

Assesment of the Scintigraphic Image Quality in Single Photon Emission Computed Tomography (SPECT) using Jaszczak Phantom

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ABSTRACT

Single Photon Emission Computed Tomography (SPECT) has advantages over other methods in that true 3-D images are easily obtained, appropriate radiopharmaceuticals are relatively less costly and more easily used, and the technology is particularly well-suited for imaging certain types of tissue. However, current methods for deriving SPECT images require design tradeoffs between sensitivity and spatial resolution. Failure to correct for image degradation could lead to low quality images and hence wrong diagnosis. This project aims at improving Scintigraphic images using a written MatLab code and filters. This study was conducted using the Single Head Single Photon Emission Computed Tomography machine at the Nuclear Medicine Department of the Korle-Bu Teaching Hospital. The e.cam[®] SPECT machine, Data Spectrum phantom, Technetium-99m and the ImageJ software were the materials used. A scintigraphic image was obtained with the e.cam[®] SPECT machine using a Low Energy High Resolution (LEHR) collimator. Tomographic images were acquired at 128 projections round the Jaszczak phantom. A MatLab algorithm code was applied to improve the contrast of the image and then five filters were applied to the images and comparative studies made. The contrast of the MatLab enhanced image was significantly better than that of the acquired image and the filters applied greatly increased the resolution of the acquired image. The acquired image had improved in quality by applying the MatLab algorithm code and filters. Improvement in quality is expected if the MatLab code is applied to acquired diagnostic Nuclear Medicine images which would help Nuclear Medicine Physicians make more accurate diagnostic decisions.

Keywords: *Scintigraphic images, radiopharmaceuticals, contrast, artifacts, grayscale intensity values, resolution, metastases.*

1. INTRODUCTION

Single Photon Emission Computed Tomography (SPECT) produces images of the body by detecting gamma ray photons emitted from radioactive isotopes injected into the body to illuminate specific organs. This technology is frequently used to produce images of tumors and their spread ¹. Reconstruction algorithms such as Filtered Back Projection are used to obtain the final image and this result in reconstructed images with lower resolution, increased noise than planar images and are susceptible to [artifacts](#) ².

This study aims at improving SPECT images using MatLab and filters so that medical officers can make good judgment of what treatment to administer.

Effective and good quality image is important for medical decision making and can reduce uncertainties inherent in the traditional methods. The presence of background artifacts in the image may lead to a false diagnosis, which has significant and broad-ranging implications. For this

reason, a study to improve the image quality is very much justified.

2. SUBJECTS AND METHODS

Materials used were the Siemens e.cam[®] SPECT system, Technetium-99m (^{99m}Tc) Source, Data Spectrum phantom (Deluxe Jaszczak phantom (model ECT/DLX/P)), Matrix Laboratory (MatLab) programming software and the ImageJ software.

The Cold rods were fitted to the Jaszczak Phantom. The Jaszczak Phantom was filled with water and an activity of 20mCi ^{99m}Tc was injected into it. The mixture was shaken for a uniform spread of the ^{99m}Tc. The Low Energy High Resolution (LEHR) collimator was then mounted on the detector head with the detector head facing downwards. Tomographic images were acquired at 128 projections round the Jaszczak phantom. Each projection was acquired for 30 seconds using a matrix size of 128×128. Three different sets of the tomographic images were obtained and the one with the worst outlook

was selected as the acquired image for this study. A MatLab algorithm code was developed and applied to the acquired image after which five different filters were applied separately to the acquired image. The ImageJ software was then used to obtain the full width at half maximum for each image and tabulated in Table 1. Comparative studies were made to identify which condition produced images of better quality. Figure 1 shows the SPECT system at the Korle-Bu Teaching Hospital. Figure 2 shows the Jaszczak Phantom while Figure 3 shows the various rods in the sectors. Rods of sectors 5 and 6 were poorly resolved so were not used in the analysis. Figure 4 shows the interface of the image J software using for the determination of the Full Width Half maximum (FWHM).



Figure 1: The SPECT machine at the Korle-Bu Teaching Hospital, Accra, Ghana



Figure 2: The Jaszczak Phantom

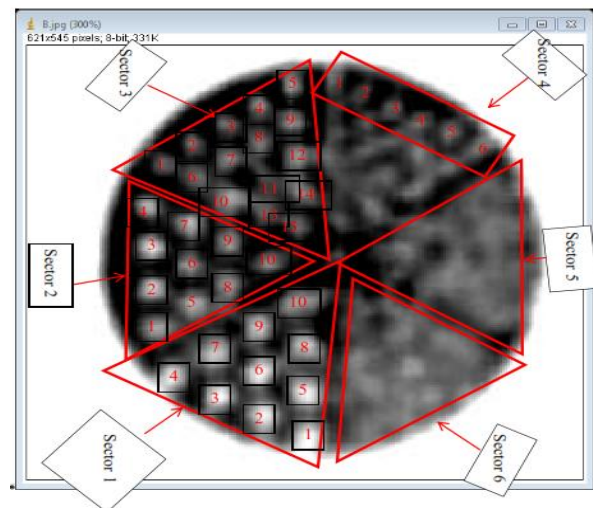


Figure 3: Sectors of the phantom image and number of sphere used for determining the FWHM

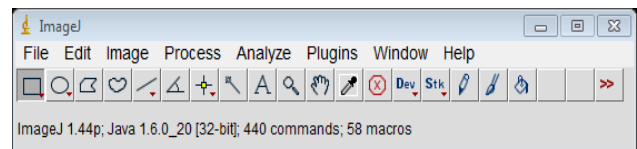


Figure 4: Opened view of the imageJ interface

3. RESULTS

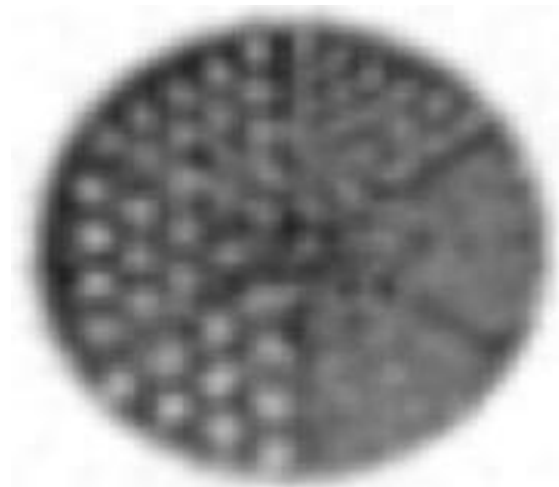


Figure 5: Acquired image



Count: 209763 Min: 30
 Mean: 237.963 Max: 255
 StdDev: 46.504 Mode: 255 (104581)

Figure 6: Histogram for Acquired image

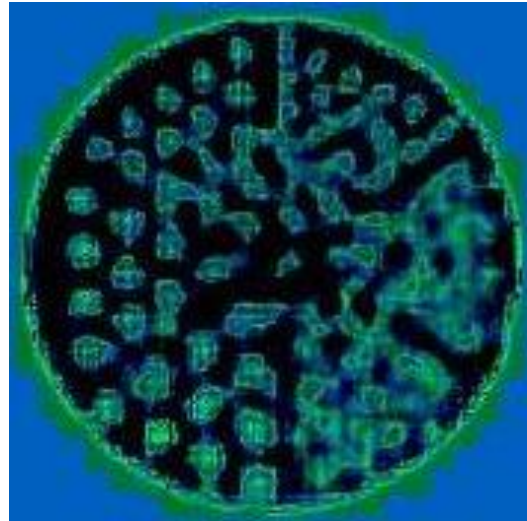


Figure 9: Trous-wavelet image

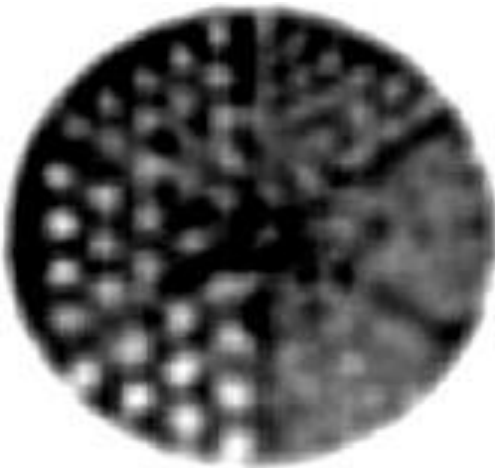
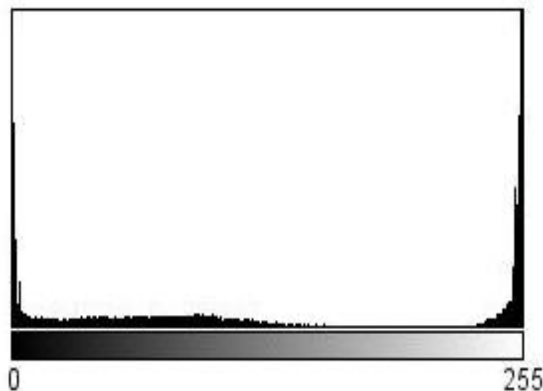


Figure 7: MatLab image



Count: 338445 Min: 0
 Mean: 224.593 Max: 255
 StdDev: 48.757 Mode: 239 (281384)

Figure 10: Histogram for the Trous-wavelet image



Count: 338445 Min: 0
 Mean: 240.787 Max: 255
 StdDev: 52.120 Mode: 255 (303059)

Figure 8: Histogram for the MatLab enhanced image

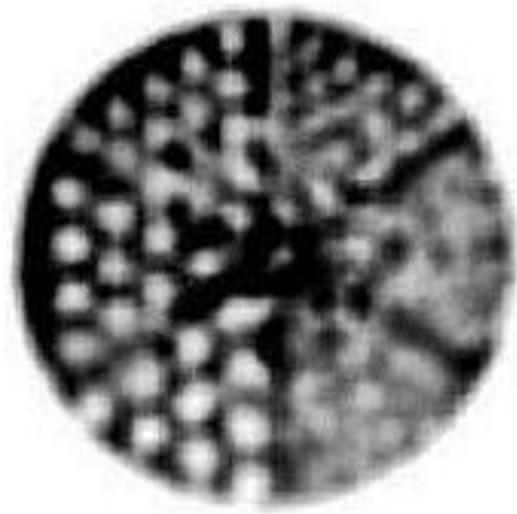


Figure 11: The CLAHE filtered image

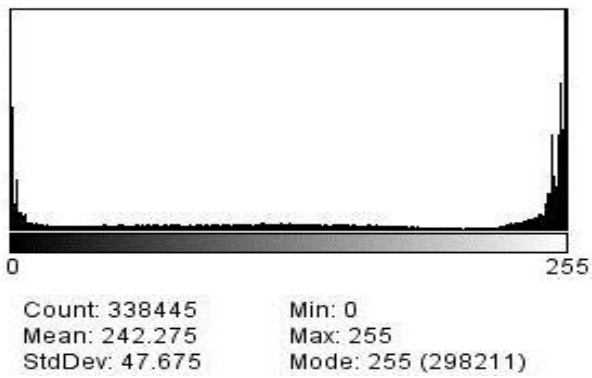


Figure 12: Histogram for the CLAHE image

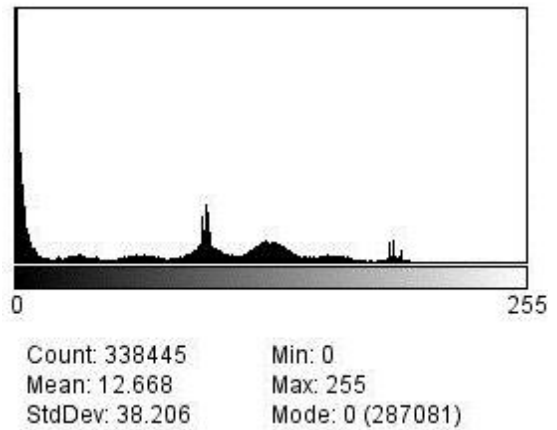


Figure 16: Histogram for the Filter Rank filtered image

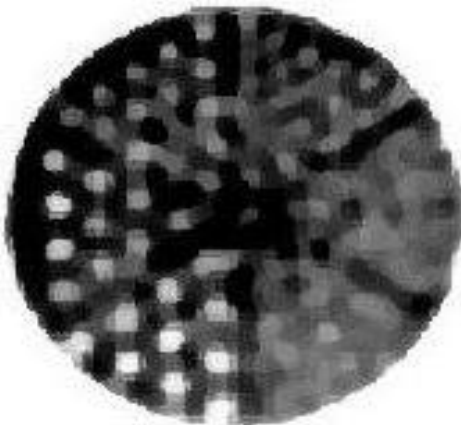


Figure 13: The Kuwahara filtered image



Figure 17: Sigma Filter Plus image

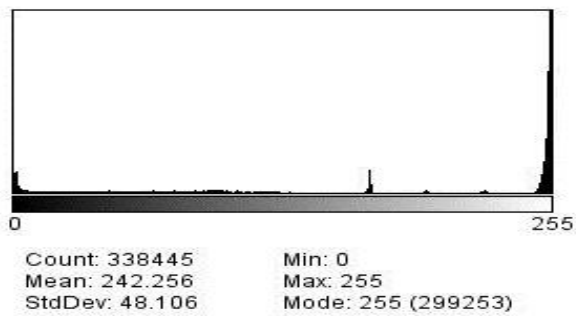


Figure 14: Histogram for the Kuwahara image

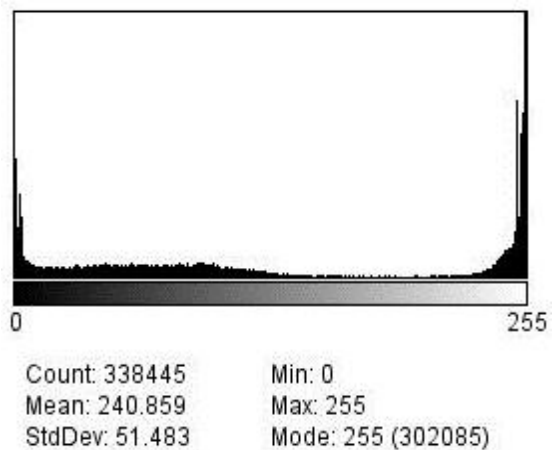


Figure 18: Histogram for the Sigma Filter Plus

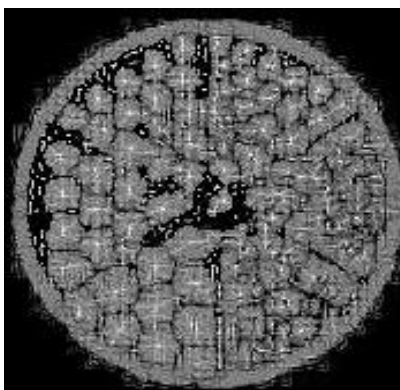


Figure 15: The Filter Rank filtered image

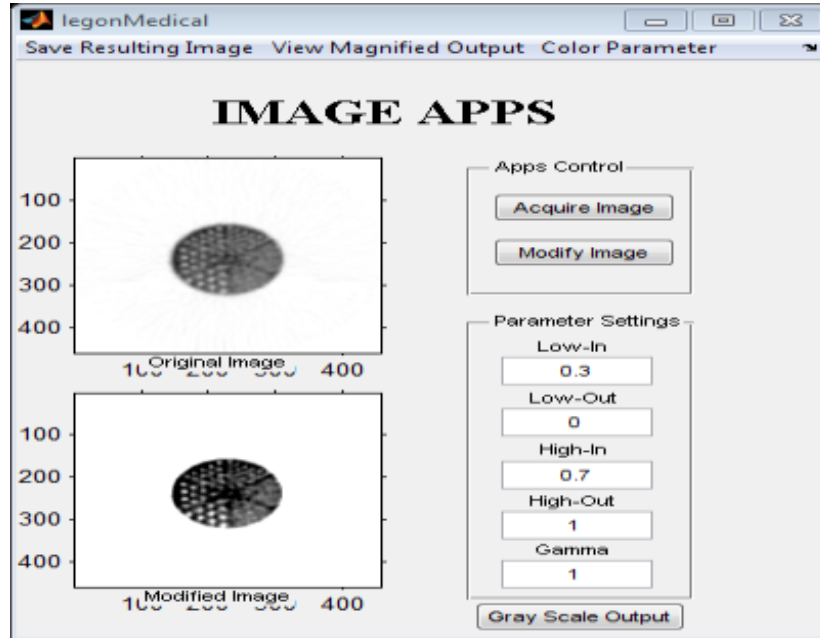


Figure 19: Graphic User Interface for the designed MatLab algorithm containing the acquired and modified images

Table 1: Comparison of Average FWHM values for all the images

| Images | Average FWHM (mm) | | | |
|----------------------|---------------------|---------------------|--------------------|---------------------|
| | Sector 1 | Sector 2 | Sector 3 | Sector 4 |
| Acquired image | 16.164±3.177 | 15.261±3.088 | 14.693±1.952 | 14.246±0.205 |
| Matlab enhanced | 15.403±1.180 | 13.629±2.978 | 12.149±3.984 | 11.609±1.458 |
| Trous-Wavelet filter | 13.873±4.852 | 11.832±3.035 | 11.271±4.257 | 10.261±1.381 |
| CLAHE Filter | 14.356±1.238 | 13.996±2.065 | 12.684±1.670 | 11.165±0.424 |
| Kuwahara Filter | 15.951±2.146 | 15.036±0.917 | 14.453±0.837 | 13.997±1.200 |
| Sigma Plus Filter | 15.170±1.583 | 14.701±1.583 | 14.489±2.122 | 13.570±0.66 |
| Filter Rank | 14.535±4.081 | 14.296±3.743 | 13.743±5.00 | 13.947±1.147 |

4. DISCUSSION

Figure 3 shows the image of the Jaszczak Phantom with the various sectors. Sectors 1 and 2 of the image contain ten (10) spheres and all were visually resolved and hence used in the analysis. Sector three (3) contains fifteen (15) spheres and all were also used in the FWHM analysis. Sector four (4) contains twenty-one (21) spheres of which only the first row which contains six (6) spheres was

clearly visible. The physical diameters of the rods are of sizes 12.7 mm, 11.1 mm, 9.5 mm, 7.9 mm, 6.4 mm and 4.8 mm from sectors 1 to 6 respectively [3].

It is noted that the E.cam® SPECT system poorly resolved sectors 5 and 6 which contains rods diameters of 6.4 mm and 4.8 mm respectively. This means metastases of diameters 6.4mm and below will be poorly resolved by the Korle-Bu Teaching Hospital SPECT system, limiting

the information the equipment would give a medical officer thus hindering diagnostic decision makings.

For an image to be said to have a good quality, the FWHM value for a reconstructed spatial resolution with scatter with a LEHR Collimator of a Siemens E.cam[®] SPECT system according to the National Electrical Manufacturers Association (NEMA) Performance Measurements of Scintillation Cameras should be ≤ 11.7 mm^[4]. Values in table 1 show an improvement in the FWHM from sectors 1 to 4. In all cases, spheres in sector 4 had a better FWHM values, because it had the least resolved diameters, hence a better resolution compared with the remaining spheres.

The MatLab enhanced image showed a better image detail in terms of its contrast and resolution. All the other images enhanced with the filters had better FWHM than the acquired image.

The poor contrast and FWHM of the acquired image can be attributed to the presence of noises and other artifacts⁴ (figure 5 and table 1).

Comparing the FWHM values in Table 1 and the processed images (images that the MatLab and filters were applied to) with the acquired image, it clearly shows an improvement in the contrast and intensity distributions of the processed images.

From the histograms the acquired image had a maximum pixel count of 209763 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 30 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 237.963 ± 46.504 . The modal grayscale intensity value was 255 with a 104581 pixel counts. This indicates that 49.86% of the pixels in the image were concentrated at 255 grayscale value, hence majority of the pixels are in the light grayscale region indicating a brighter image than that of the acquired image.

MatLab enhanced image (figure 7) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 240.787 ± 52.120 . The modal grayscale intensity value was 255 with a 303059 pixel counts. This indicates that 89.54% of the pixels in the image were concentrated at 255 grayscale value, hence majority of the pixels are in the light grayscale region indicating a brighter image compared to the acquired image.

The Troun-Wavelet filtered image (figure 9) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum

grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 224.593 ± 48.757 . The modal grayscale intensity value was 239 with a 281384 pixel counts. This indicates that 83.14% of the pixels in the image were concentrated at 255 grayscale value, hence majority of the pixels are in the light grayscale region indicating a bright image.

The CLAHE filtered image (figure 11) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 242.275 ± 47.675 . The modal grayscale intensity value was 255 with a 298211 pixel counts. This indicates that 88.11% of the pixels in the image were concentrated at 255 grayscale value, hence majority of the pixels are in the light grayscale region indicating a brighter image.

The Kuwahara filtered image (figure 13) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 242.256 ± 48.106 . The modal grayscale intensity value was 255 with a 299253 pixel counts. This indicates that 88.42% of the pixels in the image were concentrated at 255 grayscale value, hence majority of the pixels are in the light grayscale region. This indicates a brighter image.

The filter Rank filtered image (figure 15) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 12.668 ± 38.206 . The modal grayscale intensity value was 0 with a 287081 pixel counts. This indicates that 84.82% of the pixels in the image were concentrated at 0 grayscale value, hence majority of the pixels are in the dark grayscale region indicating a darker image and hence difficulty in interpreting the image in terms of the information present.

The Sigma Filter Plus filtered image (figure 17) had a maximum pixel count of 338445 which spread across the 255 possible grayscale intensities, with a minimum grayscale intensity value of 0 and maximum grayscale intensity value of 255 and a mean grayscale intensity value of 240.859 ± 51.483 . The modal grayscale intensity value was 255 with a 302085 pixel counts. This indicates that 89.26% of the pixels in the image were concentrated at 255 grayscale intensity value, hence majority of the pixels are in the light grayscale region indicating a brighter image.

The acquired image had a minimum gray value of 30 and a maximum gray value of 255, but after the MatLab

algorithm code was applied, the grayscale intensity spread across from 0 to 255. All the filtered images also showed this improvement. The pixels which indicate the amount of information in an image had a count of 209763 for the raw image and a count of 338445 for both the MatLab enhanced image and the other filtered images. This means 128682 more pixels were added to the MatLab image which is an increment of 61.35% indicating that it contains more image detail and information. The filtering could not increase the number of pixels.

The MatLab enhanced image had the highest pixel count of 303059 at a modal grayscale intensity value of 255. All the images had their modal grayscale intensity to be 255 except the Trouse-Wavelet filtered image and the filter Rank filtered image which had modal Grayscale intensity values of 239 and 0 respectively. This means that all the images are brighter and had good contrast compared to the acquired image

The highest mean grayscale intensity value was 242.275 from the CLAHE filtered image, which means majority of the pixels for this image were in the light region making the image much brighter. The lowest mean grayscale

intensity value was 12.668 from the Filter Rank filtered image, which means majority of the pixels were in the dark region of the image indicating a dark image and hence the difficulty in interpreting the image.

According to Xie, intuition about a “good” image is one with a “uniform” histogram spanning a large variety of grayscale intensity tones or values [5]. From the histograms, the MatLab enhanced image, Trouse-Wavelet Filtered image, CLAHE filtered image, Kuwahara filtered image, the filter Rank filtered image and the Sigma Filter Plus filtered image are considered as good images.

The acquired image was improved from its best FWHM value of 14.246 ± 0.205 mm to 10.261 ± 1.381 mm by applying both the MatLab and the Trouse-Wavelet Filter. This shows an improvement of 27.973% of the acquired image. The MatLab algorithm, CLAHE filter, Kuwahara filter, Sigma Filter Plus and Filter Rank, improved the resolution of the acquired image by 18.510%, 21.627%, 1.748%, 4.745% and 8.949% respectively.

Figures 20 to 25 show the MatLab algorithm code and the four different filters applied to medical images.

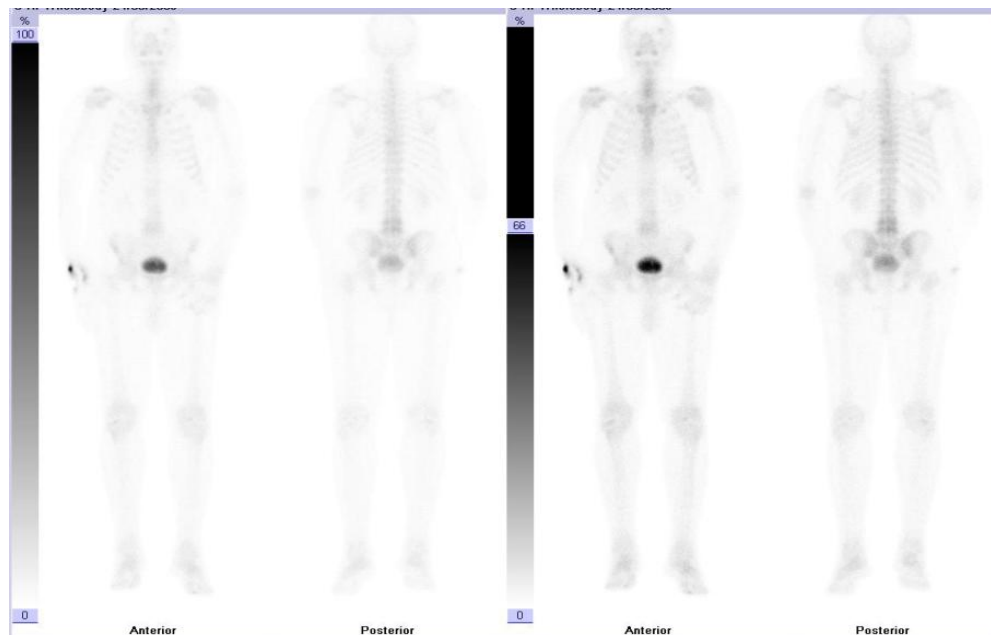


Figure 20: acquired image

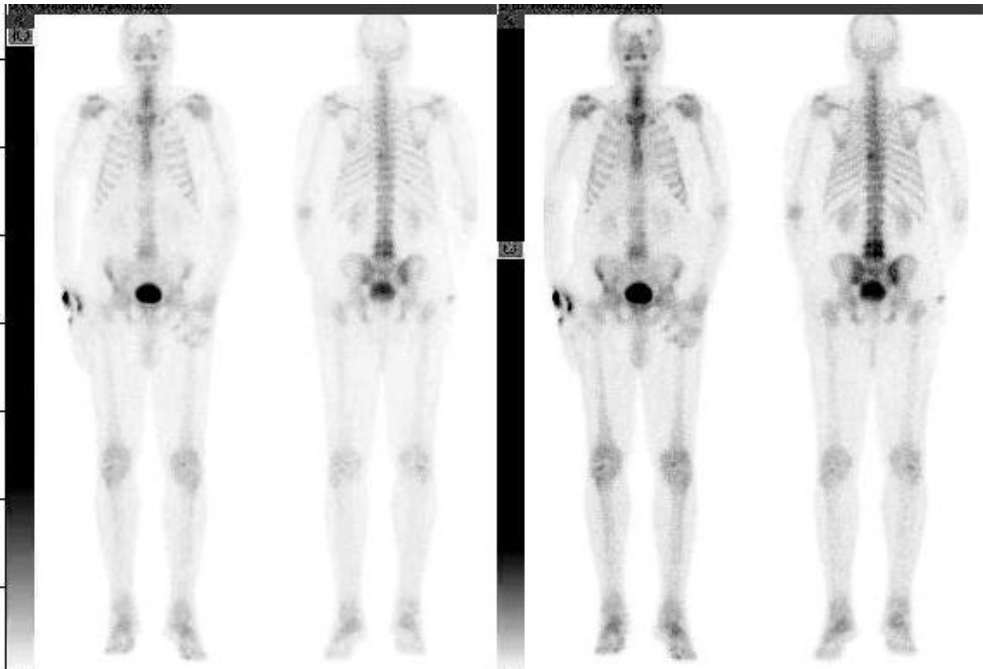


Figure 21: Matlab enhanced image

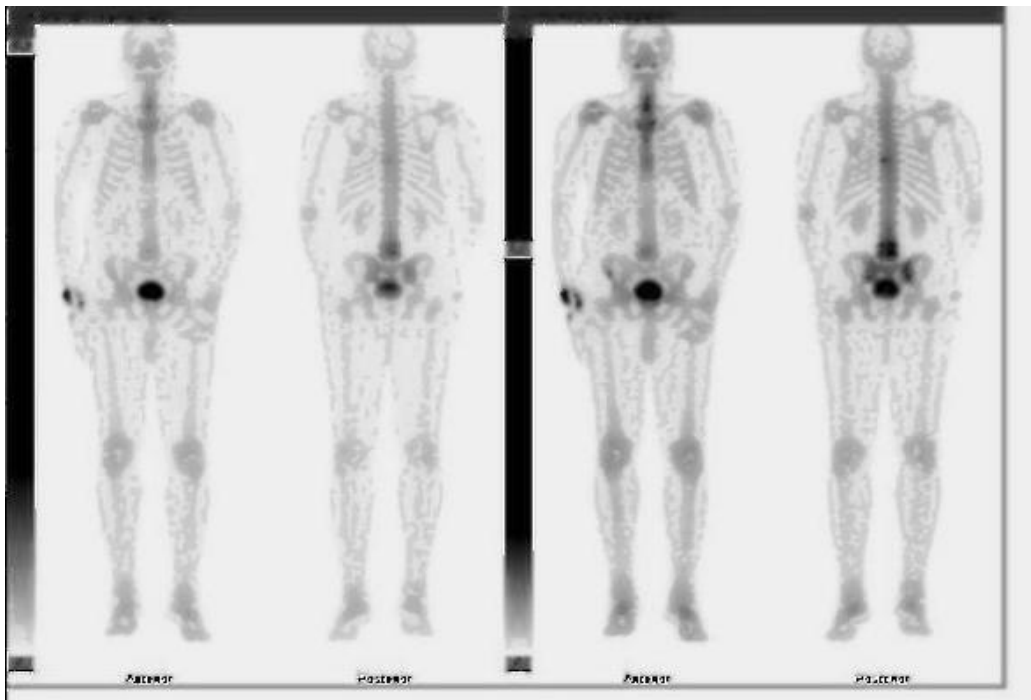


Figure 22: Trous-wavelet filtered image

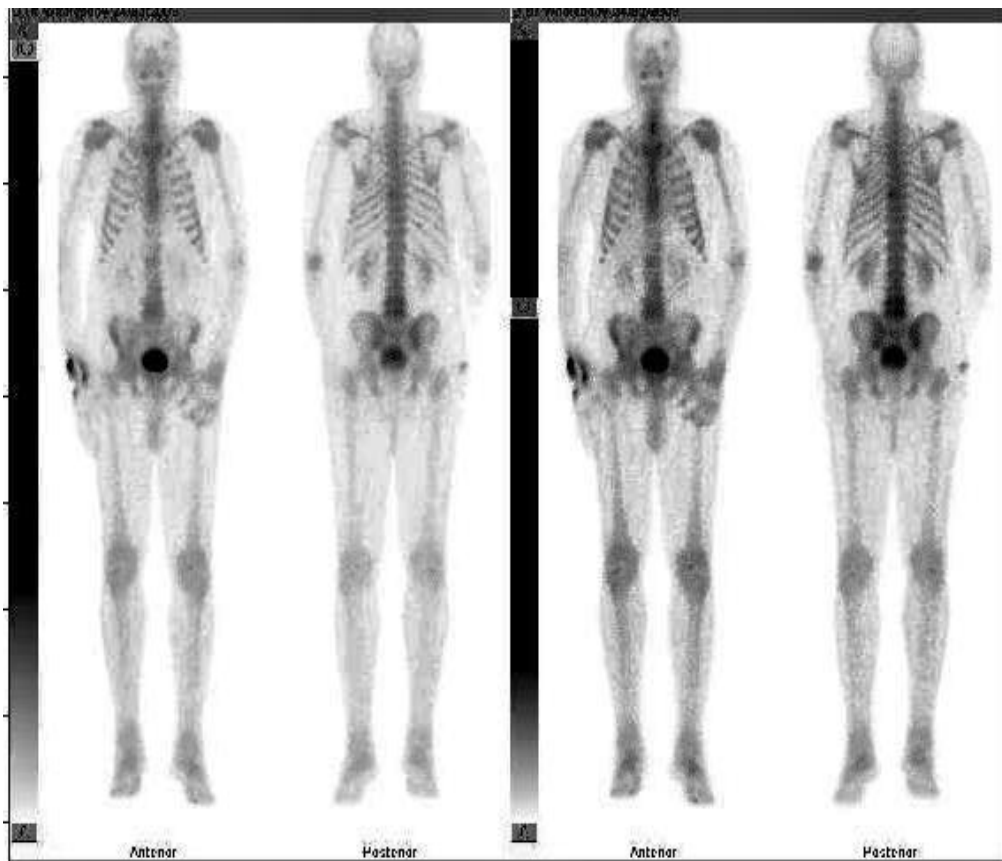


Figure 23: CLAHE filtered image

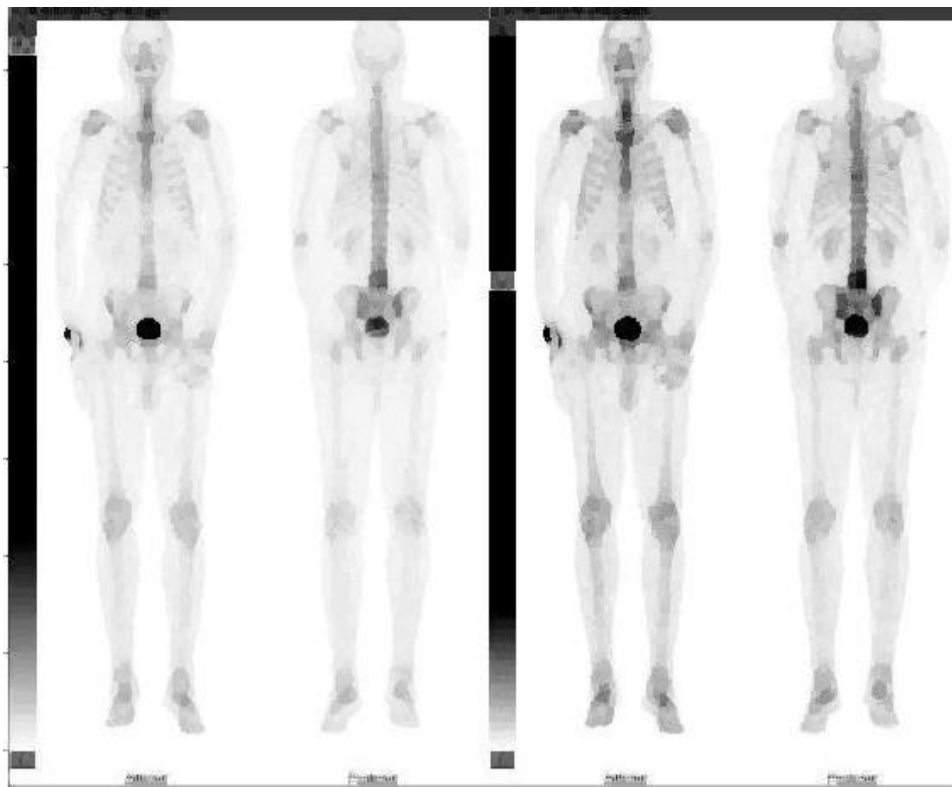


Figure 24: Kuwahara filtered image

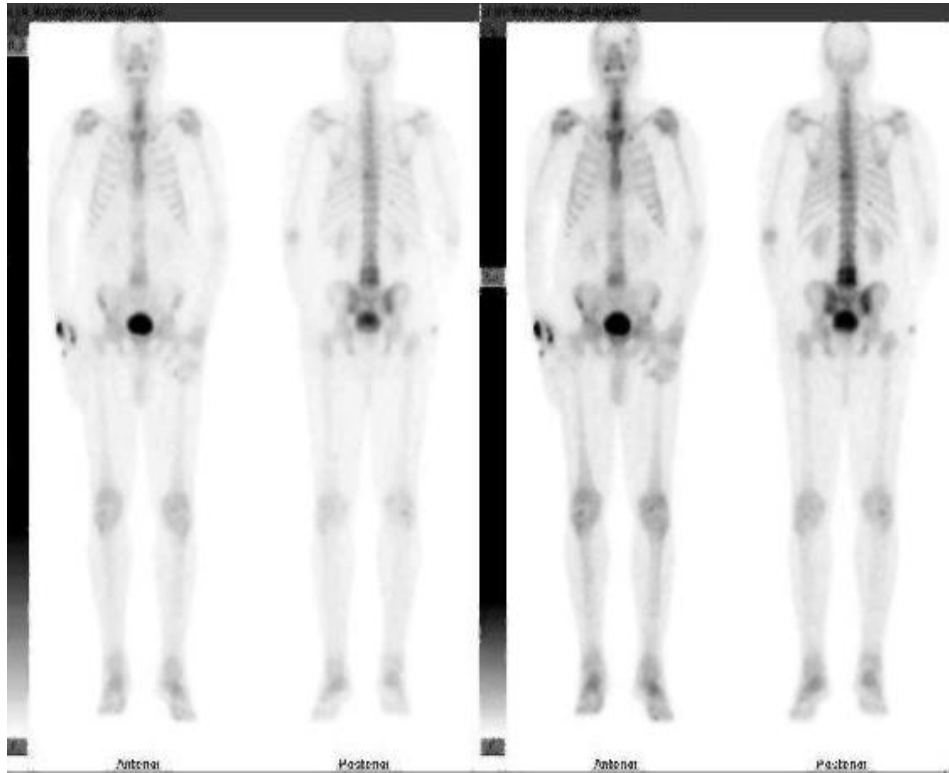


Figure 25: Sigma filtered image

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