```
1         0.000000e+00  0.000000e+00      False
2         0.000000e+00  0.000000e+00      False
3         0.000000e+00  0.000000e+00      False
4         0.000000e+00  0.000000e+00      False
…                  …             …        …
4999995   7.167321e-17 -3.274347e-24      False
4999996  -8.774278e-18 -7.028720e-26      False
4999997  -2.278728e-17  6.913789e-25      False
4999998  -1.706627e-16 -1.817492e-24      False
4999999  -2.386435e-16 -4.322219e-24      False

[5000000 rows x 22 columns]
```

[26]:
```
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(df.drop(['is_vessel'],␣
 ↪axis='columns'),allImagesTrainingValues, test_size=0.2)
```

[27]:
```
undersampler = RandomUnderSampler(sampling_strategy=1, random_state=1)
x_train, y_train = undersampler.fit_resample(x_train, y_train)

classifier = RandomForestClassifier()
classifier.fit(x_train, y_train)
```

[27]:
```
RandomForestClassifier()
```

[28]:
```
classifier.score(x_train,y_train)
```

[28]:
```
0.9999841140520287
```

[161]:
```
predictedImages = {}


for i, imageKey in enumerate(images.keys()):
    imageDf = df[df.img_id == i]
    x_train, y_train = imageDf[features], df.is_vessel
    Y = classifier.predict_proba(x_train)[:,1] > 0.5

    originalImage = images[imageKey][:,:,::-1]
    manualImage = manualVessels[imageKey]

    mask = np.pad(Y.reshape(955, 994), 2)
    mask = np.pad(mask, ((1,0), (1,0)))
    mask = np.dstack([mask] * 3)

    predictedImage = np.broadcast_to([1.0,1.0,1.0], originalImage.shape)
    predictedImage = mask*(predictedImage + originalImage)
    predictedImages[imageKey] = predictedImage
```

```
    fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(20,100))
    ax1.imshow(originalImage)
    ax2.imshow(manualImage)
    ax3.imshow(predictedImage, cmap='gray')
    if i == 4:
        break
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
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floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

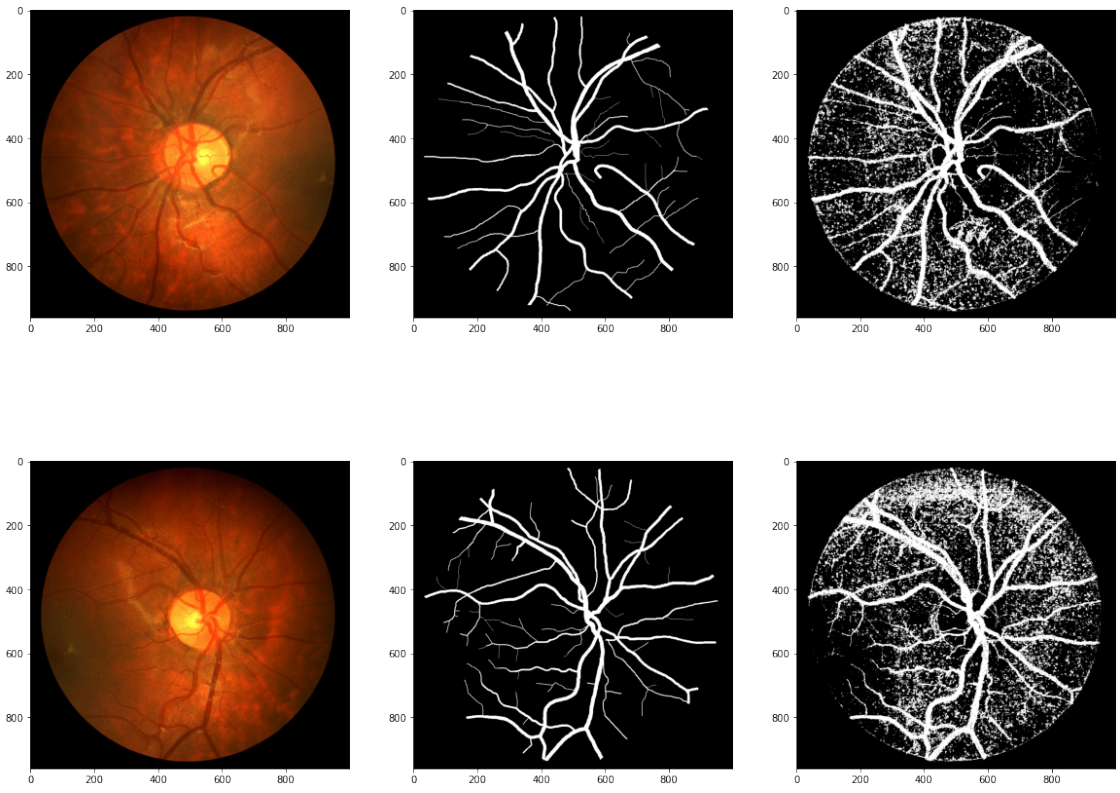

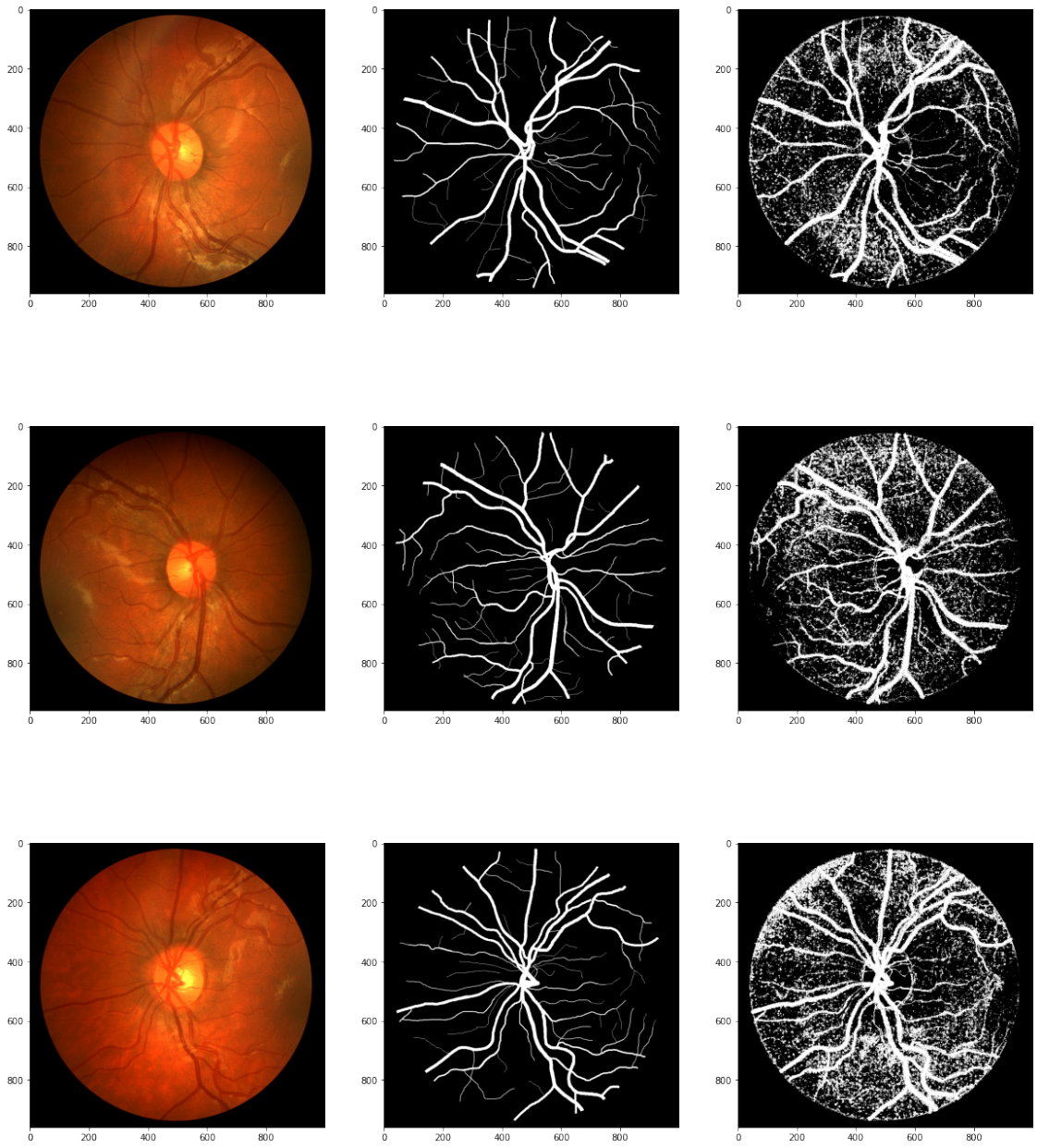

[162]:
```
from sklearn.metrics import confusion_matrix


def summary(vesselsManual, vesselsFound):
    conf = confusion_matrix(vesselsManual.flatten(), vesselsFound.flatten())
    TrueNeg, FalsePos, FalseNeg, TruePos = conf.ravel()

    accuracy = (float (TruePos+TrueNeg) / float(TruePos + TrueNeg + FalsePos +␣
 ↪FalseNeg))
```

```
    sensitivity = (TruePos / float(TruePos + FalseNeg))
    specificity = (TrueNeg / float(TrueNeg + FalsePos))
    geoMean = (sensitivity * specificity)**(1.0/2)

    return (accuracy, sensitivity, specificity, geoMean)
```

[163]:
```
for i, name in enumerate(predictedImages.keys()):
    print(name)
    vesselsFound = predictedImages[name]
    vesselsManual = manualVessels[name][:,:,1]
    _, vesselsManual = cv2.threshold(vesselsManual,10,255,cv2.THRESH_BINARY)
    _, vesselsFound = cv2.threshold(vesselsFound,10,255,cv2.THRESH_BINARY)

    results = summary(vesselsManual,vesselsFound)
    print(f"accuracy: {results[0]} sensitivity: {results[1]} specificity:␣
 ↪{results[2]} geoMean: {results[3]}")
    if i==4:
        break
```

```
01_h.jpg
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Input In [163], in <cell line: 1>()
      5 _, vesselsManual = cv2.threshold(vesselsManual,10,255,cv2.THRESH_BINARY
      6 _, vesselsFound = cv2.threshold(vesselsFound,10,255,cv2.THRESH_BINARY)
----> 8 results = summary(vesselsManual,vesselsFound)
      9 print(f"accuracy: {results[0]} sensitivity: {results[1]} specificity:␣
 ↪{results[2]} geoMean: {results[3]}")
     10 if i==4:

Input In [162], in summary(vesselsManual, vesselsFound)
      4 def summary(vesselsManual, vesselsFound):
----> 5     conf =␣
 ↪confusion_matrix(vesselsManual.flatten(), vesselsFound.flatten())
      6     TrueNeg, FalsePos, FalseNeg, TruePos = conf.ravel()
      8     accuracy = (float (TruePos+TrueNeg) / float(TruePos + TrueNeg +␣
 ↪FalsePos + FalseNeg))

File ~/.local/lib/python3.10/site-packages/sklearn/metrics/_classification.py:
 ↪307, in confusion_matrix(y_true, y_pred, labels, sample_weight, normalize)
    222 def confusion_matrix(
    223     y_true, y_pred, *, labels=None, sample_weight=None, normalize=None
    224 ):
    225     """Compute confusion matrix to evaluate the accuracy of a␣
 ↪classification.
    226
```

```
    227     By definition a confusion matrix :math:`C` is such that :math:`C_{i
 ↪j}`
   (…)
    305     (0, 2, 1, 1)
    306     """
--> 307     y_type, y_true, y_pred = _check_targets(y_true, y_pred)
    308     if y_type not in ("binary", "multiclass"):
    309         raise ValueError("%s is not supported" % y_type)

File ~/.local/lib/python3.10/site-packages/sklearn/metrics/_classification.py:
 ↪84, in _check_targets(y_true, y_pred)
     57 def _check_targets(y_true, y_pred):
     58     """Check that y_true and y_pred belong to the same classification
 ↪task.
     59
     60     This converts multiclass or binary types to a common shape, and
 ↪raises a
   (…)
     82     y_pred : array or indicator matrix
     83     """
---> 84     check_consistent_length(y_true, y_pred)
     85     type_true = type_of_target(y_true)
     86     type_pred = type_of_target(y_pred)

File ~/.local/lib/python3.10/site-packages/sklearn/utils/validation.py:332, in
 ↪check_consistent_length(*arrays)
    330 uniques = np.unique(lengths)
    331 if len(uniques) > 1:
--> 332     raise ValueError(
    333         "Found input variables with inconsistent numbers of samples: %r
    334         % [int(l) for l in lengths]
    335     )

ValueError: Found input variables with inconsistent numbers of samples: [959040
 ↪2877120]
```

[ ]: