

Medical Image Processing using MATLAB

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ABSTRACT

MATLAB and the Image Processing Toolbox provide a wide range of advanced image processing functions and interactive tools for enhancing and analyzing digital images. The interactive tools allowed us to perform spatial image transformations, morphological operations such as edge detection and noise removal, region-of-interest processing, filtering, basic statistics, curve fitting, FFT, DCT and Radon Transform. Making graphics objects semitransparent is a useful technique in 3-D visualization which furnishes more information about spatial relationships of different structures. The toolbox functions implemented in the open MATLAB language has also been used to develop the customized algorithms.

Keywords: Histogram, 3-D Surface Plot, Round-off Noise Power Spectrum

1. INTRODUCTION

MATLAB is a high-level technical language and interactive environment for data analysis and mathematical computing functions such as: signal processing, optimization, partial differential equation solving, etc. It provides interactive tools including: threshold, correlation, Fourier analysis, filtering, basic statistics, curve fitting, matrix analysis, 2D and 3D plotting functions. The operations for image processing allowed us to perform noise reduction and image enhancement, image transforms, colormap manipulation, colorspace conversions, region-of interest processing, and geometric operation [4]. The toolbox functions implemented in the open MATLAB language can be used to develop the customized algorithms.

2. 2. IMAGE PROCESSING TOOLBOX

An X-ray Computed Tomography (CT) image is composed of pixels, whose brightness corresponds to the absorption of X-rays in a thin rectangular slab of the cross-section, which is called a "voxel" [1,3]. The Pixel Region tool provided by MATLAB 7.0.1 superimposes the pixel region rectangle over the image displayed in the Image Tool, defining the group of pixels that are displayed, in extreme close-up view, in the Pixel Region tool window. The Pixel Region tool shows the pixels at high magnification, overlaying each pixel with its numeric value [2,5]. For RGB images, we find three numeric values, one for each band of the image. We can also determine the current position of the pixel region in the target image by using the pixel information given at the bottom of the tool. In this way we found the x- and y-coordinates of pixels in the target image coordinate system. The Adjust Contrast tool displays a histogram which represents the dynamic range of the X-ray CT image (Figure.1.).

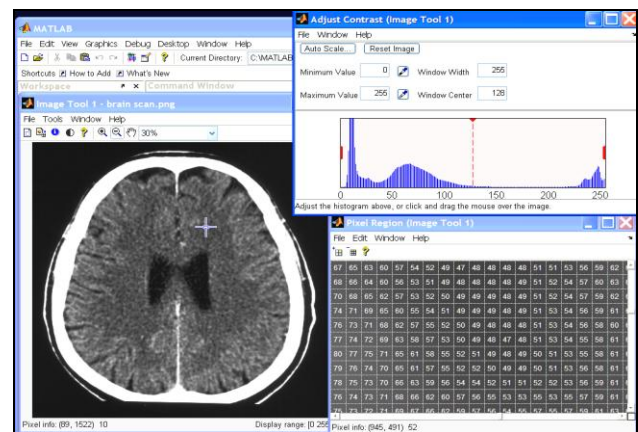


Figure 1. Pixel Region of an X-ray CT scan and the Adjust Contrast Tool

The Image Processing Toolbox provide a reference-standard algorithms and graphical tools for image analysis tasks including: edge-

detection and image segmentation algorithms, image transformation, measuring image features, and statistical functions such as mean, median standard deviation, range, etc., (Figure. 2.)

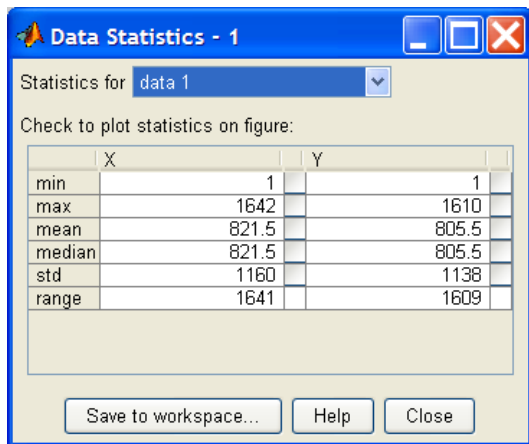


Figure 2. Data statistics of an X-ray CT scan performed by MATLAB 7.0.1.

3. PLOT TOOLS

MATLAB provides a collection of plotting tools to generate various types of graphs, displaying the image histogram or plotting the profile of intensity values (Fig. 3.a,b).

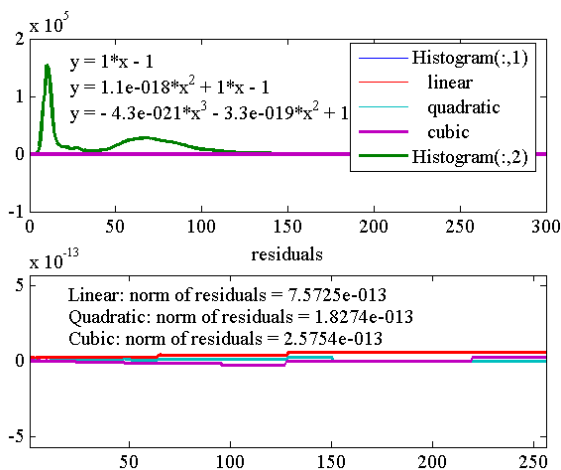


Figure 3. a. - The Histogram of X-ray CT image and the plot fits (significant digits: 2). A cubic fitting function is the best-fit model for histogram data plot. The fit curve was plotted as a magenta line through the data plot.

Area Graph of X-ray CT brain scan displays the elements in a variable as one or more curves and fills the area beneath each curve.

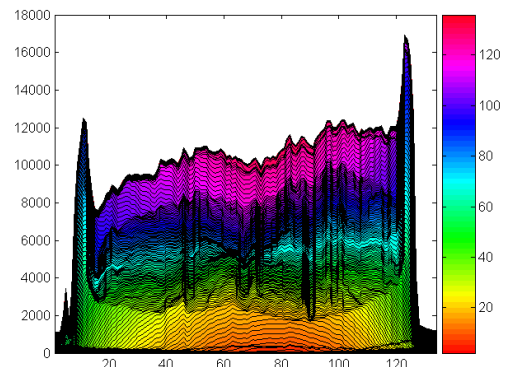


Figure 3.b. Area Graph of X-ray CT brain scan

The 3-D Surface Plot generates a matrix as a surface (Figures 4. a, b, c, d). We can also make the faces of a surface transparent to a varying degree. Transparency (referred to as the alpha value) can be specified for the whole 3D-object or can be based on an alphamap, which behaves in a way analogous to colormaps (Figures 4. a, b).

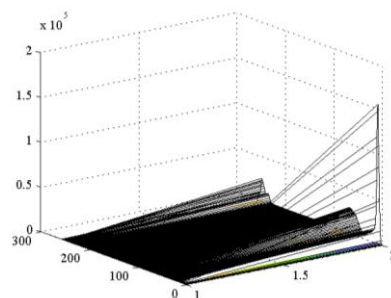


Figure 4.a. 3D Surface Plot of x-ray CT brain scan generated with histogram values, alpha(.0)

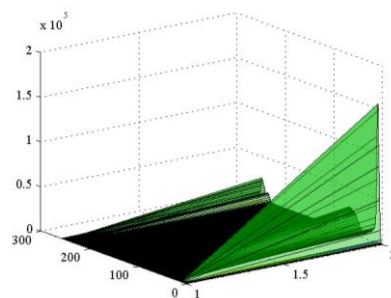


Figure 4.b. - 3D Surface Plot of x-ray CT brain scan generated with histogram values, alpha(.4)

The 'meshgrid' function is extremely useful for computing a function of two Cartesian coordinates. It transforms the domain specified

by a single vector or two vectors x and y into matrices X and Y for use in evaluating functions of two variables. The rows of X are copies of the vector x and the columns of Y are copies of the vector y (Figure 4.c).

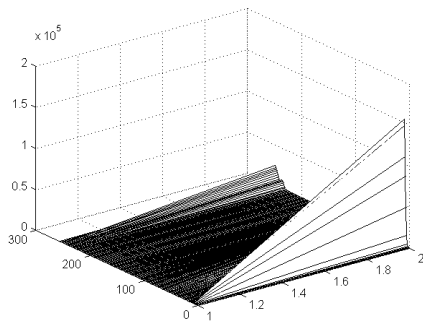


Figure 4.c. - 3D Surface Plot of x-ray CT brain scan generated with histogram values, mesh

3-D Surface Plot with Contour (Surfc) displays a matrix as a surface with contour plot below. "Lighting" is the technique of illuminating an object with a directional light source. This technique can make subtle differences in surface shape easier to see. "Lighting" processing can also be used to add realism to three-dimensional graphs. This example uses the same surface as the previous examples, but colors it yellow and removes the mesh lines (Figure 4.d.).

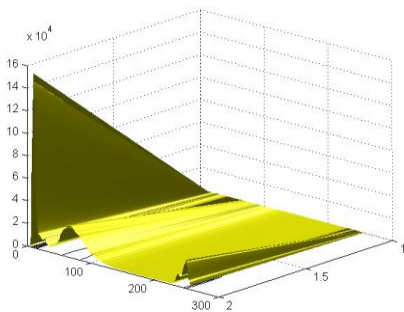


Figure 4.d. Surface Plot of x-ray CT brain scan generated with histogram values, lighting

The "Image" creates an X-ray CT image graphics object by interpreting each element in a matrix as an index into the figure's colormap or directly as RGB values, depending on the data specified (Figure 5.a.).

The "Image" with Colormap Scaling ("imagesc" function) displays an X-ray CT

image and scale to use full colormap. MATLAB supports a number of colormaps. A colormap is an m -by-3 matrix of real numbers between 0.0 and 1.0. Each row is an RGB vector that defines one color. "Jet" ranges from blue to red, and passes through the colors cyan, yellow, and orange. It is a variation of the hsv (hue, saturation, value) colormap (Figure 5.b.).

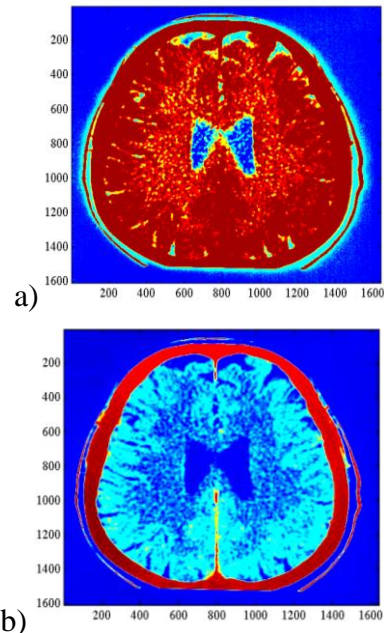


Figure 5

Contour Plot is useful for delineating organ boundaries in images. It displays isolines of a surface represented by a matrix (Figure 6.). For example:

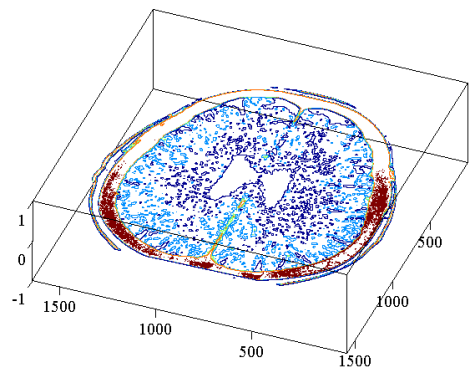


Figure 6. - Contour Plot of X-ray CT brain scan

The ezsurf(f) or surfc function creates a graph of $f(x,y)$, where f is a string that represents a mathematical function of two variables, such as x and y (Figure 7.).

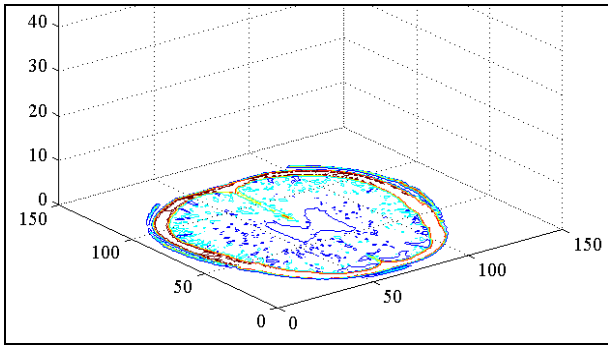


Figure 7 – Surf on X-ray CT brain scan

The `contour3` function creates a three-dimensional contour plot of a surface defined on a rectangular grid (Figure 8.).

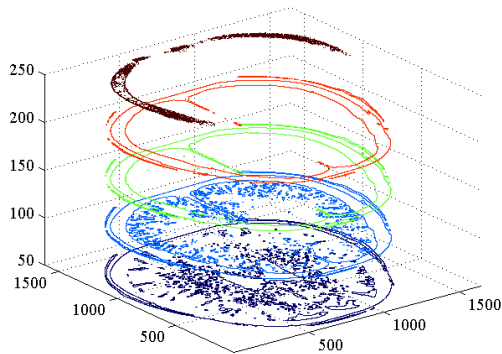


Figure 8. – Contour3 on X-ray CT brain scan

3-D Lit Surface Plot (Surface plot with colormap-based lighting, `surf` function) displays a shaded surface based on a combination of ambient, diffuse, and specular lighting models (Figure 9.).

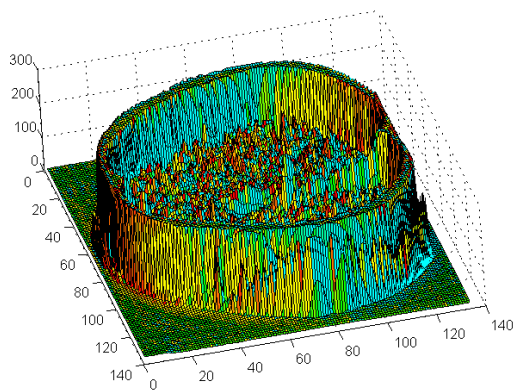


Figure 9. - 3D Lit Surface Plot of X-ray CT brain scan

The 3-D Ribbon Graph of Matrix displays a matrix by graphing the columns as segmented strips (Figure 10.).

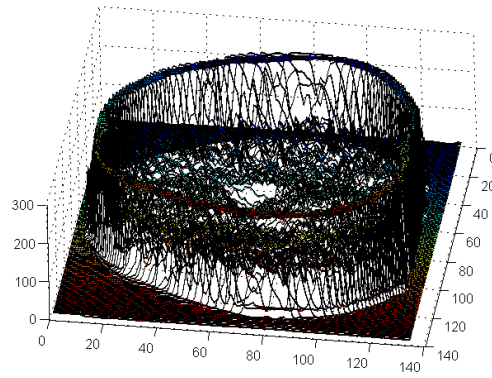
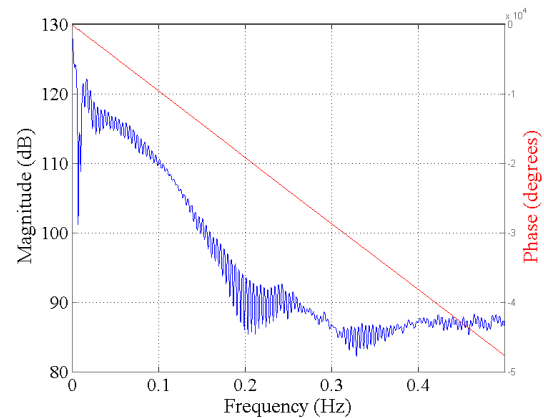


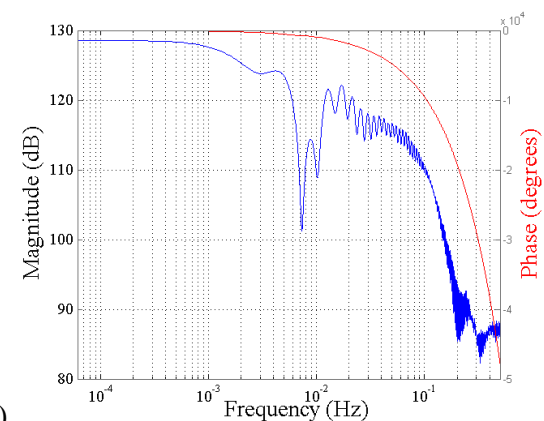
Figure 10. - The 3-D Ribbon Graph of X-ray CT brain scan

4. FILTER VISUALIZATION TOOL (FVTool)

Filter Visualization Tool (FVTool) computes the magnitude response of the digital filter defined with numerator, `b` and denominator, `a`. By using FVTool we can display the phase response, group delay response, impulse response, step response, pole/zero plot, filter coefficients and round-off noise power spectrum.(Figures: 11, 12, 13, 14, 15, 16 and 17).



a)



b)

Figure 11. Magnitude and Phase Response - Frequency scale: a) linear, b) log

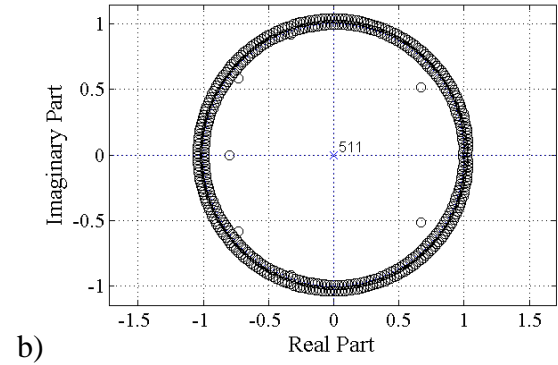
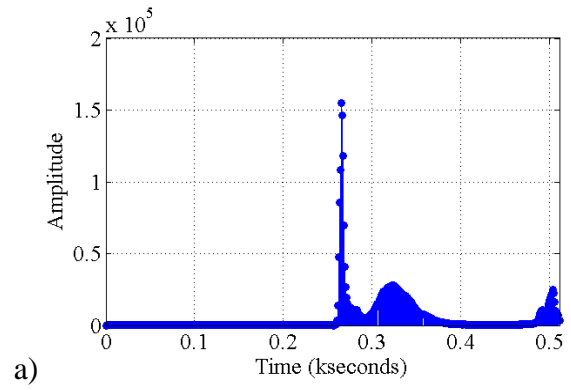
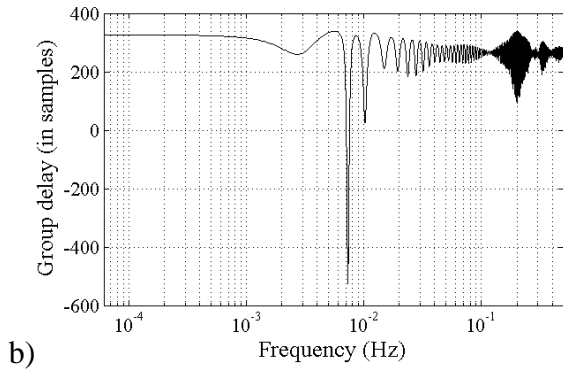
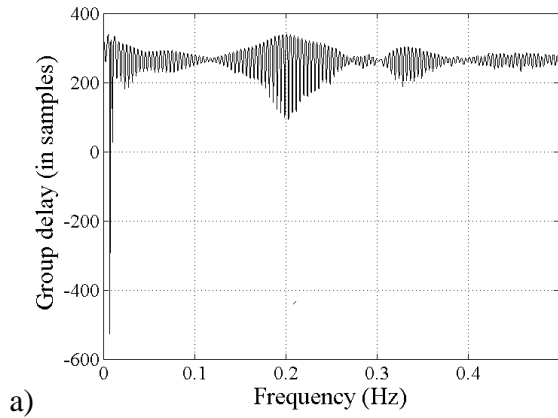


Figure 14. (a) Impulse Response (b) Pole/Zero Plot

Figure 12. Group Delay Response - Frequency scale: a) linear, b) log

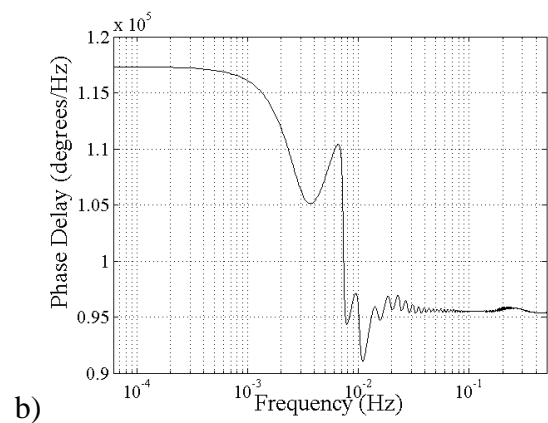
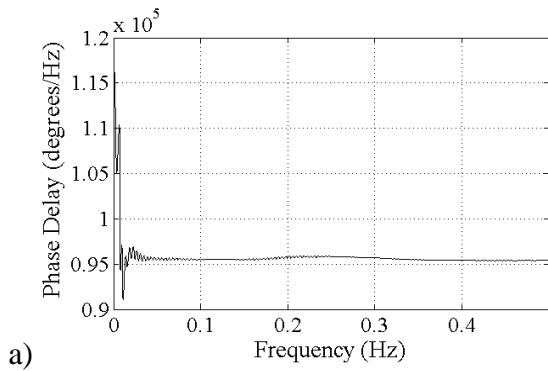


Figure 13. Phase Delay Response - Frequency scale: a) linear, b) log

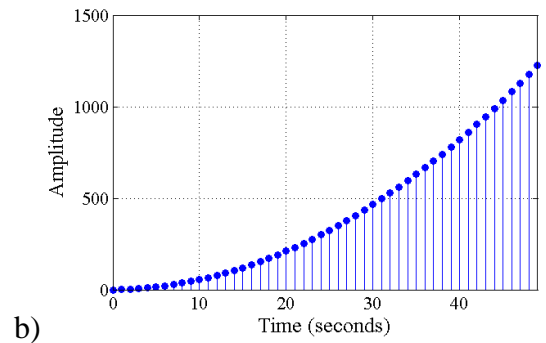
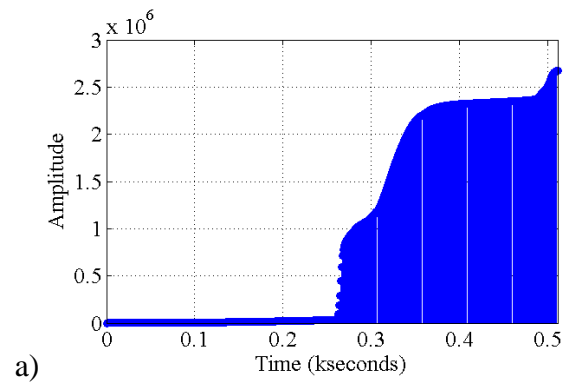


Figure 15. Step Response (a) Default (b) Specify Length: 50

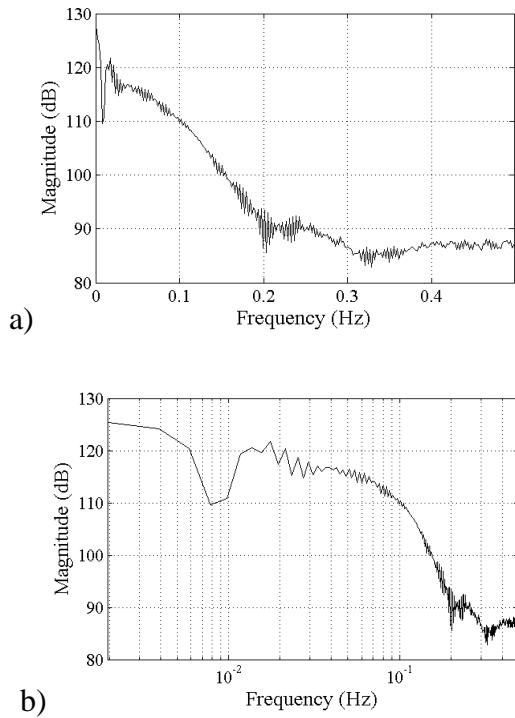


Figure 16. Magnitude Response Estimate - Frequency scale: a) linear, b) log

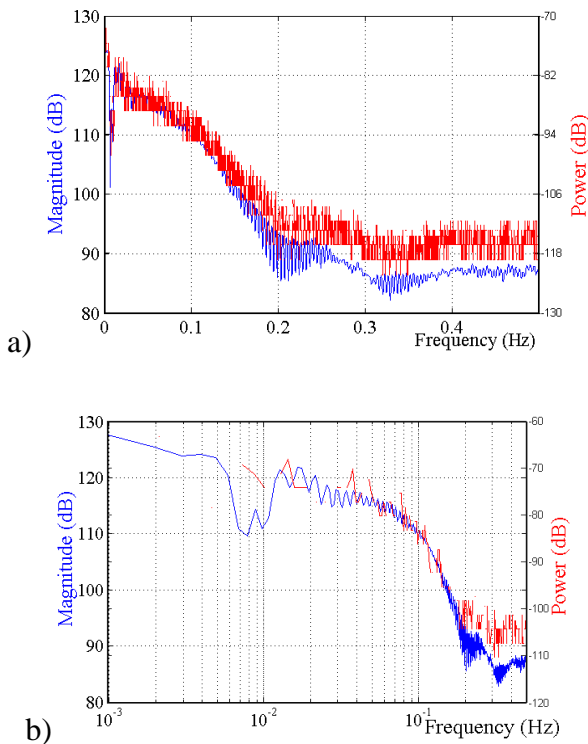


Figure 17. Magnitude Response and Round-off Noise Power Spectrum - Frequency scale: a) linear, b) log

5. CONCLUDING REMARKS

MATLAB provide functions and interactive tools for enhancing and analyzing digital images and developing image processing algorithms. MATLAB visualization tools let us to represent the information contained in the X-ray CT image data through histograms, contour plots, pixel regions, transparent overlays, and images texture-mapped onto surfaces.

The Signal Processing Toolbox (SPTool) provides a suite of interactive graphical user interfaces for: Signal plotting and analysis, spectral analysis and filter visualization: signal plotting and analysis, spectral analysis and filtering signals.

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