Brain Imaging Software

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ABSTRACT

Computed Tomography (CT) is a scanning technique allowing the generation of tomographic images of every part of the human body without superimposition of adjacent structures. This paper reveals the X-ray CT image processing and analysis algorithms available in ImageJ, Corel PHOTO-PAINT and Adobe Photoshop software by using adjustment filters, displaying image histograms and plotting the profile of intensity values. Image analysis includes texture analysis, line detection, morphology, edge detection, segmentation, region of interest processing and feature measurement such as: Standard Deviation, Area, Integrated Density, Skewness, Kurtosis and Feret's diameter.

Keywords: Skewness, Kurtosis, Profile Plot

1. INTRODUCTION

Computed Tomography (CT) is a non-invasive imaging technique where digital geometry processing can be used to generate a 3D-image of brain's tissue and structures obtained from a large series of 2D X-ray images. X-ray scans furnish detailed images of an object such as dimensions, shape, internal defects and density for diagnostic and research purposes. Computed Tomography uses an X-ray tube, an elaborate radiation detection system and a computer that assembles the measurement data into a series of transversal slice of the subject's body. There are two scan configurations that lead to rapid data collection [1, 4, 6]. In a third-generation fan beam X-ray tomography machine, a multicellular detector system is rotated continuously around the patient together with the X-ray tube. Data collection time for such scanners ranges from 1 to 20 seconds. A special computer program calculates the values of density and creates cross-sectional images of the brain. The fourth-generation scanners use a stationary 360 ^{0} ring of detector and the fan shaped X-ray beam rotates around the patient. Modern CT scanner can acquire data in a continuous helical or spiral fashion [3], shortening acquisition time and reducing artifacts such as: quantum noise, X-ray scattering by the patient, beam hardening and nonlinear partial volume effects [2]. Image imperfections can also be caused by insufficient calibration of detector sensitivity, inadequacies in the reconstruction algorithm, non-uniformity scanning motion, fluctuation in x-ray tube voltage, etc.

By using ImageJ, Adobe Photoshop CS2, Corel PHOTO-PAINT 12, MATLAB 7.0.1 and OriginPro 7.5 software I have been realized the image processing and data analysis on X-ray CT images of normal and abnormal brain. ImageJ is a public domain Java image processing program. I have been used this software in order to measure distances, to calculate area and pixel value statistics of user-defined selections and to provide density histograms and line profile plots. Adobe Photoshop 7.0 image processing software has been used in conjunction with Corel PHOTO-PAINT 12.0 programs to improve the CT images by adjusting and creating special effects. OriginPro 7.5 is a specialized program for data analysis providing FFT analysis, Profile Plots and 3D Color Maps Surface of CT images [7].

2. RESULTS AND DISCUSSION

1. Image processing

Image processing techniques can help to differentiate the abnormal tissue growth (tumors) in question from other tissues, providing more detailed information on head injuries, stroke, brain disease and internal structures than do regular X-ray CT scans. By using suitable programs into the first stage we performed multiple processing on a typical tomographic image of a normal brain S1 (Subject 1) and X-ray CT scans of an abnormal brain S2 (Subject 2) illustrated in figure 1.a,b.

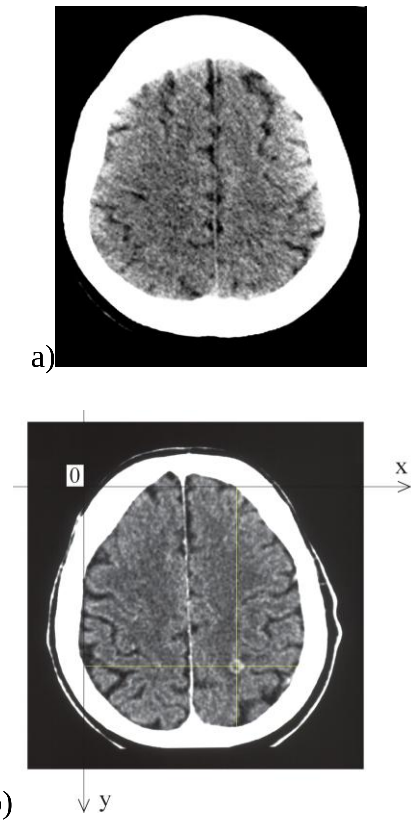


Fig. 1. **RGB-X-ray CT scan** of (a) S1-normal brain (1741 × 1990 pixels), (b) S2-abnormal brain (1718 × 1747 pixels),

The Contrast Enhancement filter has been used to adjust the tone, color and contrast in the X-ray CT images. **The Threshold** setting changes pixel contrast, which can reduce or eliminate visible dust particles and other tiny marks. The radius setting enables you to control the number of pixels involved in the smoothing effect that is applied. Threshold adjustment converts all colors to either black or white based on their brightness values (Fig. 2.a,b.). Binary slicing of digital images is very useful for highlighting individual specimen details. Single threshold level binary segmentation is often useful for isolating specific features within a complex specimen. This technique can also be used in distinguishing fine details within a sample, such as internal cellular components. In order to determine the threshold level for a given image (and the percentage of black pixels desired) a simple algorithm operates by computing the smallest nonnegative integer K such the following relation is satisfied:

$$\sum_{i=0}^{k} h(i) \geq N \cdot p. \quad (1)$$

where N is the total number of pixels n the image, p is the percentage of black pixels desired and h is the image histogram sequence [5].

The **Histogram Equalization** filter was applied to redistribute the balance of shadows, midtones and highlights in the composite channel or in individual color channels. In order to highlight the edges in the X-ray CT image of normal brain I have been applied the **Variance** filter (radius 6) from ImageJ process menu. For clarity some regions are made transparent while the significant details can be easily seen.

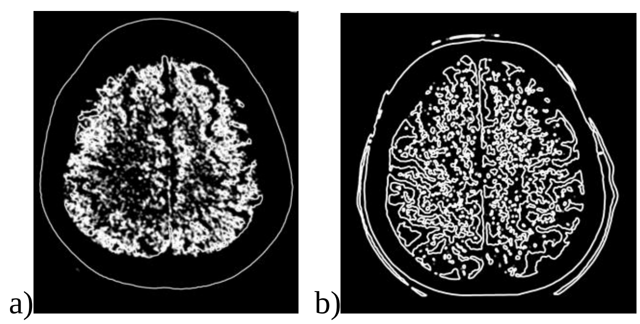


Figure 2.**-** 8-bit images performed after **Adobe Photoshop–** Image Adjustment – (Threshold - Level 80) folowed by **ImageJ–** Filter (Variance: Radius 7) Process: Enhance Contrast (Saturated Pixels 3 %, Equalize Histogram on X-ray CT scan of X-ray CT scan on (a) S1 normal brain (b) S2.abnormal brain

Adobe Photoshop filters used in conjunction with Corel PHOTO-PAINT processing enable to apply automated effects to an image, allowing us to correct lighting and perspective fluctuations, increasing the focus and adding depth to RGB X-ray CT image. **Psychedelic** effect was used to shift an entire RGB image from one color range to another. **Contour** filters detect and accentuate the edges of objects and selections in the X-ray CT images of the ischemic brain. **Hue** represents color, **saturation** indicates the color depth or richness and **lightness** shows the overall percentage of white in the X-ray CT images (Fig. 3.).

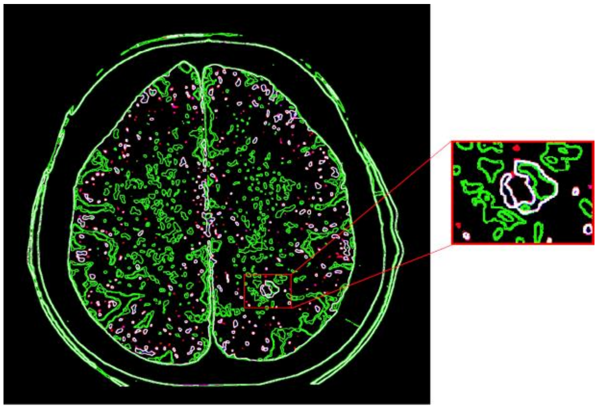


Figure 3. - Corel PHOTO-PAINT effects: Color Transform (Psychedelic: 95 level) followed by **Adobe Photoshop** multiple filtering: Stylize (Trace Contour: 250 level, Upper Edge followed by Find Edges) and image adjustments: Invert followed by Hue (116)-Saturation (16)-Lightness (0) on X-ray CT scan of S2 abnormal brain.

Brush Strokes filter can be also use to emphasize the edges of the objects. The abnormal tissues are clearly visible after the CT image processing (Fig. 4.).

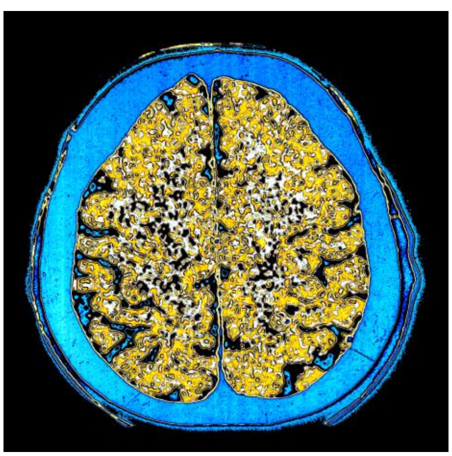


Figure 4. - **Corel PHOTO-PAINT** effects: Color Transform (Psychedelic: 192 level) followed by **Adobe Photoshop** filtering: Brush Strokes (Ink Outlines: Stroke Length 7, Dark Intensity 50, Light Intensity 7) followed by image adjustments: Hue (-146)-Saturation (50)-Lightness (0) on X-ray CT scan of (a) S2 abnormal brain.

2. Data analysis and interpretations

The Pixel Region tool provided by MATLAB 7.0.1 shows the pixels at high magnification, overlaying each pixel with its numeric value. For RGB images, we find three numeric values, one for each band of the image (Fig. 5. a). 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 calculating the X-ray CT image mean, median standard deviation, range, etc., (Fig. 5.b.)

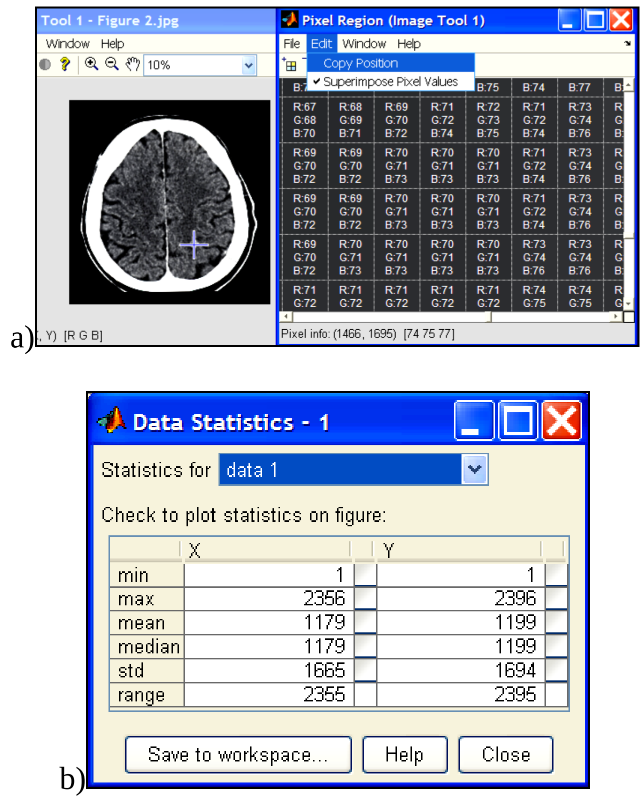
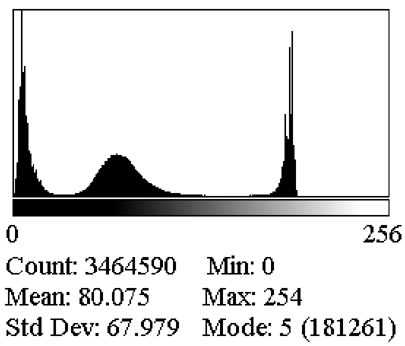


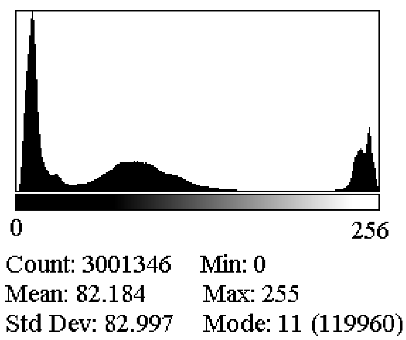
Figure 5. – **MATLAB 7.0.1**.-Image Processing on X-ray CT S2-abnormal brain scan (RGB image, 2356 × 2396 pixels): (a) The Pixel Region (b) Data Statistics

Histogram illustrates the number of pixels distributed on X-ray CT image (y-axis) for each level (gray value) from darkest (0) to brightest (256). The total pixel count was also calculated and displayed, as well as the mean, modal, minimum and maximum gray value by using

ImageJ program (Fig. 6.a,b). Count indicates the total number of pixels corresponding to the intensity level. Mean (80.075 for S1 and 82.184 for S2 shows the average intensity value. It is the sum of the gray values of all the pixels in the selection divided by the number of pixels. Std Dev (Standard Deviation) indicates how widely intensity values vary. Min (0) and Max (255) represents the minimum and maximum gray values within the X-ray CT images. The Mode (Modal Gray Value) was computed as the midpoint of the histogram interval with the highest peak. Figure 6.a indicates that all the pixels had been shifted to the left, shadow side of the histogram. For this reason I concluded that there are no pure whites in the S1 X-ray CT normal brain scan.



a)



b)

Figure 6. – **ImageJ** Histograms of (a) S1- X-ray CT normal brain scan (b) S2- X-ray CT abnormal brain scan

Particles Analyze command counts and measures objects in binary or threshold images. Once the image has been segmented we can obtain various information regarding particle size and numbers. By using ImageJ software we can also perform a set of measurement on a selected object (the brain tumor showed in Fig. 1.b.). The Integrated Density represents the sum of the values of the pixels in the selection, being equivalent to the product of Area and Mean gray value. Median (127) exhibits the middle value of the pixels in the selected brain tumor. The Feret's diameter (Caliper length = 0.911 cm) is the longest distance between any two points along the selection boundary. The measurement results are presented in calibrated units (Table 1). A fundamental task in many statistical analyses is to characterize the location and variability of data set. **Skewness** is a parameter that describes the asymmetry of a PDF (Probability Density Function) while **Kurtosis** is a parameter that depicts the shape (the degree of peakedness - broad or narrow) of a PDF.

For univariate data: $X_1, X_2, \ldots, X_n$, the formula for Skewness is given by:

$$\text{skew} = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^3}{(n-1)s^3} \qquad (2)$$

and the Kurtosis is defines as:

$$\text{kurt} = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^4}{(n-1)s^4} \qquad (3)$$

where $\bar{X}$ is the sample mean, s is the standard deviation and n is the number of data points. The Skewness for a normal distribution is zero and the kurtosis for a standard normal distribution is three. This statistical measure was used to describe the distribution of observed data around the mean. Positive values for the Skewness (0.067) show that data are skewed right. Negative Kurtosis (- 0.509) indicates a ''flat distribution''.

Table 1. The measurement results of a brain tumor

Results

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Area	Mean	StdDev	Mode	Min	Max	Kurt
0.468	127.666	32.986	139	67	213	-0.509

Perim.	Circ.	Feret	IntDen	Median	Skew	Kurt
2.459	0.974	0.911	59.780	127	0.067	-0.509

Profile Plot displays a two-dimensional graph of the intensities of pixels along a line (x-axis or y axis) within the X-ray images (Fig.7. a,b). For plotting the S2 X-ray CT of abnormal brain I have been used the figure 1.b.

High peaks depict calcified tissue while boundary valleys with lowest gray values show low density tissues (lack of tissue) in Profile Plots on x-axis and y-axis. The matrix which describes the location of brain tumor on x-axis and y-axis versus gray value GV_x and GV_y respectively can be written (Fig. 7.a,b):

$$M_x = \begin{bmatrix} x_1 & x_2 \\ GV_{x1} & GV_{x2} \end{bmatrix} = \begin{bmatrix} 6.80 & 7.67 \\ 62.33 & 186 \end{bmatrix} \quad (4)$$

$$M_y = \begin{bmatrix} y_1 & y_2 \\ GV_{y1} & GV_{y2} \end{bmatrix} = \begin{bmatrix} 8.33 & 9 \\ 130.54 & 84.99 \end{bmatrix} \quad (5)$$

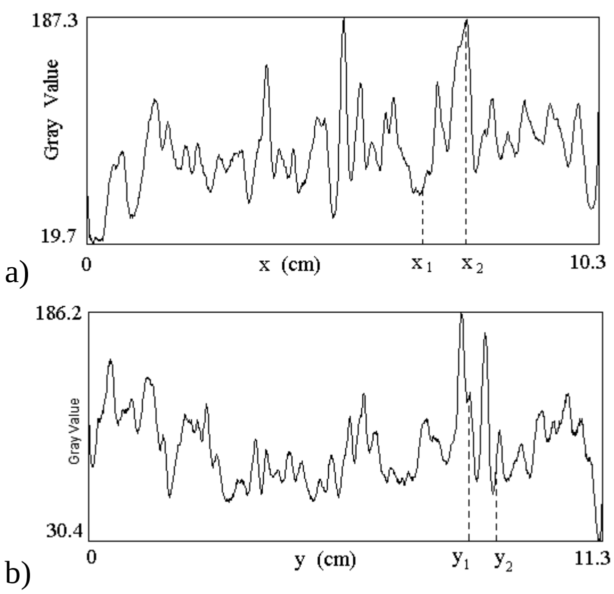


Figure 7. a,b - **ImageJ** Profile Plots of S2 X-ray CT abnormal brain scan – a) on x-axis: x_1 = 6.80 cm, x_2 = 7.67 cm b) on y-axis: y_1 = 8.33 cm, y_2 = 9 cm

In order to acquire the power spectrum as a function of frequency we have been applied the Fast Fourier Transform (FFT) analysis by using the histogram values (Fig. 8.a,b,c,d,) or profile plot values (Fig. 9.a,b).

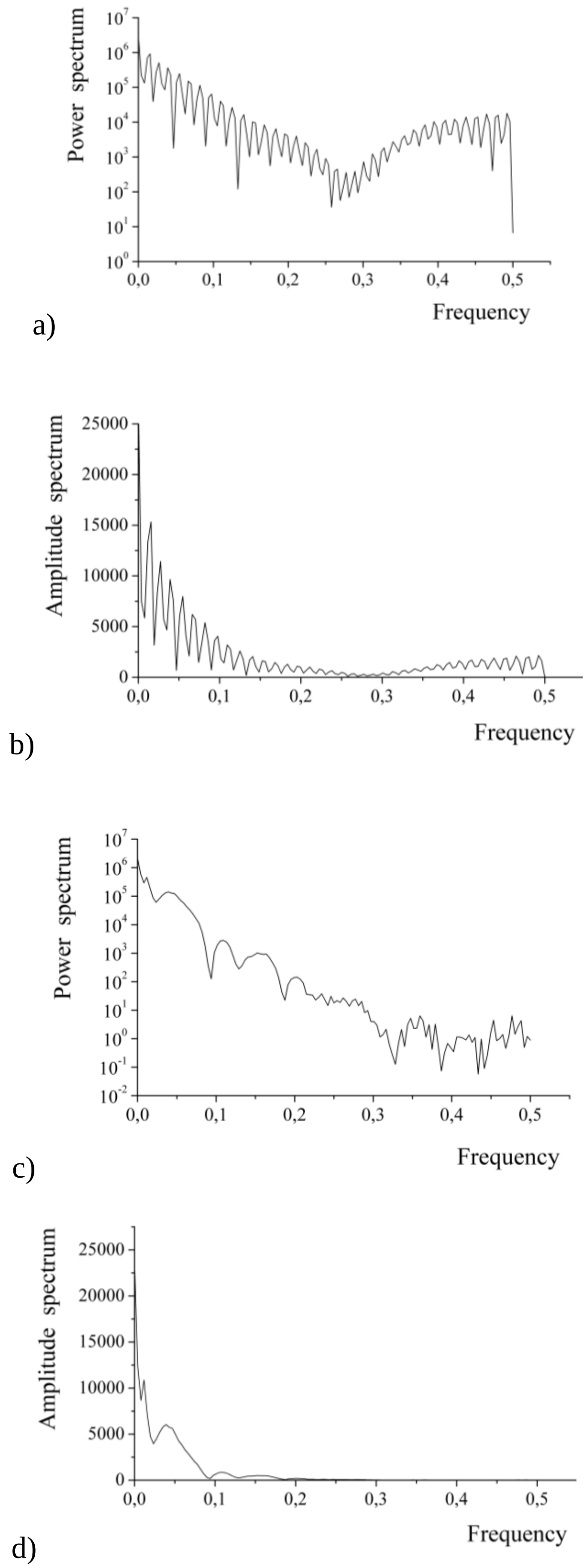
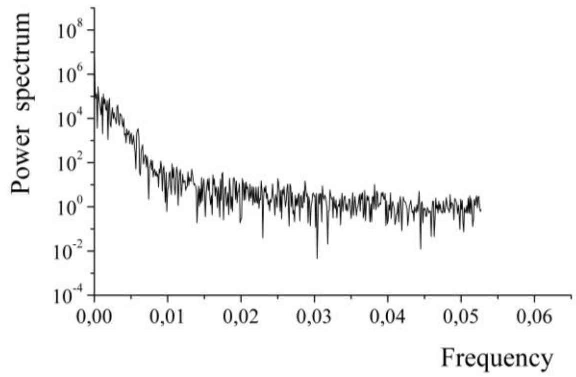
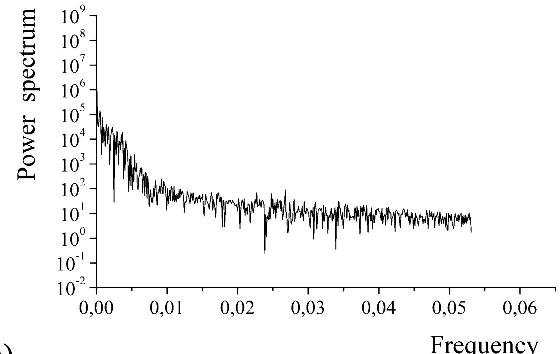


Figure 8. - **OriginPro** FFT analyze using histogram values of (a,b) - S1- X-ray CT normal brain scan, (c,d) - S2- X-ray CT abnormal brain scan



a)



b)

Figure 9. a,b - **OriginPro** FFT analyze using profile plot values of S2- X-ray CT abnormal brain scan on (a) x-axis and (b) y-axis

3. CONCLUSIONS

Image processing of X-ray CT scans can reveal the characteristic pattern of psychiatric and neurological disease showing multiple perfusion deficits or asymmetric perfusion in both hemispheres and it can also help distinguish between a disorder and a normal brain. While an X-ray CT scan may indicates a normal brain, sometimes the different image processing programs reveal discrete and small areas of decreased perfusion. The X-rays penetrate the tissues differently depending on the type of tissue. The solid tissue, such as bone, appears white and the air appears black. By using in conjunction some Image Processing, we can obtain a detailed image of brain structures. Image analysis with MATLAB 7.0.1., OriginPro 7.5 and ImageJ programs revealed Histograms, Profile Plots, Power Spectra and measurements on a brain tumor with a Feret's Diameter of 0.911 cm.

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