Department of Electrical
& Computer Engineering
Faculty of Engineering & Architectural Science

Course Title:	Biomedical Image Analysis
Course Number:	BME 872
Semester:	Winter 2021

Instructor:	April Khademi
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Assignment/Lab Title:	Medical Image Management, Histograms and Point Operations

Due Date:	February 7th, 2021
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2.1 Loading, Saving and Viewing Medical Images

1. **Medical Image Viewing and Loading**

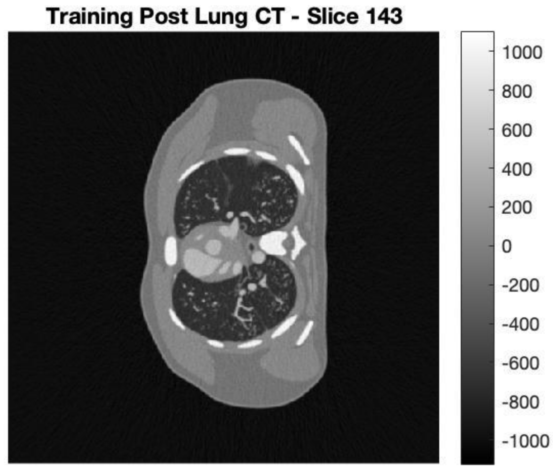

Figure 1: Slice from the middle of the lung CT scan

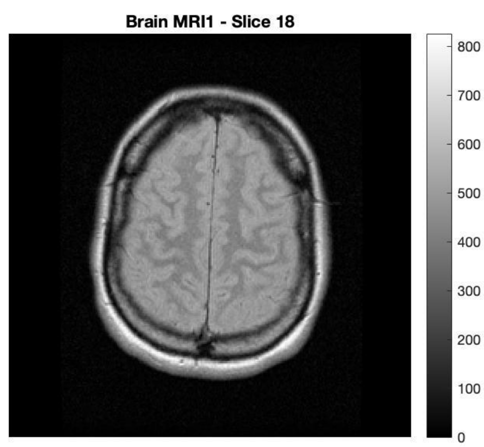

Figure 2: Slice 18 of brainMRI1

The intensity value and ranges in this image indicate the values that are in each pixel of the image. The pixels for this image range between approximately -1100 and 1100 for the lung CT scan and between 0 and 800 approximately for the neurological MRI. In these images the lower end range is represented by black and the upper end range is being represented with white.

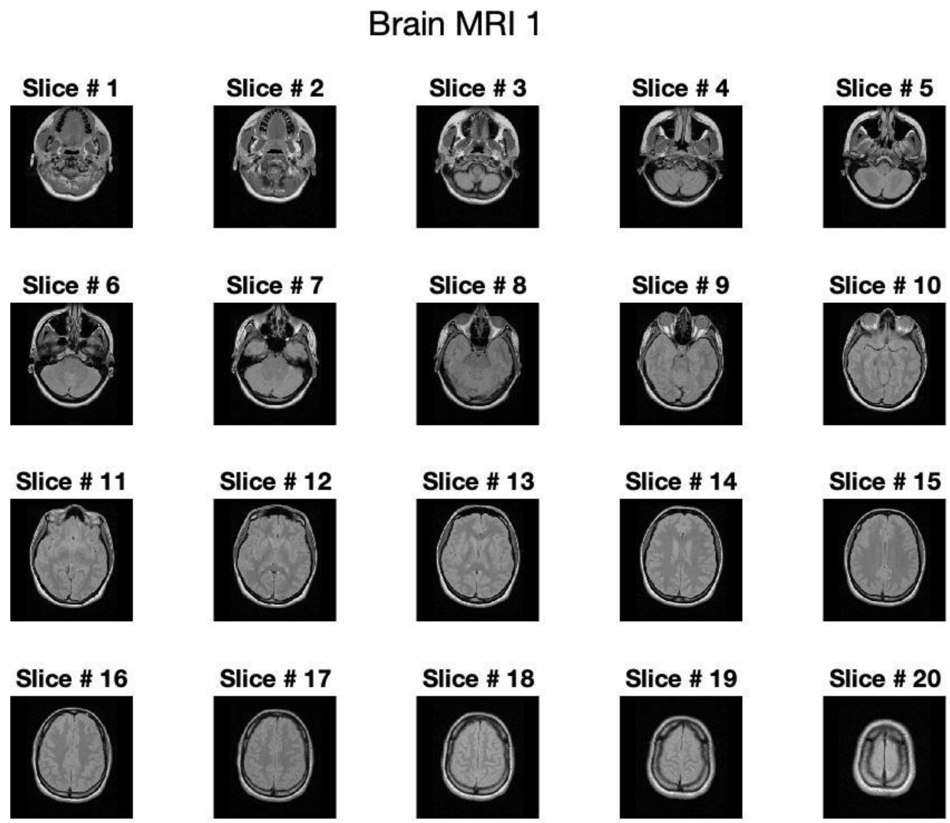

Figure 3: All slices of brainMRI1 on a single subplot

This figure is a 20 image subplot showing different slices of the brain arranged inferior to superior slices. In the first slices you can see the the brainstem and the jaw and in slice #3 the cerebellum comes into view. By slice #8 the cerebrum is in view as well as the eye sockets. The eye sockets disappear by slice #12.

2. Medical Image Writing

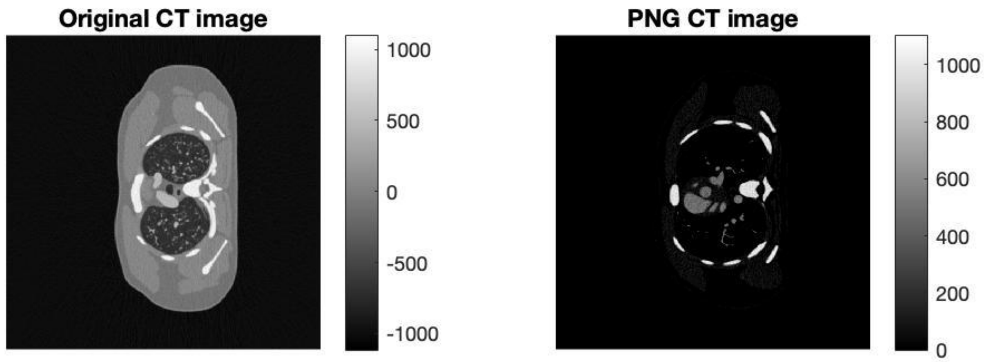

Figure 4: Slice 143 of Lung CT volume, original and saved as PNG file and then reloaded

The results are different than what I expected. This is due to PNG data storage format being unsigned integers. From the first image on the left the color bar shows that there are negative values being used to represent pixels in the image. When this was saved to a PNG image the sign was ignored. Therefore, when the image is read back in, that information is lost. To correct for this error, the original image intensity values could have been shifted to positive values. This could've been done by subtracting the global minimum intensity value from every pixel in the image. This way that the relative intensities would remain the same but all be positive and no information would be lost.

3. Medical Image Headers

```
                      Filename: '/Users/andrewmullen/Desktop/Winter 2021/BME 872/Lab1/Lab1 - BrainMRI1/brain_020.d
                   FileModDate: '01-Sep-2016 12:01:16'
                      FileSize: 132914
                        Format: 'DICOM'
                 FormatVersion: 3
                         Width: 256
                        Height: 256
                      BitDepth: 16
                     ColorType: 'grayscale'
FileMetaInformationGroupLength: 180
    FileMetaInformationVersion: [2×1 uint8]
       MediaStorageSOPClassUID: '1.2.840.10008.5.1.4.1.1.4'
    MediaStorageSOPInstanceUID: '0.0.0.0.1.8811.2.20.20010413115754.12432'
             TransferSyntaxUID: '1.2.840.10008.1.2.1'
        ImplementationClassUID: '0.0.0.0'
     ImplementationVersionName: 'NOTSPECIFIED'
   SourceApplicationEntityTitle: 'NOTSPECIFIED'
                     ImageType: 'ORIGINAL\PRIMARY\MPR'
                   SOPClassUID: '1.2.840.10008.5.1.4.1.1.4'
                SOPInstanceUID: '0.0.0.0.1.8811.2.20.20010413115754.12432'
                     StudyDate: '20010316'
                    SeriesDate: '20010316'
               AcquisitionDate: '20010316'
                   ContentDate: '20010323'
                     StudyTime: '143008'
                    SeriesTime: '143414'
               AcquisitionTime: '143415'
                   ContentTime: '143022'
               AccessionNumber: ''
                      Modality: 'MR'
                  Manufacturer: 'GE Medical Systems'
               InstitutionName: ''
        ReferringPhysicianName: [1×1 struct]
                   StationName: 'MRS1'
              StudyDescription: 'BRAIN'
             SeriesDescription: 'FSE PD AXIAL OBL'
       PerformingPhysicianName: [1×1 struct]
                 OperatorsName: [1×1 struct]
         ManufacturerModelName: 'SIGNA'
                   PatientName: [1×1 struct]
                     PatientID: '123565'
              PatientBirthDate: ''
                    PatientSex: 'F'
                    PatientAge: '028Y'
                 PatientWeight: 61.2350
```

Figure 5: Part 1 of MRI info header

```
         AdditionalPatientHistory: ''
                 ScanningSequence: 'SE'
                  SequenceVariant: 'SK'
                      ScanOptions: 'SP'
                MRAcquisitionType: '2D'
                     SequenceName: 'fse'
                   SliceThickness: 5
                   RepetitionTime: 2300
                         EchoTime: 22
                  NumberOfAverages: 1
                 ImagingFrequency: 63.8615
                      EchoNumbers: 1
            MagneticFieldStrength: 1.5000
             SpacingBetweenSlices: 2
       NumberOfPhaseEncodingSteps: 256
                  EchoTrainLength: 8
                   PixelBandwidth: 31.2500
                 SoftwareVersions: '3'
                     ProtocolName: 'CLINICAL BRAIN'
                        HeartRate: 0
            CardiacNumberOfImages: 0
                    TriggerWindow: 0
           ReconstructionDiameter: 220
                  ReceiveCoilName: 'HEAD'
                AcquisitionMatrix: [4×1 uint16]
   InPlanePhaseEncodingDirection: 'ROW'
                        FlipAngle: 90
                              SAR: 0.0313
                  PatientPosition: 'HFS'
                 StudyInstanceUID: '0.0.0.0.2.8811.20010413115754.12432'
                SeriesInstanceUID: '0.0.0.0.3.8811.2.20010413115754.12432'
                          StudyID: '8811'
                     SeriesNumber: 2
                AcquisitionNumber: 31763
                   InstanceNumber: 20
               PatientOrientation: 'L\PH'
                    ImagePosition: [3×1 double]
             ImagePositionPatient: [3×1 double]
                 ImageOrientation: [6×1 double]
          ImageOrientationPatient: [6×1 double]
              FrameOfReferenceUID: '0.0.0.0.4.8811.2.20010413115754.12432'
              ImagesInAcquisition: 1
       PositionReferenceIndicator: 'NA'
                    SliceLocation: 73.8000
                  SamplesPerPixel: 1
```

Figure 6: Part 2 of MRI info header

```
              SamplesPerPixel: 1
    PhotometricInterpretation: 'MONOCHROME2'
                         Rows: 256
                      Columns: 256
                 PixelSpacing: [2×1 double]
                BitsAllocated: 16
                   BitsStored: 16
                      HighBit: 15
          PixelRepresentation: 1
      SmallestImagePixelValue: 0
       LargestImagePixelValue: 784
            PixelPaddingValue: 0
                 WindowCenter: 0
                  WindowWidth: 0
             RescaleIntercept: 0
                 RescaleSlope: 1
                  RescaleType: 'SIGNAL INTENSITY (UNITLESS)'
```

Figure 7: Part 3 of MRI info header

```
infoCT =

  struct with fields:

                  Filename: 'Lab1/Lab1 - LungCT/training_post.mhd'
                    Format: 'MHA'
            CompressedData: 'false'
           TransformMatrix: [1 0 0 0 1 0 0 0 1]
          CenterOfRotation: [0 0 0]
                ObjectType: 'image'
        NumberOfDimensions: 3
                BinaryData: 'true'
                 ByteOrder: 'false'
                    Offset: [-199.6093 -199.6093 1.2405e+03]
     AnatomicalOrientation: 'RAI'
           PixelDimensions: [1 1 1]
                Dimensions: [512 512 286]
                  DataType: 'short'
                  DataFile: 'training_post.raw'
                  BitDepth: 16
                HeaderSize: 351
```

Figure 8: Info CT header

Brain MRI header values:

Manufacturer: “GE Medical Systems”
Slice Thickness: 5
Pixel width: 0.8594
Number of bits: 16x256x256 = 1 048 576
Date of Birth = N/A
Pixel Bandwidth = 31.25
Rescale Type: ‘SIGNAL INTENSITY (UNITLESS)’

2.2 Intensity Histograms

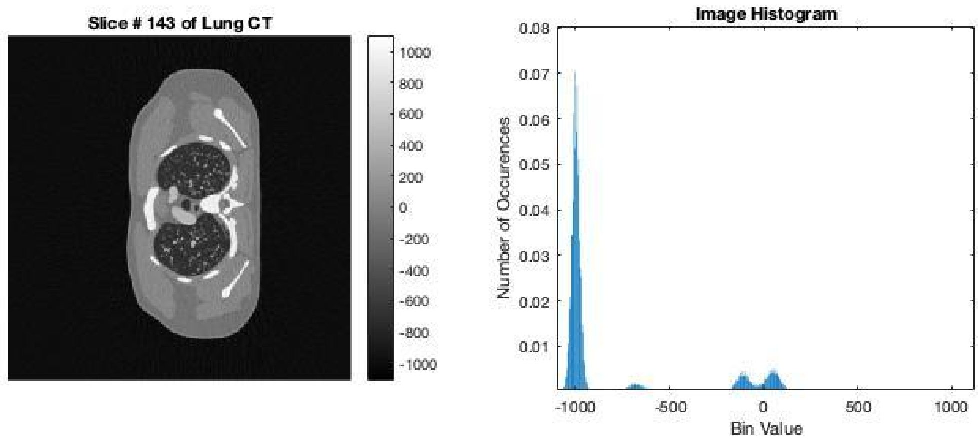

Figure 9: Slice #143 lung CT image and histogram

In this lung CT histogram you can clearly see 4 peaks with another smaller one at approximately bin value = 1000. Each of these spikes is in reference to a different tissue/structure present in the CT scan. The first, largest spike is referring to the background, and the next spike (at approximately bin value = -700) would be referring

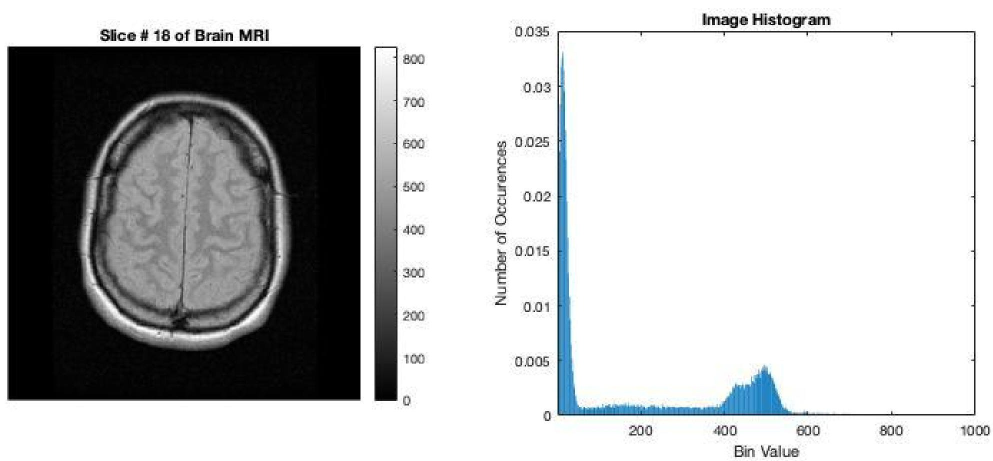

Figure 10: Slice #18 of brain MRI image and histogram

In the histogram for slice #18 of brain MRI1 you can see there are 2 or 3 noticeable features. The first spike represents the dark pixels like the background. The second spike, that contains two spikes near bin value 400-550. These spikes are most likely referring to the various gray and white matter tissues in the brain.

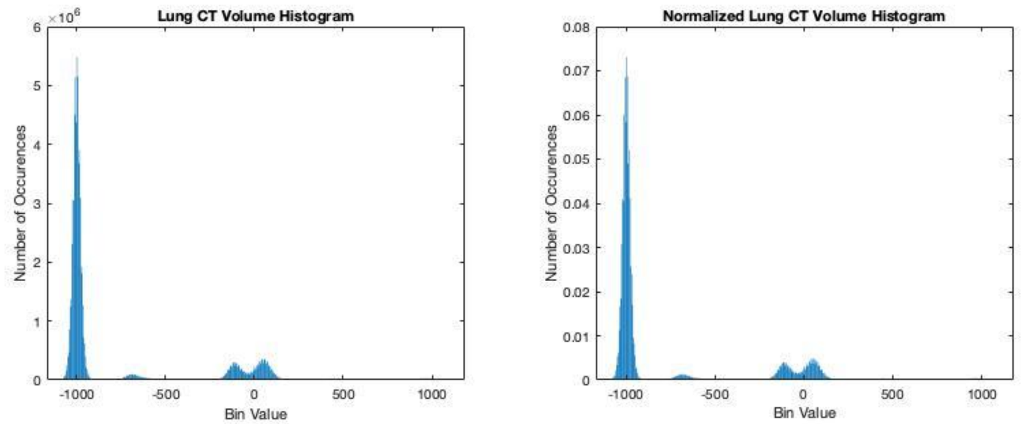

Figure 11: Lung CT volume histogram and normalized probability density function

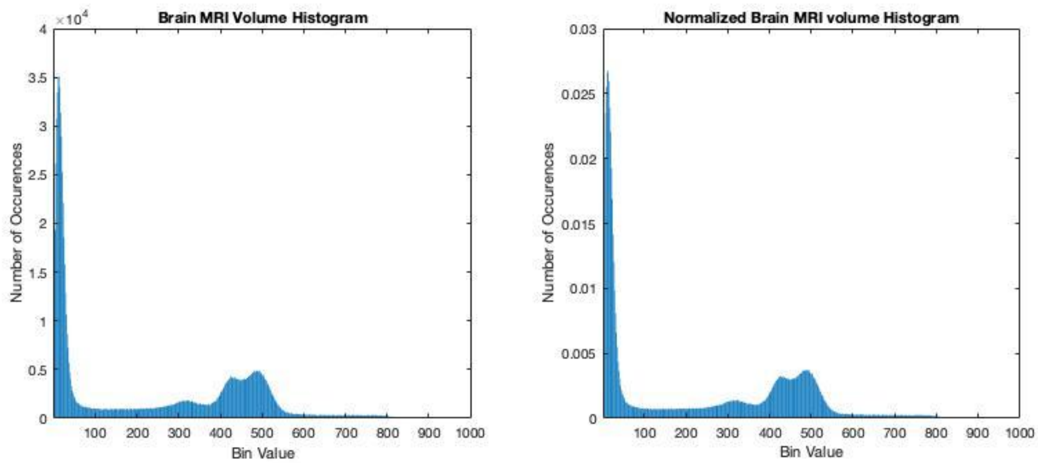

Figure 12: Brain MRI volume histogram and normalized probability density function

The difference between the histograms and the normalized histograms for both the Lung CT volume and the brain MRI volume lies only in the value on the y axis. In the normalized histogram the frequency values/number of pixels belonging to that bin has been divided by the number of pixels in the whole volume leading to a normalized output.

2.3 Point Operations

1. **Intensity Scaling and Shifting**

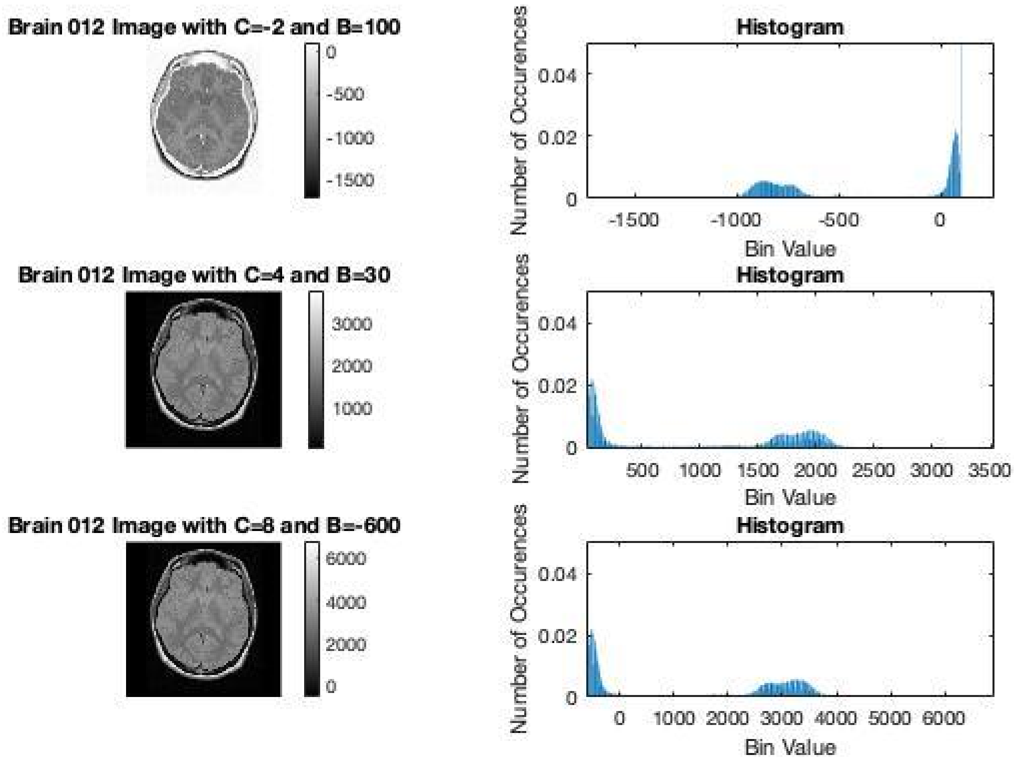

Figure 13: CT Brain images with intensity scaling and shifting applied
C = [-2, 4, 8], B = [100, 30, -600]

The image was being manipulated by being multiplied by C and shifted by B. Multiplying the image by C created an expansion of the bin values on the x axis of the histogram. This means that it increased the range that the pixel intensity values were spread over. Shifting the image with a value of B, increased the pixel intensity values uniformly and therefore created a shift either left or right on the x axis of the histogram. Other than these changes the general shape of the histogram remained the same. This is because all point operations were done to every pixel.

2. Image Masking and Overlays

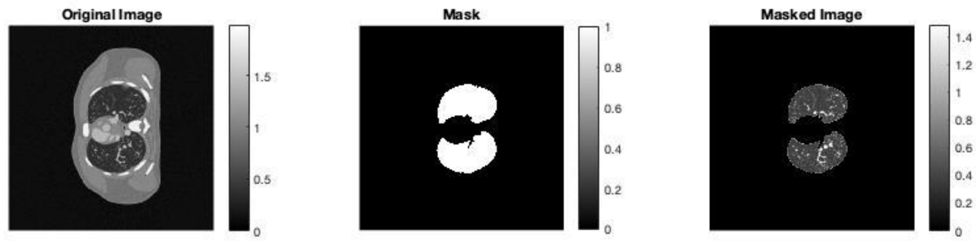

Figure 14: Original image, mask, and masked image for slice 143 of a lung CT scan

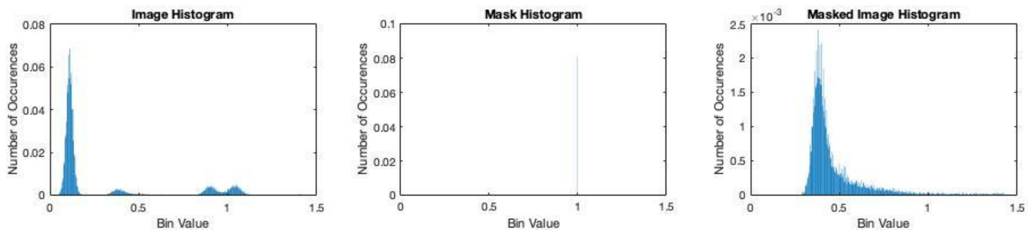

Figure 15: Histograms for original image, mask and masked image in figure

From the three histograms the masked lung volume one shows a peak at approx 0.4. When comparing this to the original image histogram there are 4 visible spikes. Thresholding this image from 0.3-0.6 therefore could lead to detection of the pulmonary regions.

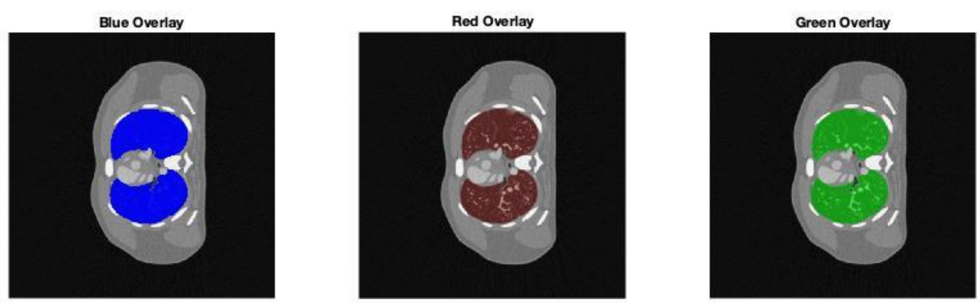

Figure 16: Blue, red and green overlay images with varying transparencies

3. Image Subtraction

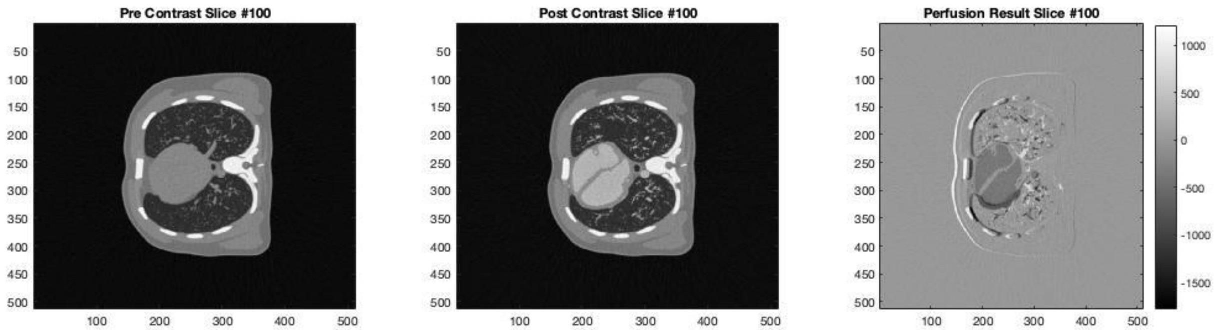

Figure 17: Pre-contrast, Post-contrast and Subtracted Image Slice #100

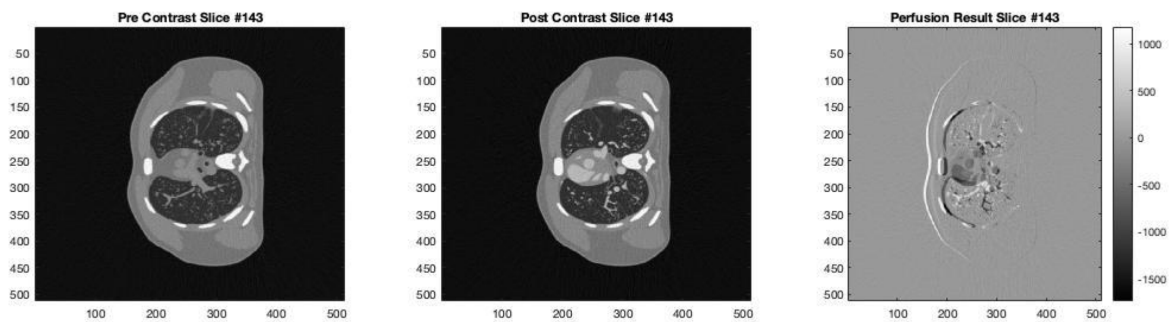

Figure 19: Pre-contrast, Post-contrast and Subtracted Image Slice #14

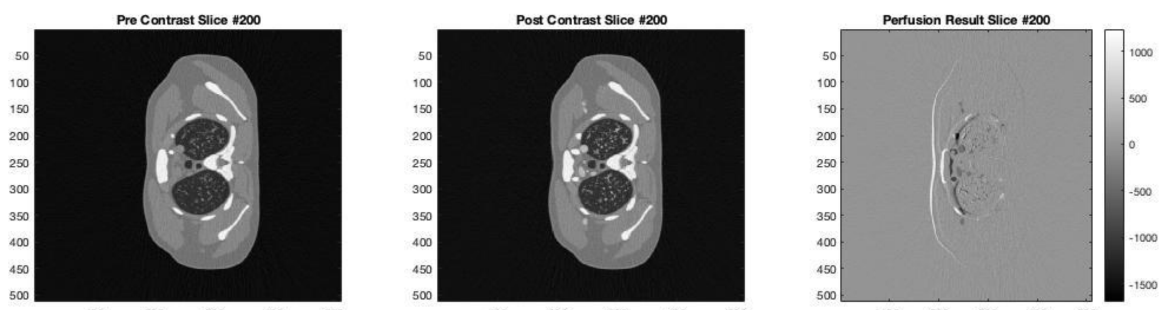

Figure 19: Pre-contrast, Post-contrast and Subtracted Image Slice #200

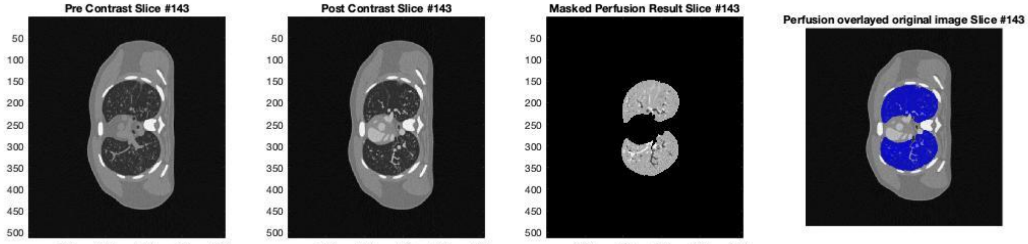

Figure 20: Perfusion masked and overlaid images for slice #143

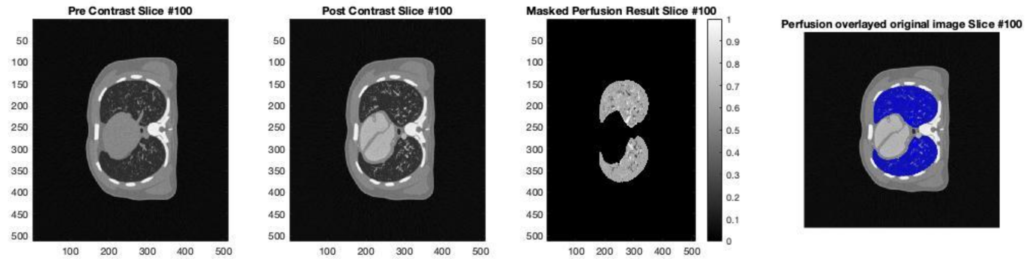

Figure 21: Perfusion masked and overlaid images for slice #100

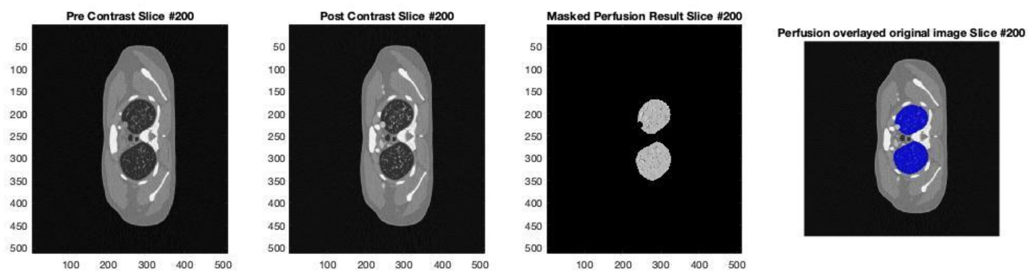

Figure 22: Perfusion masked and overlaid images for slice #200

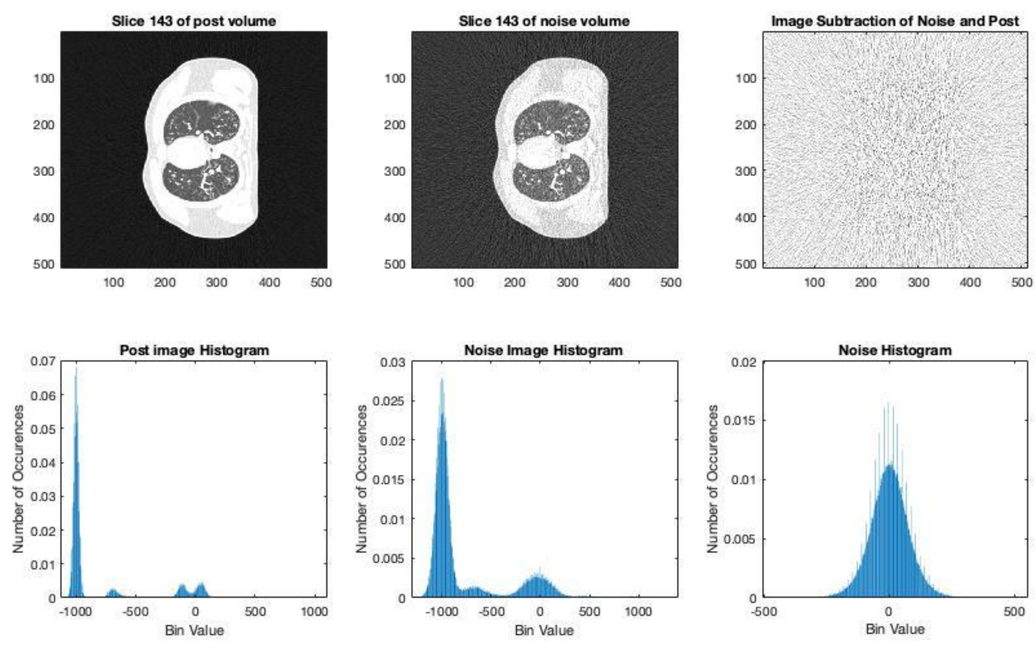

Figure 23: Lung CT slice #143 with noise, without noise and the subtracted noise

The subtracted result of subtracting the noisy image from the other image reveals the noise that is present in the image. This makes sense as the noisy image is made up of the image and noise so subtracting the other image cancels out the image leaving just noise. The noise histogram possesses a normal distribution with a mean of zero which is consistent with the definition of random noise.

4. Synchronized Averaging

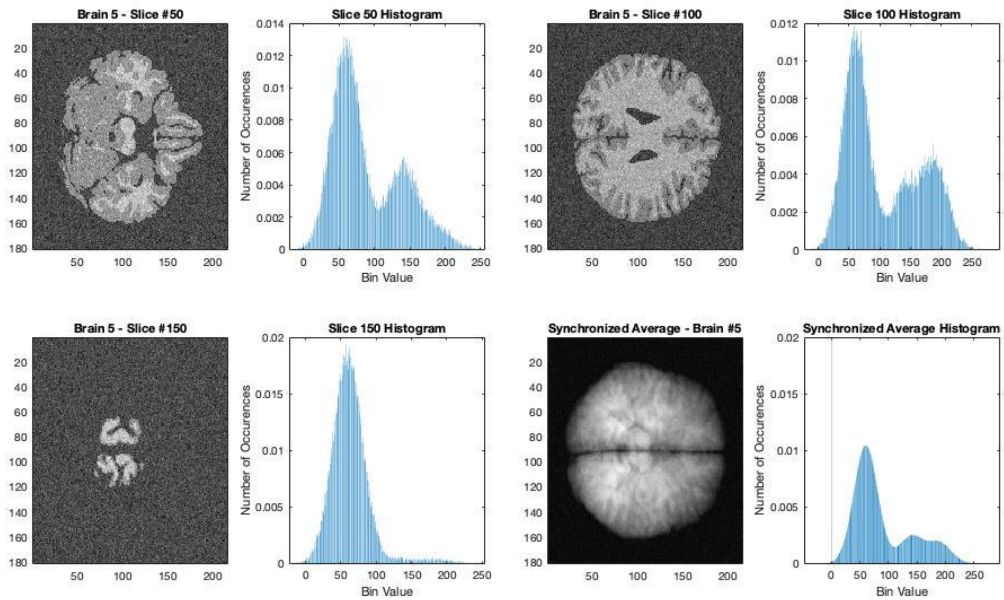

Figure 24: Sample images, their histograms and the synchronized average plus histogram of brain #5

The final result of averaging all of the images in the brain #5 volume is a smoother output of the input images. The slices individually are filled with noise as evident with the grainy look to the background and the overall image. This noise is cancelled out by the synchronized averaging process. This is due to the inherent property of noise being random and having a mean of zero.