Image Analysis in X-ray Computed Tomography

Emilia Dana Seleţchi 1, Victor Şutac 2

1University of Bucharest, Faculty of Physics, Bucharest, ROMANIA
E-mail: seletechi@gmail.com
2Cygnus Scientific Society, Suceava, ROMANIA
E-mail: visutac@yahoo.com

Abstract
Computed Tomography (CT) is a powerful nondestructive evaluation method for producing 2-D or 3-D cross-sectional image of body tissues and organs. X-ray scans furnish detailed images of an object such as dimensions, shape, internal defects and density for diagnostic and research purposes. The image-analysis technique includes: image acquisition, image processing, measurements, data processing, and interpretation. Statistical functions enable to analyze the general characteristics of a neuroimage by displaying the image histogram or plotting the profile of intensity values. Image processing with Adobe Photoshop, ImageJ, Corel PHOTO-PAINT, Origin, etc. software has been used in order to achieve high-resolution, objective and quantified observations on CT images of brain structures. Data analysis of CT images can help distinguish between a neurological disease, a common disorder and a normal brain.

Keywords: X-ray Computed Tomography, Histogram, Plot Profile, Surface Plot

1. Introduction
Computed tomography (CT), originally known as computed axial tomography (CAT) is considered the first non-invasive radiological method allowing the generation of tomographic images of every part of the human body without superimposition of adjacent structures. Supposing that we have a very narrow pencil beam of monochromatic X rays and no scattering reaching the detector which traverse a medium of constant linear attenuation coefficient $\mu$ for a distance $x$. The beam is attenuated in accordance with Beer's law:

$$ I = I_0 \exp(-\mu x) $$

$I$ and $I_0$ are the transmitted and the incident intensities.

When the medium is no homogeneous, we must integrate along the absorption path:

$$ I = I_0 \exp\left(-\int \mu[x, y] \, dl\right) $$

$l$ = the straight line joining the source and detector (Barrett and Swindell, 1981; Duliu, 1993, Bistriceanu, 1996; Webb, 1996).

Beam hardening artifacts caused by polychromatic X-ray sources are most noticeable in the CT images. X-ray scatter also leads to another type of error in the
measurement of a projection. Modern CT scanner can acquire data in a continuous helical or spiral fashion, shortening acquisition time and reducing artifacts.

2. ImageJ Applications

ImageJ is a public domain Java image processing program. It can display, edit, analyze and process 8-bit, 16-bit and 32-bit images. It can calculate area and pixel value statistics of user-defined selections. This program is used to measure distances and angles creating density histograms and line profile plots. ImageJ supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering. It does geometric transformations such as scaling, rotation and flips. All analysis and processing functions are accessible at any magnification factor.

Histogram of gray values illustrates the number of pixels distributed on image (y-axis) found for each gray value or levels (x-axis) from darkest (0) to brightest (256). The total pixel count is also calculated and displayed, as well as the mean, modal, minimum and maximum gray value. With RGB (24-bit) images, the mean is calculated by converting each pixel to gray scale by using the formula: gray = 0.299 red + 0.587 green + 0.114 blue or the formula: gray = (red + green + blue)/3 if Unweight RGB to Grayscale Conversion is checked in Edit/ Options/ Conversions. The ”spikes” (white vertical lines) in a histogram represents lost data.

Plot Profile displays a two-dimensional graph of the intensities of pixels along a line within the image. The x-axis represents distance along the line and the y-axis is the pixel intensity (Fig. 3. and Fig. 4.).

Analyze Particles command counts and measures objects in binary or threshold images. Edge enhancement, the opposite of smoothing, can be realized by having negative values in the filtering matrix. This filter is useful for delineating organ boundaries in images.

Two X-ray CT scans of a brain (woman 33 years old) and their corresponding histograms are illustrated in Fig. 1. (a, b.) and Fig. 2. (a, b).

![Figure 1. – X-ray CT scans of the brain (Emergency Hospital, Bucharest)](image)

a) 2.555 x 2.484 pixels, 8-bit, b) 1861 x 2101 pixels, 8-bit
The histogram revealed the statistical information about the intensity values of the pixels:
- Mean shows the average intensity value. It is the sum of the gray values of all the pixels in the selections divided by the number of pixels.
- Standard Deviation (Std Dev) represents how widely intensity values vary.
- Count indicates the total number of pixels corresponding to the intensity level underneath the pointer.

Figure 2. a,b – Histograms of 1.(a,b) X-ray CT images (300 x 200 pixels, 8-bit)

Figure 3. – Plot Profile of 1.a. X-ray CT image (520 x 250 pixels, 8-bit)

Figure 4. – Plot profile of 1.b. X-ray CT image (520 x 250 pixels, 8-bit)
Figure 5. a,b - ImageJ multiple processing: **Binary** – Threshold followed by **Filtering** – Variance (Radius 5 pixels) of 1. a,b – X-ray CT scans of the brain. Additionally for 1.b. X-ray CT scan we have been applied an initial Processing: **Enhance Contrast** (Saturated Pixels 0.5 %, Equalize Histogram)

3. Corel PHOTO-PAINT 12.0 Applications

Corel PHOTO-PAINT is a bitmap drawing program for photo editing. Like Corel DRAW and Adobe Photoshop, it places objects in layers, allowing manipulation of effects on specific layers.

Corel PHOTO-PAINT provides filters to adjust color and tone of images. The Local equalization filter allows the enhancement of the contrast near image edge revealing details in both light and dark regions. The filter uses neighboring pixels to create a stylized effect. In Corel PHOTO-PAINT, the colors are defined by color modes. 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.

Figure 6. a) **Effects** – Color Transform – Psychedelic 127 of 1.a.X-ray CT image (RGB)

b) **Adjustments** (Hue 63, Saturation 100, Lightness 0) applied after Psychedelic Effect for 1.a. X-ray CT image (RGB)
Hue represents color, saturation indicates the color depth or richness and lightness shows the overall percentage of white in the image.

![Image](image1.png)

**Figure 7.** a) **Double Effects** – Color Transform - Bit Planes (Level 6) followed by Color Transform – Psychedelic 160 of 1.a. X-ray CT image (8-bit Gray scale)

b) **Double Effects** – Color Transform – Psychedelic 204 followed by Bit Planes (Level 6) of 1.a. X-ray CT image (RGB)

4. **Adobe Photoshop 7.0 applications**

Adobe Photoshop is one of the most popular and up-to-date image editing software which allows us to transform scanned photographs, slides and original artwork by cropping, rotation, resizing, adjusting and by creating special effects. Invert represents an effect to convert every colour in our image to its exact opposite. The only colour that doesn’t change is medium grey, because it is its own opposite. Threshold Adjustment converts all colours to either black or white based on their brightness values. Posterize option can retain as many colour as you like, by dividing automatically the full range of 256 colours brightness values into a specified number of equal increments. The Adobe Photoshop Filters enable to apply automated effects to an image, allowing us to correct lighting and perspective fluctuations, increasing the focus of an image and adding depth to an image.

![Image](image2.png)

**Figure 8.** – a) **Filters** – Brush Strokes – Accented Edges (Edge Width 4, Brightness 45, Smoothness 14) for 1.b. X-ray CT image (RGB)

b) **Filters** – Stylize – Glowing Edges (Edge Width 4, Brightness 11, Smoothness 8) for 1.b. X-ray CT image (RGB)
All the Filtering were performed after Psychedelic Effect (Red 50, Green 100, Blue 80, Frequency 50, Blend 50)

5. OriginPro 7.5 applications

Origin converts each pixel to an RGB value giving the corresponding matrix cell an index number to a gray scale palette, based on the RGB value of the pixel. Origin can also create Histograms of the intensity values in the image, Plot Profiles of Images and Plot Profile of Contour Images. Surface Plot displays a three-dimensional graph of the intensities of pixels in a gray scale or pseudo color image.

Figure 9. a) Filters – Stylize – Trace contour (Level 45, Edge Lower – Find Edges) followed by Image Adjustments – Invert for 1.b. X-ray CT image (RGB)
b) Filters – Stylize – Trace contour (Level 165, Edge Upper – Find Edges) followed by Image Adjustments – Invert for 1.b. X-ray CT image (RGB)

Figure 10. a) Plot Profile and b) Plot of Contour Profile of 1.a. X-ray CT image.
Figure 11. - 3 D Color Map Surface of 1.a. X-ray CT image: a) before processing, b) after ImageJ multiple processing illustrated in Fig. 5.a.

Figure 12. a) Plot Profile and b) Plot of Contour Profile of 1.b. X-ray CT image.

Figure 13. - 3 D Color Map Surface of 1.b. X-ray CT image: a) before processing, b) after ImageJ multiple processing illustrated in Fig. 5.b.
6. Conclusions

Image enhancement technique allows the increasing of the signal-to-noise ratio and accentuates image features by modifying the colors or intensities of an image. Image analysis includes texture analysis, line detection, morphology, edge detection, segmentation, region of interest processing and feature measurement. Image enhancement includes linear and nonlinear filtering, deblurring and automatic contrast enhancement. 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 (George et al, 1991) 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. Plot Profiles and Surface Plots allow the analysis of these images after processing. The image processing of X-ray CT scans presented in this paper, show a very active and normal brain, but we have been identified small calcifications (perfusion deficits) in the central sulcus area (Right) and angular area (Left).

References

7.1 Books

7.2 Conference Proceedings:

7.3 Internet Sources
http://rsb.info.nih.gov/ij/docs/menus/analyze.html
http://www.bayphoto.com/bayweb/pro_help/histograms.htm
http://www.cam.ac.uk/cs/docs/leaflets/m440/m440.pdf
http://www.kf.vu.lt/~albud/multim/engl/help.doc
http://www.hku.hk/cc/document/photoshop/