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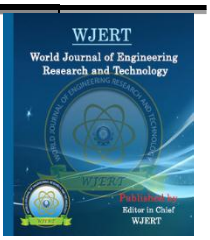

ANALYSING THE POWER INTENSITY VARIATION ON THE QUALITY OF HEAD TOMOGRAPHIC IMAGES

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ABSTRACT

Tomography is a non-invasive exam technique that provides a great amount of visual information of virtually inaccessible areas of the body. This paper analyses the quality of a set of tomographic images taken with different irradiated power, controlled by current value, searching for the smaller current that can provide sufficient quality images.

KEYWORDS: Tomography; Biomedical image processing; Image analysis.

INTRODUCTION

Tomography image analysis is one of the most important steps in clinical diagnosis for many different pathologies, as they provide a great amount of visual information of virtually inaccessible areas of the body, such as the brain. Despite their important role in medicine, exposing the patients to unnecessary amounts of radiation causes serious health problems. The goal of this research project is to identify the lowest power needed such that the tomographic image conveys all the information needed for diagnosis. In this study a phantom is used and the images acquired under different power intensities are compared pairwise by calculating their Peak Signal-to-Noise Ratio. The computation of the PSNR is made between images related to the same section of the head tomography, but acquired at different electric current values, which implies a variation in the applied power.

In the following section, the background related to the topic studied in this paper is presented. Section III discusses the methodology used to compute the results of interest. Section IV presents the results obtained from the experiment, and Section V draws the conclusion and points at possible extensions to this work.

2. Background

The study of biomedical images is of paramount importance in helping health specialists in achieving better diagnostics in non-invasive, risk-controlled, and as less harmful as possible manner. Computed Tomography uses X-ray beams to acquire images. It is common belief that a higher radiation level determines yields a better quality image, allowing the visualization of small structures such as tumors at very early stages. At the same time, higher levels of radiation may cause short, medium or long-term health distresses to patients and, depending on his/her health condition, age, etc, can have disastrous effects.[1]

Determining the lowest radiation level in which it is possible to identify possible lesions is therefore of great importance for both physician and patient.

2.1 Computed Tomography

Computed Tomography is one of the most important exams for modern diagnosis for a large number of pathologies. It basically acquires an image of a section of a given body part, or even the whole body. It uses X-ray beams that move around an axis, positioned at the target section, usually in the same plane. The resulting image is formed by applying projective geometry techniques.[2,3]

Its fundamental difference from a standard X-ray image is that it only represents the structures found in the thin target section, while X-ray images contain the information of all the possible sections of a given area, overlapped not allowing a detailed analysis of structures.

One of the greatest advantages of CT is that the whole scanned area maybe reconstructed in different manners, including three dimensional models of the area, also known as 3D rendering.[4]

A CT scan results in a set of images which may contain a large number of images, depending on the thickness represented by each section; thinner sections will lead to a larger set of images. The set of images is usually stored in the DICOM image format, which is a standard of NEMA (The Association of Electrical and Medical Imaging Equipment Manufacturers), based in Washington, D.C., USA.

2.2 Digital Image File Formats

There are many different digital image file formats available to store visual information, each with its own capabilities and target platform objectives. In this paper, two formats are extensively studied: the DICOM and the TIFF formats.

DICOM acronym stands for Digital Imaging and Communications in Medicine, managed by the Medical Imaging and Technology Alliance, division of NEMA. The DICOM format is an image standard for many different medical equipment, including CT scanners. The images in DICOM are designed to store more than simply the resulting image, as it is often related to a set of multiple images acquired from the same area. Working with them as single isolated images will often lead to scrambling the results of different patients. For the purpose of improving the storage capabilities, the DICOM format also includes text fields and graphic elements, which may include the name of the facility where the images were acquired, the patient data, acquisition data (Brilliance, index of image in the set, voltage and current used, section thickness, plane axis, etc), making the storage and organization of these images easier.

Plain images in DICOM are stored with 12 bit per pixel grayscale, which is reproduced as an image that contains more shades of gray that can be presented by common computer screens. To see an image with a suitable representation of the target observed tissue, an adjustment in the grayscale Level and Window is necessary. This adjustment is specific to the observed tissue, and in the specific case of the samples used in this paper, which represents the Posterior Fossa, the Level and Window values are adjusted to 35 and 150, respectively.

The TIFF format is used in this work due to its characteristic of good grayscale representation, including different bits per pixel representations. The sample images provided were converted to 16-bit per pixel TIFF images, which prevent any loss of information in the conversion process.

2.3 Peak Signal-to-Noise Ratio

The PSNR is an index that represents the ratio between the maximum possible power of a signal and the power of a corrupting noise affecting the quality of its representation. PSNR is often used to compare the result of a compression standard to the original artifact, leading to a numeric representation of its fidelity.[5]

The PSNR depends on the Medium Square Error (MSE), as one image may be considered a slightly different version of the original. In the case of monochrome images, the expression of MSE must be evaluated in a two dimensional matrix, as follows:

$$MSE = \frac{1}{m \cdot n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left[I(i,j) - K(i,j) \right]^2 \qquad (1)$$

Where the values *I* and *K* represent the 16-bit value of the pixel at coordinates (*i*,*j*).

The PSNR can then be defined as

$$PSNR = 10 \cdot \log_{10}\left(MAX_I^2 / MSE \right) \qquad (2)$$

Where *MAXI* is the maximum value assumed by the pixel, which is 212, or 4096, for the 12-bit original DICOM images.

From the PSNR expression it is possible to conclude that most similar images will have higher values of PSNR. In the case of two equal images, the difference between their pixels will be zero, thus the value of the MSE, is also zero. If that is the case, the computed PSNR would result in infinite, indicating that they are equal. In the same way, very different images would have high MSE and, consecutively, small PSNR.

3. Methodology

In order to evaluate the PSNR of the tomographic images obtained with different power values, it is necessary to assemble a statistically representative sample of images. A set of tomographic images of a phantom comprised of 87 sections, with the images being acquired at six different power values (100, 150, 200, 250, 300 and 350 mAs) which will be compared pairwisely.

Amongst the 87 sections in the studied set, 21 contain 4 round areas of different densities that simulate structures of different tumor tissues, which are called “the four coins”. The main focus of this study is to evaluate which is the lowest power at which these structures can be perfectly visualized. A tomographic image encompasses the “subject” and surrounding medium. In this study, the subject is called “the region of interest” (RoI), while the four coins are called the “regions of critical interest” (RoCI).

3.1 Computational Tools

The images provided by the tomograph used in this study for the evaluation of the minimum power levels are stored in the DICOM standard format, which is the standard file format for biomedical images. The current available computational tools for image processing have poor manipulation capabilities in the DICOM format, which is built on grayscale with 16 bits per pixel (bpp). Thus this study started by choosing a suitable intermediate file format for image processing. First tests with BMP, which is a lossless format, were unfruitful, since the standard conversion tool provided by ImageJ.[6] is only able to save it in RGB scale with 24 bpp, where each set of 8 bits represent one of the color components.

ImageJ is recognized as a standard open source program for image processing, given the amount of supported formats and available plug-ins and ease of additional features development. We used ImageJ as a basis for our own plug-in, designed to create masks, calculate the PSNR for a set of images, and to store the result as TIFF images and plaintext tables. ImageJ provides extensive support to the TIFF image format, which suits perfectly for image format conversion without loss of information.

The first program for PSNR calculation was coded in C# language, using Visual Studio 2008, but the .Net Framework provides no satisfactory support for grayscale images, as it focuses at artifacts that can be presented on standard computer screens, which is not the case of 16-bpp grayscale files.

The DICOM images contain other information fields such as patient data, hospital information, etc. that are not necessary for image analysis and should be discarded in the conversion. When ImageJ opens DICOM images, it already excludes those auxiliary fields, leaving only a 16-bpp grayscaleimage. Although it is needed to adjust the Window/Level of the images for a correct visualization, this effect does not alter pixel values, which means that such operation does not implies in modification of the original information. After this correction, the images were saved as 16-bpp grayscale TIFF files, maintaining the original information as desired.

Example of the resulting images can be seen in Figure 1 (a) and (b), representing section 30 acquired with 100 mAs and 300 mAs, respectively. As can be observed, the image in Figure 1 (a) has more image artifacts and noise than the one in Figure 1 (b).

To correctly analyze the images, the area external to the head, which corresponds to ionized air and offers no information of the tissues inside the head area, should not influence the PSNR calculation thus a mask should be designed to exclude the value of the external area. As the experiments were conducted using a phantom and thus several images are available with different levels of power, such mask was obtained by subtracting the 300 mAs image from the 350 mAs. The resulting image was then subtracted the 250 mAs image, yielding an image that was binarized and color inverted. All these steps were automated with ImageJ and the result could be saved for later use as the mask for that specific section.

The next step was calculating the PSNR, by making the difference between each pair of images acquired with different current for the same section, using the mask for that section to exclude the external pixel from the computation. As an example, in section 43, six images were available, according to the used current (100, 150, 200, 250, 300 and 350 mAs). Excluding the comparison with itself, 15 different comparisons were made. The image generated by the difference computed for each pixel is shown in Figure 1 (c). A resulting matrix generated by the PSNR computation for each section was then saved for later comparison.

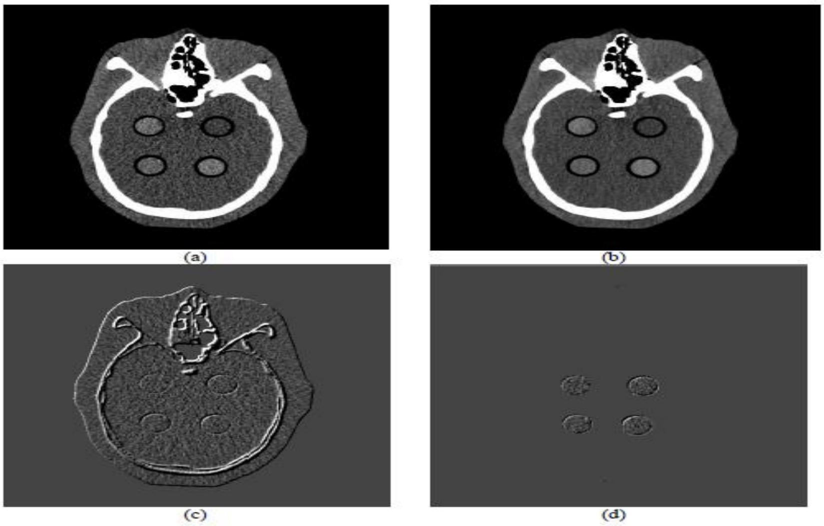
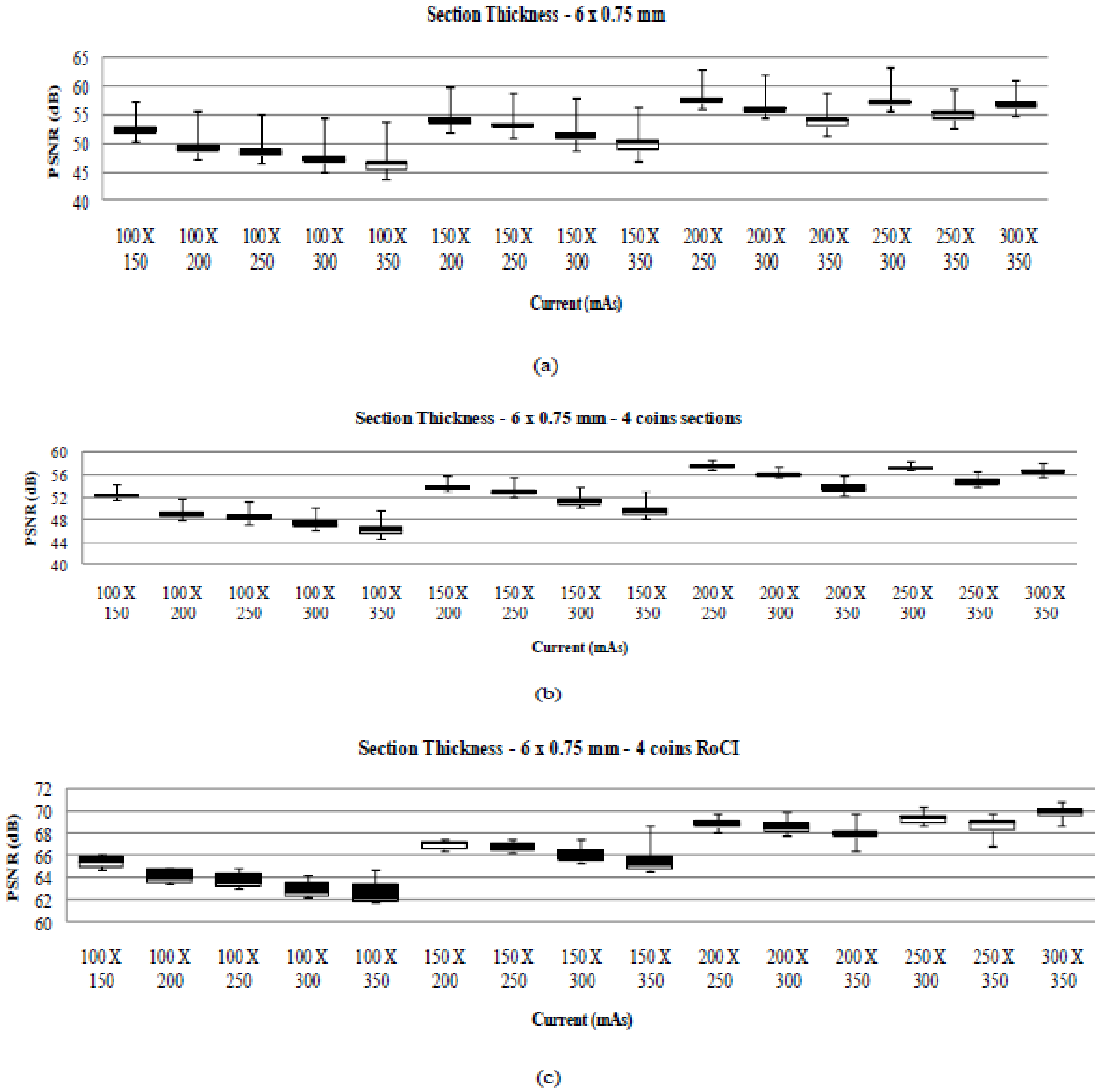


Figure 1: Original and processed images (a) Original image for section 30 at 100 mAs, adjusted for Level 35 and Window 150. (b) Original image for section 30 at 350 mAs, adjusted for Level 35 and Window 150. (c) Resulting image of the difference of images (a) and (b), with a mask excluding the area external to the head. (d) Result image of the difference of images (a) and (b), with a mask excluding the area external to Critical Region of Interest.

After computing the PSNR for all the sections, it was defined that the PSNR study should also be made in the Region of Critical Interest, represented by the areas inside the "4 coins". A mask was designed so that only the pixels contained inside the 4 coin area would be evaluated. The resulting image of the pixel difference inside the 4 coin area is shown in Figure 1 (d).



(a)

(b)

(c)

Figure 2: Box Plot Graphs for the computed PSNR for three different sets.

(a) All the 87 available sections, with a mask excluding the area external to the head.

(b) A selection of the 21 sections where the 4 coins can be observed (from 23 to 43), in (a).

(c) The 21 sections containing the 4 coins, using the mask which represents only the 4 coins areas.

4. RESULTS

The result of the computation executed in the available sample had the expected result, meaning that increment in current does not offer additional information after a certain value.

The Box Plot representation offer a good visualization of the gathered results, as it takes in consideration all the points of a sample. Organizing the results of the 87 sections offers a coherent vision of the event. As can be seen in Figure 2, the results are very coherent, with little dispersion or error, corroborating the formulated thesis that the increase in irradiated power after a certain value adds no information to the tomographic process.

Observing the comparisons made to the 100 mAs image, it is possible to see that the PSNR value decreases as the difference in current increases, as expected, due to their stronger differences.

If analyzed as a whole, the results point that as the used current increases, the images will become more similar, as observed in the case of 250 mAs compared to 350 mAs and 300 mAs compared to 350 mAs, which yields very similar results.

The results in Figure 2 (c) indicate that inside the RoCI is even more similar than the external area, which is greatly influenced by its small size. Despite that, it is possible to see that the less similar images, obtained with 100 mAs and 350 mAs, have an approximate value of 63, which is a high rate of similarity. It is also possible to see that the PSNR behavior observed for the whole image is also reflected in the RoCI.

5. Conclusion and Future works

This work suggests that the gain of information with the increase in current deceases beyond 200 mAs for the offered sample, obtained with 120 kV. For other samples, this point can also be calculated, or be close to this value of current, if the CT machine has a similar sensibility.

The experiments performed allows one to conjecture that higher current values will present even more similar results than those offered here, as the external curve has a saturation behavior. This must be investigated further.

Also as for future works, it is necessary to use a more extensive set of image samples and to compare the results for different test phantoms. Other points that can be further studied are:

the use of different section thickness, variation in the applied voltage, use of different machines (benchmarking).

Further planned studies include the creation of tools to study the histogram and entropy in biomedical images, in the intention of detecting lesion structures.

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