HUB4045F - Liam Breytenbach - BRYLIA002 - Assignment 4

August 28, 2025

#

HUB4045F - Liam Breytenbach - BRYLIA002 - Assignment 4:

13 May 2023

#

Necessary Packages:

- Scipy
- Numpy
- OpenCV
- Pydicom
- Matplotlib
- Trimesh

#

Viewing Installed Packages

[1]:
```
pip list
```

```
Package                            Version
---------------------------------- -------------------
alabaster                          0.7.12
anaconda-client                    1.7.2
anaconda-navigator                 1.9.12
anaconda-project                   0.8.3
argh                               0.26.2
asn1crypto                         1.3.0
astroid                            2.3.3
astropy                            4.0
atomicwrites                       1.3.0
attrs                              19.3.0
autopep8                           1.4.4
Babel                              2.8.0
backcall                           0.1.0
backports.functools-lru-cache      1.6.1
backports.shutil-get-terminal-size 1.0.0
backports.tempfile                 1.0
backports.weakref                  1.0.post1
```

bcrypt	3.1.7
beautifulsoup4	4.8.2
bitarray	1.2.1
bkcharts	0.2
bleach	3.1.0
bokeh	1.4.0
boto	2.49.0
Bottleneck	1.3.2
certifi	2019.11.28
cffi	1.14.0
chardet	3.0.4
Click	7.0
cloudpickle	1.3.0
clyent	1.2.2
colorama	0.4.3
comtypes	1.1.7
conda	4.8.2
conda-build	3.18.11
conda-package-handling	1.6.0
conda-verify	3.4.2
contextlib2	0.6.0.post1
cryptography	2.8
cycler	0.10.0
Cython	0.29.15
cytoolz	0.10.1
dask	2.11.0
decorator	4.4.1
defusedxml	0.6.0
diff-match-patch	20181111
distributed	2.11.0
docutils	0.16
entrypoints	0.3
et-xmlfile	1.0.1
fastcache	1.1.0
filelock	3.0.12
flake8	3.7.9
Flask	1.1.1
freetype-py	2.4.0
fsspec	0.6.2
future	0.18.2
gevent	1.4.0
glob2	0.7
greenlet	0.4.15
h5py	2.10.0
HeapDict	1.0.1
html5lib	1.0.1
hypothesis	5.5.4
idna	2.8

imageio	2.6.1
imagesize	1.2.0
importlib-metadata	1.5.0
importlib-resources	5.12.0
intervaltree	3.0.2
ipydatawidgets	4.3.3
ipykernel	5.1.4
ipython	7.12.0
ipython-genutils	0.2.0
ipywidgets	7.5.1
isort	4.3.21
itsdangerous	1.1.0
jdcal	1.4.1
jedi	0.14.1
Jinja2	2.11.1
joblib	0.14.1
json5	0.9.1
jsonschema	3.2.0
jupyter	1.0.0
jupyter-client	5.3.4
jupyter-console	6.1.0
jupyter-core	4.6.1
jupyterlab	1.2.6
jupyterlab-server	1.0.6
keyring	21.1.0
kiwisolver	1.1.0
lazy-object-proxy	1.4.3
libarchive-c	2.8
llvmlite	0.31.0
locket	0.2.0
lxml	4.5.0
MarkupSafe	1.1.1
matplotlib	3.1.3
mccabe	0.6.1
menuinst	1.4.16
mistune	0.8.4
mkl-fft	1.0.15
mkl-random	1.1.0
mkl-service	2.3.0
mock	4.0.1
more-itertools	8.2.0
mpmath	1.1.0
msgpack	0.6.1
multipledispatch	0.6.0
navigator-updater	0.2.1
nbconvert	5.6.1
nbformat	5.0.4
networkx	2.4

nltk	3.4.5
nose	1.3.7
notebook	6.0.3
numba	0.48.0
numexpr	2.7.1
numpy	1.18.1
numpydoc	0.9.2
olefile	0.46
opencv-python	4.7.0.72
openpyxl	3.0.3
packaging	20.1
pandas	1.0.1
pandocfilters	1.4.2
paramiko	2.7.1
parso	0.5.2
partd	1.1.0
path	13.1.0
pathlib2	2.3.5
pathtools	0.1.2
patsy	0.5.1
pep8	1.7.1
pexpect	4.8.0
pickleshare	0.7.5
Pillow	7.0.0
pip	20.0.2
pkginfo	1.5.0.1
platformdirs	3.5.1
pluggy	0.13.1
ply	3.11
pooch	1.7.0
prometheus-client	0.7.1
prompt-toolkit	3.0.3
psutil	5.6.7
py	1.8.1
pycodestyle	2.5.0
pycosat	0.6.3
pycparser	2.19
pycrypto	2.6.1
pycurl	7.43.0.5
pydicom	2.3.1
pydocstyle	4.0.1
pyflakes	2.1.1
pyglet	2.0.7
Pygments	2.5.2
pylint	2.4.4
PyNaCl	1.3.0
pyodbc	4.0.0-unsupported
PyOpenGL	3.1.0

pyOpenSSL	19.1.0
pyparsing	2.4.6
pyreadline	2.1
pyrender	0.1.45
pyrsistent	0.15.7
PySocks	1.7.1
pytest	5.3.5
pytest-arraydiff	0.3
pytest-astropy	0.8.0
pytest-astropy-header	0.1.2
pytest-doctestplus	0.5.0
pytest-openfiles	0.4.0
pytest-remotedata	0.3.2
python-dateutil	2.8.1
python-jsonrpc-server	0.3.4
python-language-server	0.31.7
pythreejs	2.4.2
pytz	2019.3
pyvista	0.38.6
pyvistaqt	0.10.0
PyWavelets	1.1.1
pywin32	227
pywin32-ctypes	0.2.0
pywinpty	0.5.7
PyYAML	5.3
pyzmq	18.1.1
QDarkStyle	2.8
QtAwesome	0.6.1
qtconsole	4.6.0
QtPy	1.9.0
requests	2.22.0
rope	0.16.0
Rtree	0.9.3
ruamel-yaml	0.15.87
scikit-image	0.16.2
scikit-learn	0.22.1
scipy	1.4.1
scooby	0.7.2
seaborn	0.10.0
Send2Trash	1.5.0
setuptools	45.2.0.post20200210
simplegeneric	0.8.1
singledispatch	3.4.0.3
six	1.14.0
snowballstemmer	2.0.0
sortedcollections	1.1.2
sortedcontainers	2.1.0
soupsieve	1.9.5

```
Sphinx                             2.4.0
sphinxcontrib-applehelp            1.0.1
sphinxcontrib-devhelp              1.0.1
sphinxcontrib-htmlhelp             1.0.2
sphinxcontrib-jsmath               1.0.1
sphinxcontrib-qthelp               1.0.2
sphinxcontrib-serializinghtml      1.1.3
sphinxcontrib-websupport           1.2.0
spyder                             4.0.1
spyder-kernels                     1.8.1
SQLAlchemy                         1.3.13
statsmodels                        0.11.0
sympy                              1.5.1
tables                             3.6.1
tblib                              1.6.0
terminado                          0.8.3
testpath                           0.4.4
toolz                              0.10.0
tornado                            6.0.3
tqdm                               4.42.1
traitlets                          4.3.3
traittypes                         0.2.1
trimesh                            3.21.6
typing-extensions                  4.5.0
ujson                              1.35
unicodecsv                         0.14.1
urllib3                            1.25.8
vtk                                9.2.6
watchdog                           0.10.2
wcwidth                            0.1.8
webencodings                       0.5.1
Werkzeug                           1.0.0
wheel                              0.34.2
widgetsnbextension                 3.5.1
win-inet-pton                      1.1.0
win-unicode-console                0.5
wincertstore                       0.2
wrapt                              1.11.2
xlrd                               1.2.0
XlsxWriter                         1.2.7
xlwings                            0.17.1
xlwt                               1.3.0
xmltodict                          0.12.0
yapf                               0.28.0
zict                               1.0.0
zipp                               3.15.0
Note: you may need to restart the kernel to use updated packages.
```

1 Question 1 [20 marks]: Segmentation

2 A)

[2]:
```
pip install opencv-python
```

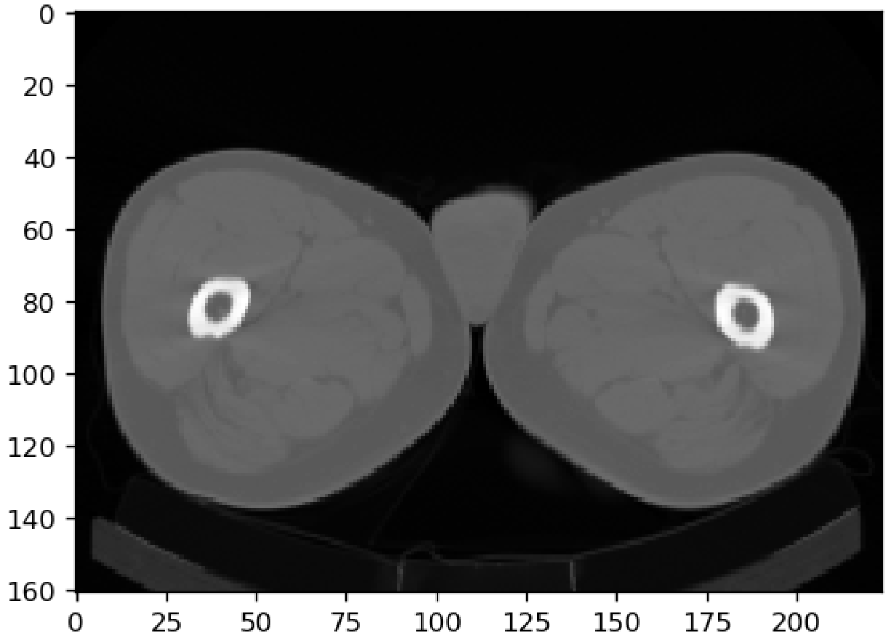
```
Requirement already satisfied: opencv-python in
c:\users\starl\anaconda3\lib\site-packages (4.7.0.72)
Requirement already satisfied: numpy>=1.17.0; python_version >= "3.7" in
c:\users\starl\anaconda3\lib\site-packages (from opencv-python) (1.18.1)
Note: you may need to restart the kernel to use updated packages.
```

[3]:
```
# Import necessary packages
from __future__ import division
import cv2, numpy as np
from matplotlib import pyplot as plt, cm


## Install dicom reader package if necessary

import sys

!{sys.executable} -m pip install pydicom

import pydicom as DCM
import matplotlib.pyplot as plt

# read image file into program
dicom_image_file_0 = DCM.read_file('CTimage.dcm')
```

```
Requirement already satisfied: pydicom in c:\users\starl\anaconda3\lib\site-
packages (2.3.1)
```

[4]:
```
# CT image
I_ct = dicom_image_file_0.pixel_array

#Display the MR Image
plt.figure(dpi=120)
plt.imshow(I_ct,'gray')
```

[4]:
```
<matplotlib.image.AxesImage at 0x248d5d7f288>
```



[5]:
```
########   For future Use   ########
I_ct_n = cv2.normalize(I_ct,I_ct,0,255,cv2.NORM_MINMAX) # rescale dynamic range:
 ↪ 0-255
I_ct_he = cv2.equalizeHist(cv2.convertScaleAbs(I_ct_n)) # int16 -> uint8
hist_obj = cv2.createCLAHE(clipLimit=2, tileGridSize=(18,18))
I_ct_hea = hist_obj.apply(cv2.convertScaleAbs(I_ct_n))

#noise reduction
I_ct_hea_avg = cv2.blur(I_ct_hea,(5,5))
I_ct_hea_med = cv2.medianBlur(I_ct_hea,5)
I_ct_hea_nlm = cv2.fastNlMeansDenoising(I_ct_hea,2,7,35)
I_ct_hea_test = cv2.fastNlMeansDenoising(I_ct_hea,100,1,80)

#erosion
kernel = np.ones((5,5),np.uint8)
I_ct_hea_nlm_erosion = cv2.erode(I_ct_hea_nlm, kernel,iterations=1)

#dilation
I_ct_hea_nlm_dilation = cv2.dilate(I_ct_hea_nlm, kernel,iterations=1)


#opening
opening = cv2.morphologyEx(I_ct_hea_nlm, cv2.MORPH_OPEN, kernel)

#closing
```

```
closing = cv2.morphologyEx(I_ct_hea_nlm, cv2.MORPH_CLOSE, kernel)

#gradient
gradient = cv2.morphologyEx(I_ct_hea_nlm, cv2.MORPH_GRADIENT, kernel)

#tophat
tophat = cv2.morphologyEx(I_ct_hea_nlm, cv2.MORPH_TOPHAT, kernel)

#blackhat
blackhat = cv2.morphologyEx(I_ct_hea_nlm, cv2.MORPH_BLACKHAT, kernel)
```

3 B)

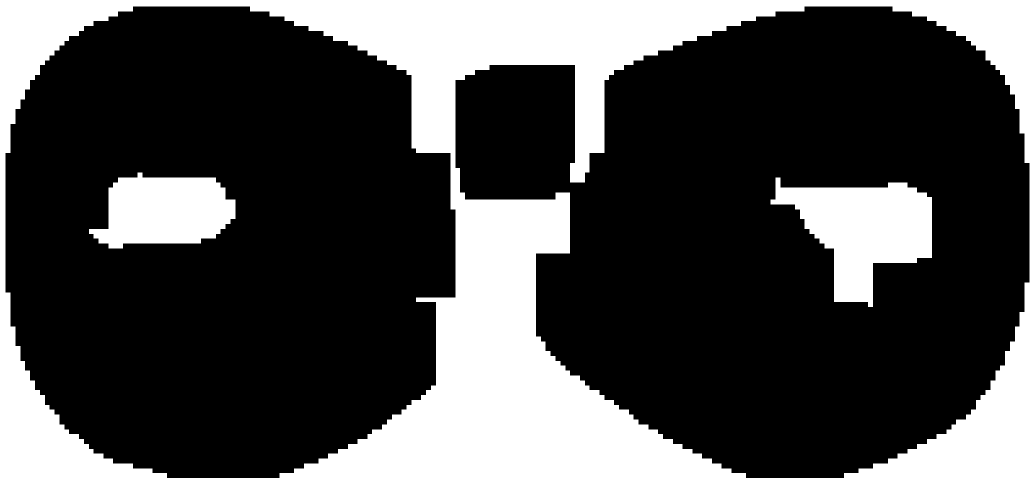
[6]:

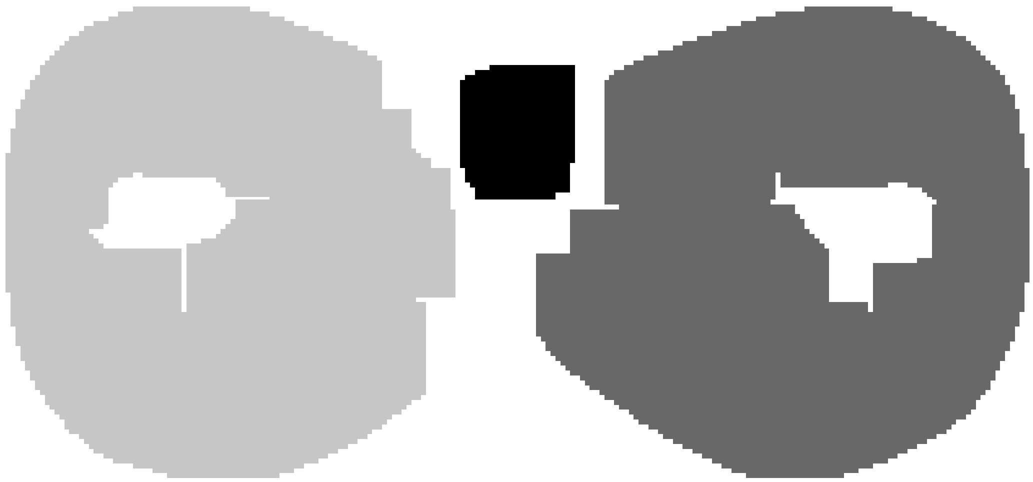
```
# Function used to show relevant images in graw scale
# This function is taken from ipython-books (Refferenced at the end)
def show(img, cmap=None):
    cmap = cmap or plt.cm.gray
    fig, ax = plt.subplots(1, 1, figsize=(8, 6))
    ax.imshow(img, cmap=cmap)
    ax.set_axis_off()
    plt.show()
```

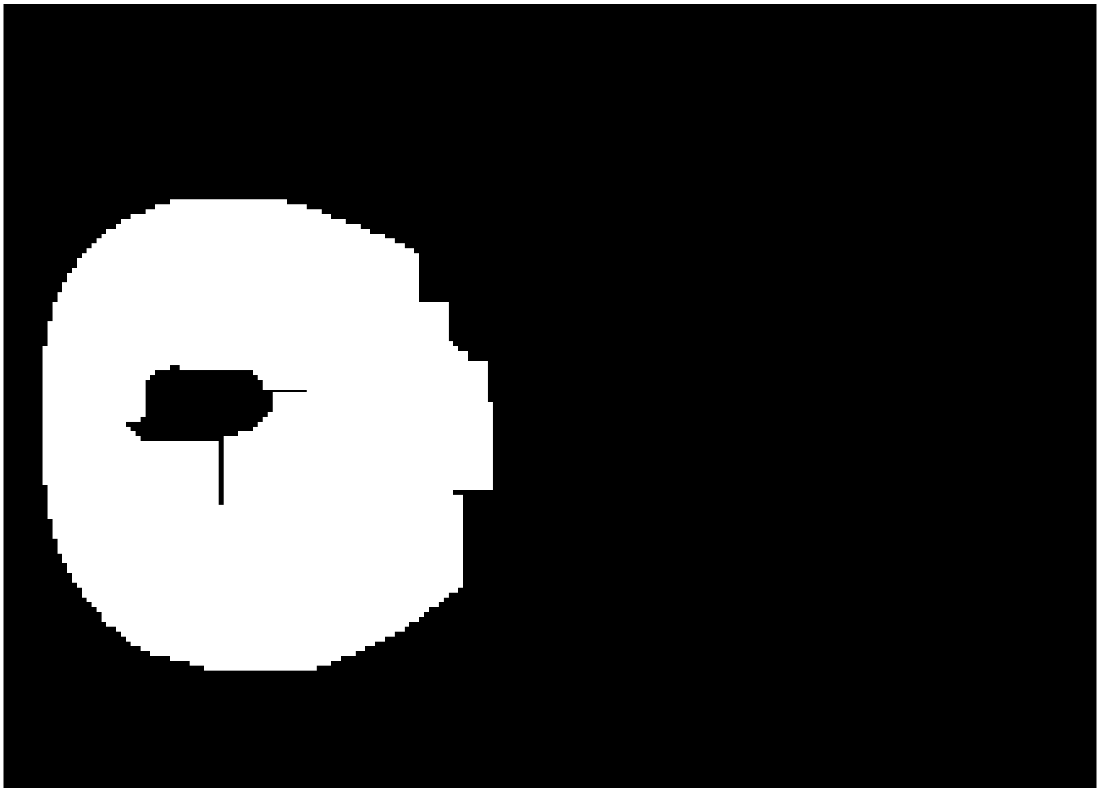
[7]:

```
from skimage.feature import canny
from skimage import data
import matplotlib.pyplot as plt
import numpy as np
from skimage.filters import threshold_otsu
from skimage.segmentation import clear_border
from skimage.morphology import label, closing, square
from skimage.measure import label, regionprops
import trimesh
import pydicom as dicom

%matplotlib inline


#Fething the Image
leg_segment = I_ct

# Image enhancement (adjust the image through erosion and dilation)
I_ct_ntt = cv2.normalize(leg_segment, leg_segment,0,255,cv2.NORM_MINMAX) #␣
 ↪rescale dynamic range: 0-255
I_ct_heatt = hist_obj.apply(cv2.convertScaleAbs(I_ct_ntt))
I_ct_hea_nlmtt = cv2.fastNlMeansDenoising(I_ct_heatt,2,5,90)
I_ct_hea_nlm_erosiontt = cv2.erode(I_ct_hea_nlmtt, kernel,iterations=4)
```

```
I_ct_hea_nlm_dilationtt = cv2.dilate(I_ct_hea_nlm_erosiontt,␣
↪kernel,iterations=4)

#Displaying the Image Enhancement
show(I_ct_hea_nlm_dilationtt < 99)

#Creating a variable to store the desired appearance
x = I_ct_hea_nlm_dilationtt > 99

#Dividing the Segmented Regions into Individual Parts
labels = label(x)
img_bin = clear_border(labels)
show(img_bin, 'Greys')

#Creating an array of the Segmented Parts
regions = regionprops(labels)
boxes = np.array([label['BoundingBox']
                  for label in regions
                  if label['Area'] > 1])


# Getting the first item in the Segmented Parts array
first_box = boxes[0]

# Creating a binary mask with the same shape as the labeled regions
mask = np.zeros((labels.shape[0], labels.shape[1], 3), dtype=np.uint8)

#Storing portion of mask for future calculations
l = labels == 1

# Making the mask white
mask[labels == 1] = (255,255,255)

# Setting all other pixels as black
mask[mask != 255] = 0

#Displaying The Isolated leg on the left in white
show(mask)



left_leg_segment = mask
```



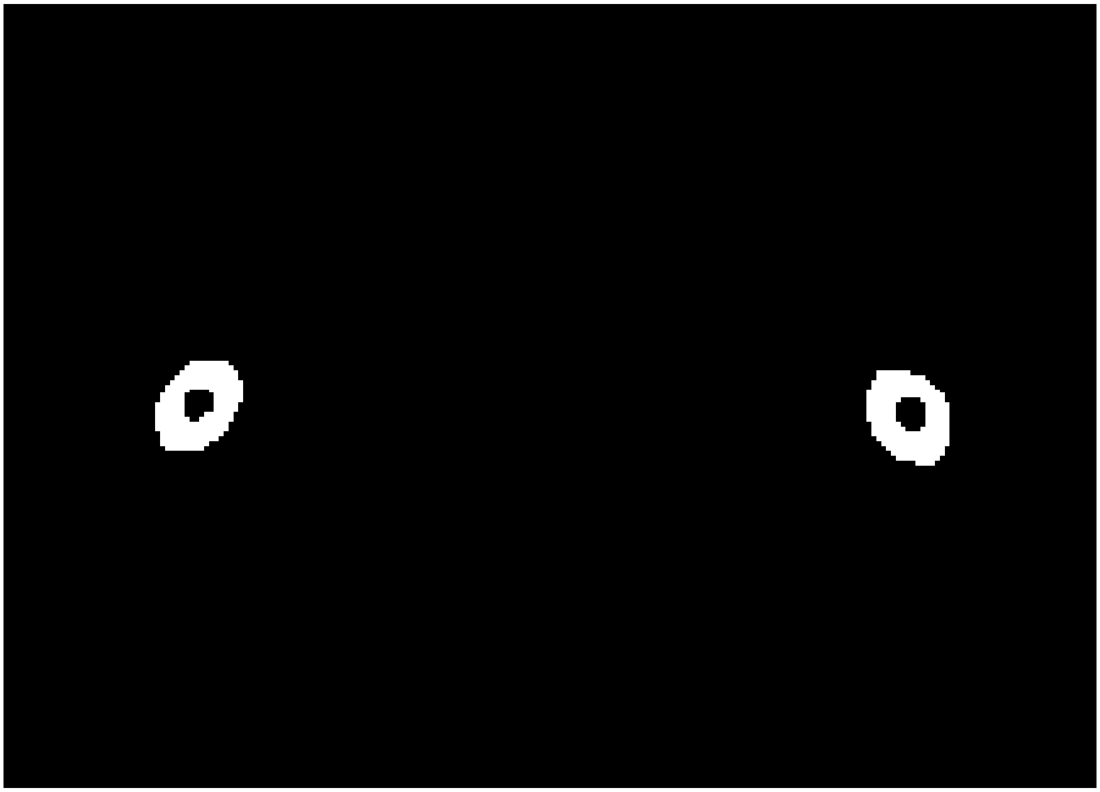


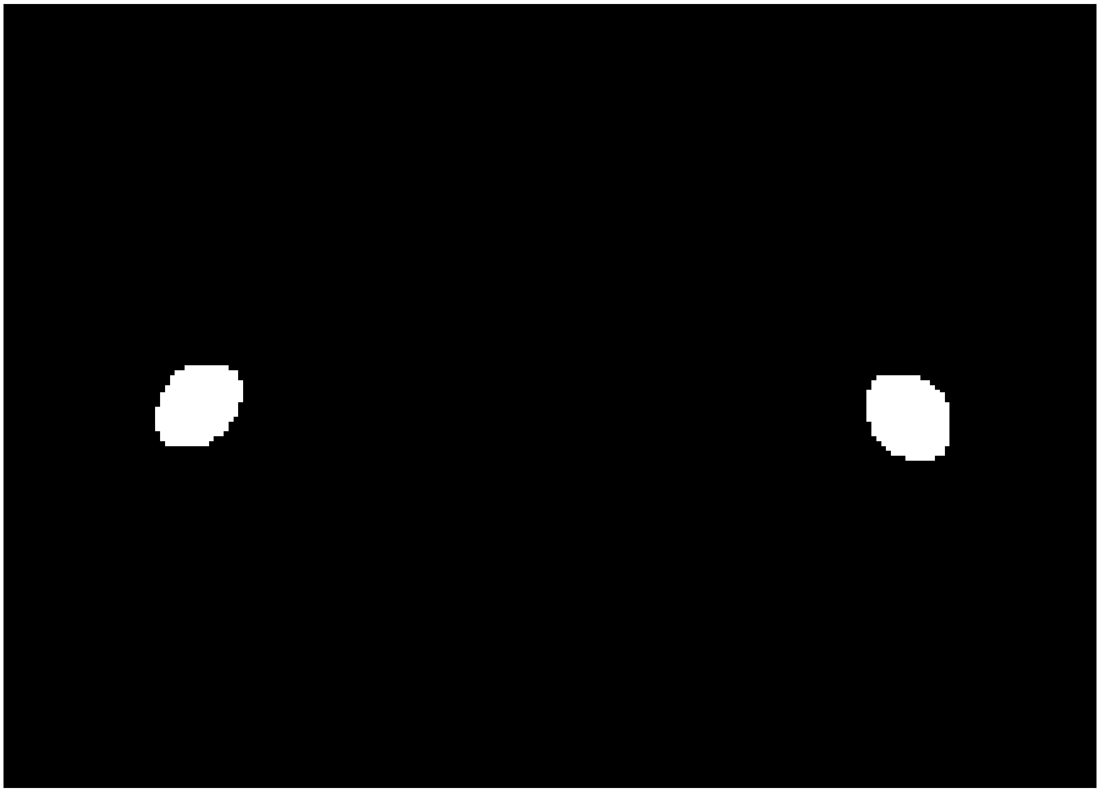


4 C)

[8]:
```
from skimage.feature import canny
from skimage import data
import matplotlib.pyplot as plt
import numpy as np
from skimage.filters import threshold_otsu
from skimage.segmentation import clear_border
from skimage.morphology import label, closing, square
%matplotlib inline

#Fetching Original Image
bone = I_ct

#Displaying Bone after Threshold is applied
threshold_otsu(bone)
show(bone > 115)

#Finding the Edges and Filling in the Holes
edges = canny(bone/255.)
```

```python
from scipy import ndimage as ndi
fill_bone = ndi.binary_fill_holes(edges)

#Processing the Image and clearing the borders
img_bone = clear_border(closing(fill_bone > 0, square(3)))
show(img_bone)



#Creating a variable to store the desired appearance
x = img_bone

#Dividing the Segmented Regions into Individual Parts
labels = label(x)
img_bin = clear_border(labels)
show(img_bin, 'Greys')

#Creating an array of the Segmented Parts
regions = regionprops(labels)
boxes = np.array([label['BoundingBox']
                  for label in regions
                  if label['Area'] > 1])


# Getting the first item in the Segmented Parts array
first_box = boxes[0]

# Creating a binary mask with the same shape as the labeled regions
mask = np.zeros((labels.shape[0], labels.shape[1], 3), dtype=np.uint8)


#Storing portion of mask for future calculations
b = labels == 1

# Making the mask yellow
mask[labels == 1] = (220, 200, 1)

# Setting all other pixels as black
mask[mask != (220, 200, 1)] = 0

#Displaying The Isolated leg on the left in white
show(mask)

left_bone_segment = mask
```





5 D)

[9]:
```
# Apply threshold to obtain binary mask
segmented_bone_mask = b

# Calculate the Area of the segmented region
segmented_bone_area = np.sum(segmented_bone_mask)

# Print the calculated Area
print("Segmented Left Bone area:", segmented_bone_area)


# Apply threshold to obtain binary mask of Leg Area
segmented_leg_mask = l

# Calculate the Total Area
segmented_leg_area = np.sum(segmented_leg_mask)

# Print the calculated Total Area
print("Total Left Leg area:", segmented_leg_area)
```

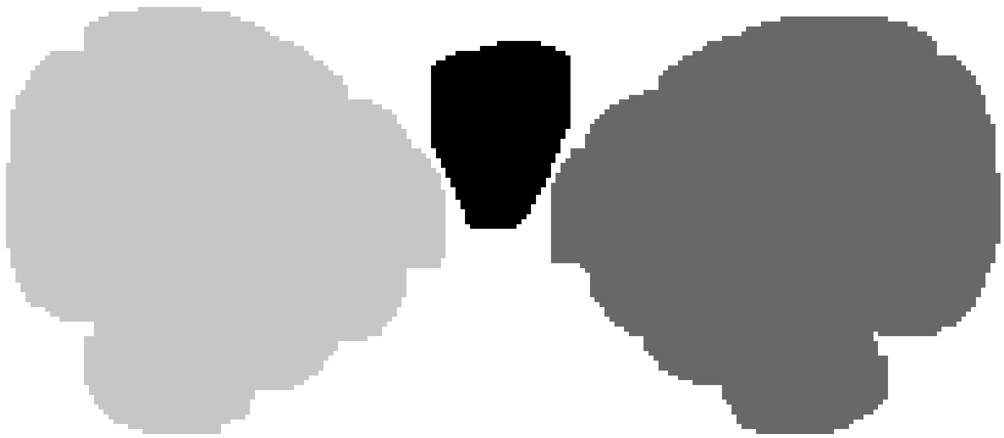
```python
#Percentage of Leg Area
percentage = round((segmented_bone_area/segmented_leg_area)*100, 2)
print(f"The left bone area is {percentage} % of the left leg area")
```

```
Segmented Left Bone area: 246
Total Left Leg area: 6944
The left bone area is 3.54 % of the left leg area
```

6 E)

[10]:
```python
#Fething the Image
muscle_segment = I_ct

# Image enhancement (adjust the image through erosion and dilation)
I_ct_ntt = cv2.normalize(muscle_segment, muscle_segment,0,255,cv2.NORM_MINMAX)␣
↪# rescale dynamic range: 0-255
I_ct_heatt = hist_obj.apply(cv2.convertScaleAbs(I_ct_ntt))
I_ct_hea_nlmtt = cv2.fastNlMeansDenoising(I_ct_heatt,2,7,35)
I_ct_hea_nlm_erosiontt = cv2.erode(I_ct_ntt, kernel,iterations=1)
I_ct_hea_nlm_dilationtt = cv2.dilate(I_ct_hea_nlm_erosiontt,␣
↪kernel,iterations=2)

#Displaying the Image Enhancement
show(I_ct_hea_nlm_dilationtt <94)

#Creating a variable to store the desired appearance
x = I_ct_hea_nlm_dilationtt > 94

#Dividing the Segmented Regions into Individual Parts
labels = label(x)
img_bin = clear_border(labels)
show(img_bin, 'Greys')

#Creating an array of the Segmented Parts
regions = regionprops(labels)
boxes = np.array([label['BoundingBox']
                  for label in regions
                  if label['Area'] > 1])


# Getting the first item in the Segmented Parts array
first_box = boxes[0]

# Creating a binary mask with the same shape as the labeled regions
```

```
mask = np.zeros((labels.shape[0], labels.shape[1], 3), dtype=np.uint8)


#Storing portion of mask for future calculations
m = labels == 1

# Making the mask red
mask[labels == 1] = (170,0,0)

# Setting all other pixels as black
mask[mask != (170,0,0)] = 0

#Displaying The Isolated Muscle on the left in red
show(mask)



left_muscle_segment = mask
```



7 F)

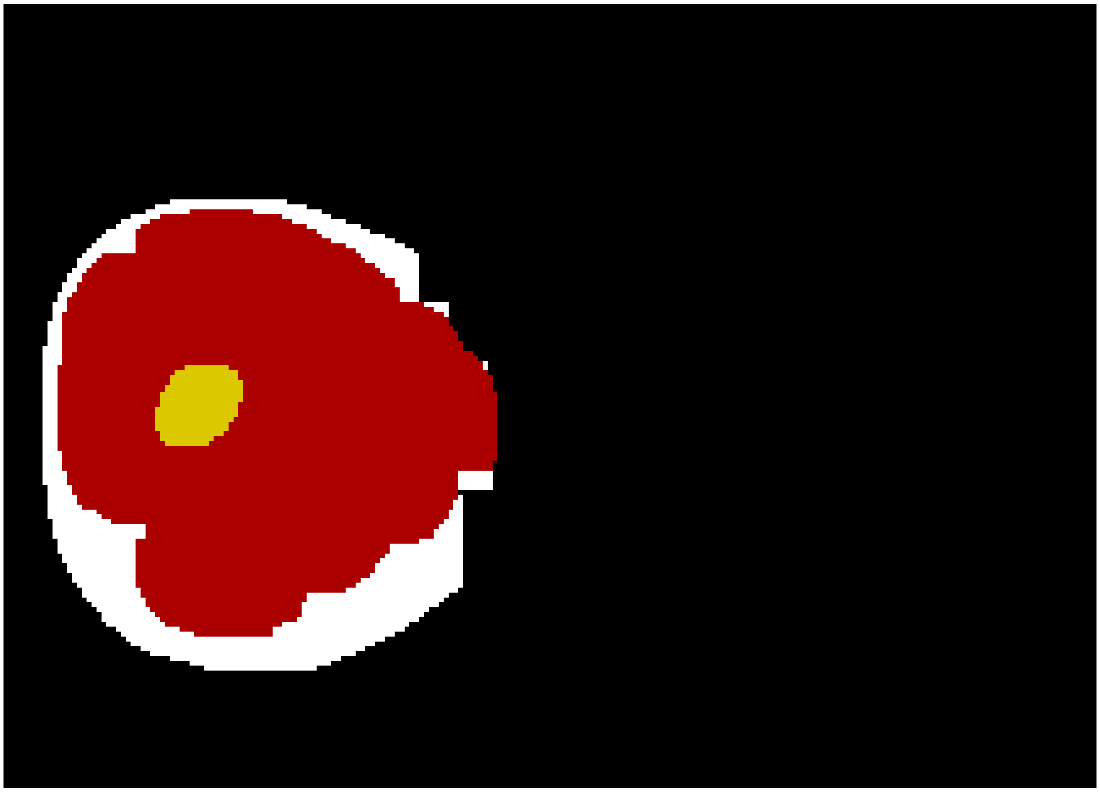
[11]:
```
# Apply threshold to obtain binary mask
segmented_muscle_mask = m

# Calculate the Area of the segmented region
segmented_muscle_area = np.sum(segmented_muscle_mask)

# Print the calculated Area
print("Segmented Left Muscle area:", segmented_muscle_area)




# Apply threshold to obtain binary mask of Leg Area
segmented_leg_mask = l

# Calculate the Total Area
segmented_leg_area = np.sum(segmented_leg_mask)
```

```python
# Print the calculated Total Area
print("Total Left Leg area:", segmented_leg_area)


#Percentage of Leg Area
percentage = round((segmented_muscle_area/segmented_leg_area)*100, 2)
print(f"The left muscle area is {percentage} % of the left leg area")
```

```
Segmented Left Muscle area: 5739
Total Left Leg area: 6944
The left muscle area is 82.65 % of the left leg area
```

8 Segemented Image

[12]:
```python
import numpy as np
import matplotlib.pyplot as plt
from skimage.measure import label, regionprops


# Create an empty array for the overlay
overlay = np.zeros((labels.shape[0], labels.shape[1], 3), dtype=np.uint8)

# Overlay the leg mask
mask1 = l
overlay[mask1] = (255, 255, 255)

# Overlay the muscle
mask2 = m
overlay[mask2] = (170,0,0)

# Overlay the bone mask
mask3 = b
overlay[mask3] = (220, 200, 1)

# Display the overlay
show(overlay)
```



9 Question 2 [10 marks]: Import surfaces

[13]:
```
pip install trimesh
```

```
Requirement already satisfied: trimesh in c:\users\starl\anaconda3\lib\site-
packages (3.21.6)
Requirement already satisfied: numpy in c:\users\starl\anaconda3\lib\site-
packages (from trimesh) (1.18.1)
Note: you may need to restart the kernel to use updated packages.
```

10 A)

[14]:
```
import trimesh

# Load the surface meshes
femur1 = 'femur1.stl'
mesh1 = trimesh.load_mesh(femur1)
mesh1.show()
```

[14]: <IPython.core.display.HTML object>

[15]:
```
# Load the surface meshes
femur2 = 'femur2.stl'
mesh2 = trimesh.load_mesh(femur2)
mesh2.show()
```

[15]: <IPython.core.display.HTML object>

11 B)

In order to compare the shapes of the two femurs the requirements would be to find the correspondence between corresponding points or regions on the surfaces. Correspondence means establishing a mapping or alignment between corresponding points, edges, or regions on different surfaces. This involves image registration, where similar attributes in the two images line up perfectly to identify corresponding landmarks or regions on the surfaces. By establishing correspondence, we can then analyze the differences and similarities between the shapes of the two femurs.

12 C)

12.0.1 i)

[16]:
```
# Finding the number of vertices on each femur
vertices_femur1 = mesh1.vertices.shape[0]
vertices_femur2 = mesh2.vertices.shape[0]

#Printing Result
print(f"Femur 1 has {vertices_femur1} vertices")
print(f"Femur 2 has {vertices_femur2} vertices")
```

```
Femur 1 has 1000 vertices
Femur 2 has 1000 vertices
```

12.0.2 ii)

[17]:
```
# Finding the number of vertices on each femur
faces_femur1 = mesh1.faces.shape[0]
faces_femur2 = mesh2.faces.shape[0]

#Printing Result
print(f"Femur 1 has {faces_femur1} faces")
print(f"Femur 2 has {faces_femur2} faces")
```

```
Femur 1 has 1996 faces
Femur 2 has 1996 faces
```

12.0.3 iii)

If the number of vertices, faces and edges between the 2 femurs are equal, and the connectivity between the surfaces are also equal, we can say the the 2 femurs are Iso-Topological.

[18]:
```
# Counting the number edges for each femur
edges_femur1 = len(mesh1.edges) // 2
edges_femur2 = len(mesh2.edges) // 2

iso_topological = False

# Comparing the counts
if vertices_femur1 == vertices_femur2 and faces_femur1 == faces_femur2 and␣
↪edges_femur1 == edges_femur2:
    # Comparing the connectivity of the surfaces
    for vertex in range(len(mesh1.vertices)):
        neighbors1 = set(mesh1.vertex_neighbors[vertex])
        neighbors2 = set(mesh2.vertex_neighbors[vertex])

        if neighbors1 != neighbors2:
            iso_topological = False
            break
        else:
            iso_topological = True
else:
    iso_topological = False

if iso_topological == True:
    print ("Femur 1 and Femur 2 are Iso-Topological")
else:
    print("Femur 1 and Femur 2 are not Iso-Topological")
```

```
Femur 1 and Femur 2 are Iso-Topological
```

13 Question 3 [20 marks]: Shape matching

13.0.1 A) Direct Method

13.0.2 i)

[19]:
```
#Creating array to hold the average positions
average_positions = []


#Iterating through the femur1 and femur2 vertices to find the average of each
for i in range(len(mesh1.vertices)):
    vertex1 = mesh1.vertices[i]
    vertex2 = mesh2.vertices[i]
```

```python
    average_position = (vertex1 + vertex2) / 2
    average_positions.append(average_position)

# Array of the average positions
average_positions = np.array(average_positions)


# Printing the average positions
for position in average_positions:
    print(position)
```

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13.0.3 ii)

[20]:
```python
#Creating a mesh from the average positions
average_meshA = trimesh.Trimesh(vertices = average_positions, faces = mesh1.
 ↪faces)

# Displaying the average surface
average_meshA.show()
```

[20]: <IPython.core.display.HTML object>

13.0.4 iii)

The resulting average surface display above does look like a representative shape that would describe the 2 surfaces in our dataset. Just from inspection of femur1 and femur2 displayed in Q3i, we can see that the overall image looks similar when rotated. We can also see that from the starting orientation (the pose) of the combined image is a combination of the starting orientation of femur1 and femur2. This can be seen bellow.

$$Femur1$$

$$Femur2$$

$$FemurAverage$$

13.0.5 B) Rigid alignment method

13.0.6 i)

[56]:
```python
from scipy.spatial import procrustes

# Getting the vertices of each mesh
vertices1 = mesh1.vertices
vertices2 = mesh2.vertices

# Performing Procrustes analysis
mtx1, mtx2, disparity = procrustes(vertices1, vertices2)

print(disparity)
```

```
#Creating a mesh from the average positions
average_meshB = trimesh.Trimesh(vertices = mtx2, faces = mesh2.faces)

# Displaying the average surface
average_meshB.show()
```

0.0014234619899051635

[56]: <IPython.core.display.HTML object>

13.0.7 C)

[57]:
```
# Creating a scene and adding the meshes obtained from Q3A and B
scene = trimesh.Scene([average_meshA, average_meshB])

# Displaying the scene
scene.show()
```

[57]: <IPython.core.display.HTML object>

13.0.8 D)

To improve the registration process, we can normalize and preprocess the meshes. We can preprocess the meshes by normalizing their scale, orientation, and position. This makes sure that the meshes are in a consistent coordinate system that ensures their initial alignments are the same. We can also apply noise reduction, smoothing, or other preprocessing techniques to enhance the quality of the meshes.

Incorporating additional information such as color or texture information into the registration process can provide further indications for mis-alignment and improve the registration accuracy.

By incorporating these techniques, data characteristics and desired registration accuracy can be obtained for specific medical purposes.

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