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REDUCING OF RADIATION DOSE FOR X-RAY USING CONTOURLET TRANSFORM AND BLOCK THRESHOLDING TECHNIQUE



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Abstract. Medical Image Denoising represents one of the fundamental challenges in the field of biological image processing and computer vision. X-Ray imaging is one of the widest used image acquisition technique in hospitals. Image denoising goal is to enhance the original X-Ray image by suppressing noise from a noise-contaminated version of the image. In this paper, a comprehensive survey of the types of noise added in X-Ray examination images was conducted, and to develop a database of five known types of X-Ray examinations in the hospital, three devices were randomly selected and 100 patients included in this survey. The survey results have been compared with the results of the International Atomic Energy Agency (IAEA) and the data have been useful to serve as a national guide or reference.

Secondly, a denoising algorithm using Contourlet transform with blocking method was proposed to improve the quality of X-Ray images, which reduces the radiation dose resulting from repeated radiographic attempts to patients and workers.

Keywords: X-ray, Blocking, Block thresholding, Contourlet, MRI images and Standard Deviation of Blocks

Introduction. To ensure the safety of workers in the radiation fields, as well as to reduce the dose received by the patient, an image improvement program should be applied by image processing of diagnostic radiology departments in medical institutions, as it leads to accurate diagnosis without exposure to unjustified radiation doses by reducing the noise generated by the devices. It takes a set of measures related to the performance, equipment, and X-Ray devices used in medical diagnosis, including digital image processing. Quality assurance programs have been established and approved in the rules and laws of most countries in the world and in the safety standards of international organizations [1]. The image improvement system aims to:

1 - Improve the image of the various body tissue structures on the X-Ray film or screen.

2 - Reducing radiation exposure to patients and workers.

3 - Reducing costs (film consumption, radiant tube life).

The quality assurance program is defined as the organized effort by workers in the diagnostic medical institution in order to maintain that there is no change in the technical specifications of devices over time.

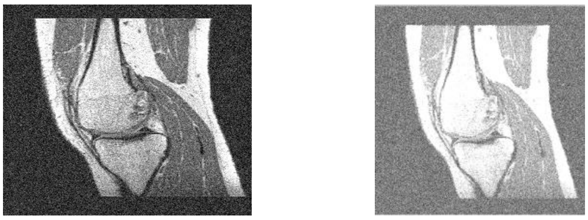
A database of radiation doses has been created and has helped in comparison. For the first time, we did with radiopathic physicians working in X-Ray units performed 500 examinations. The result was that the annual dose 0.05 mSv and chest exams accounted for 63% of the total, that the radiation doses decreased After conducting quality assurance tests for the devices in this study. The dose was measured by (RMI Model 240) device and is intended for X-Ray with quality assurance tests. Analysis of test results showed that the causes of added noise and distortion was as below:

- 92% have tube voltage within the permissible limit.
- 90% have exposure time within the permissible limit.
- 86% to 98% straightness of its X-Ray beam is acceptable.
- 81% has a good radiation focus.
- 88% have *mAs* within the permissible limit.

The medical image denoising target lies primarily in the preservation category of image data quality in which the image signal transfer process affects the signal using many types of communication channels [2]. Denoising images is an important technique for image processing analysis. In this work, two noise models, Additive Noise Model (AWGN), and Impulsive Noise were used (Salt & Pepper) [3], for experimental requirements, noise signal gets added to the original signal (Image) to produce a corrupted noisy signal [4, 5]. The additive noise model follows the following rule:

$$W(x,y) = s(x,y) + n(x,y) \quad \text{….. (1)}$$

Where, $s(x,y)$ is the original image intensity and $n(x,y)$ denotes the noise introduced to produce the corrupted signal $W(x,y)$ at (x,y) pixel boundary, the two types of noise mentioned before (AWGN, Salt & Pepper) are evenly distributed over the signal [6]. This means that each pixel at the noise image, is the sum of true pixel value and random gaussian noise distributed value. Figure (1) shows the normal noise distribution over the transmission channel [6].



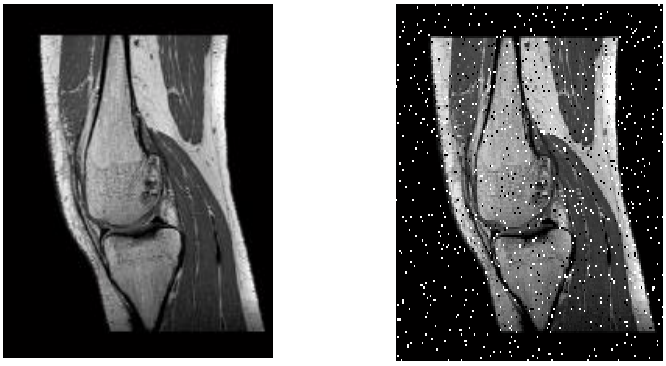
a b

Figure *1*. a – Noisy image of (AWGN) with, Mean (μ)=0.5, Variance (σ^2) = 0.05,
b – Noisy image of (AWGN) with Mean (μ)=1.5, Variance (σ^2)= 0.5

The probability density of the normal distribution is:

$$PG(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\mu)^2/2\sigma^2} \text{.... (2)}$$

Where: μ is the mean or expectation of the distribution, σ is the standard deviation, $\sigma^2$is the variance [7]. The Impulsive noise (Salt & Pepper) effect is shown in Figure (2). impulse noises are classified into two major types, salt and pepper noise (equal height impulses) impulse values are represented as 0 and 255 pixel value and random-valued impulse noise (unequal height impulses) impulse values are between 0 and 255.

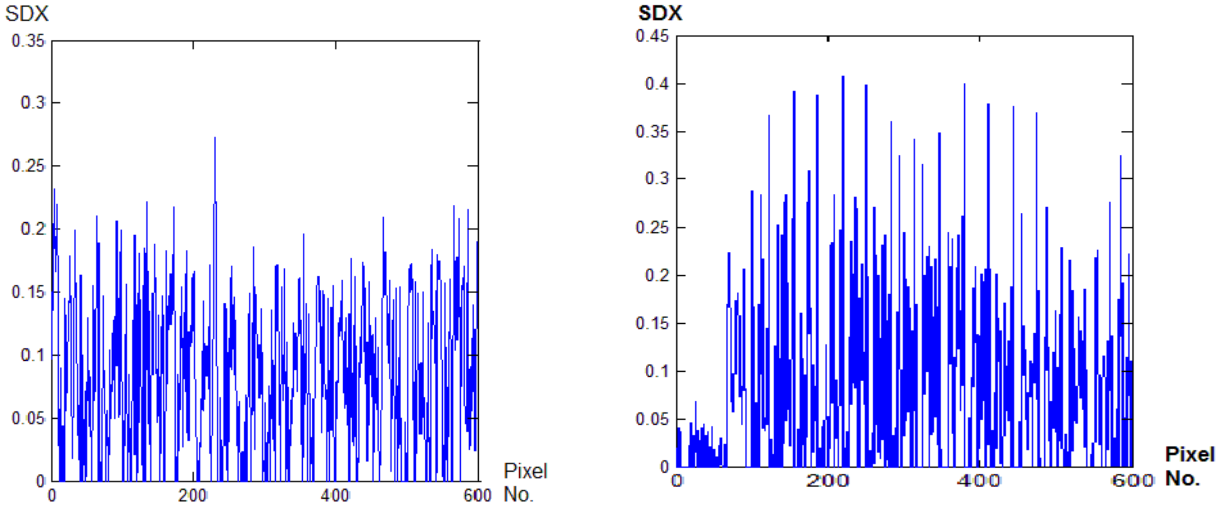


a b

Figure *2.* – The effect of impulsive noise: a – Original (X-Ray) image, b – noisy image with salt & pepper noise

The Proposed Method (CTB). In this paper, the focusing will be done with specific type of digital image (X-RAY). The multi-frame X-RAY scanner, that received from a digital photo-light scanner, has complain from many types of additive noise [8,9,10]. Denoising (noise removal) by comparing the variance σ^2 of intensity occurred, with the mean value of normal standard image, such as Barbara. Compartment between the standard deviation variation of Barbara, figure 3a with the same variation of figure 3b of X-RAY -knee image, shows the difference of intensity shots in X-RAY much more than a slandered image such as Barbara, thus, the analysis and the next preprocessing techniques, such as 2D wavelet transform and contourlet transform, will concentrated for the field of X-RAY images [11]. Figure 3 shows the standard deviation variation differences between the slandered and X-RAY image [12, 13].

The recent ideas has been proposed by the researchers, for how to select the good threshold value for image denoise (or compression) [8], although they are mostly used the wavelet transform bands, they suggest other types of transform such as (DCT) [9]. In this paper, the focusing will be done on the contourlet transform with blocking operation [14].

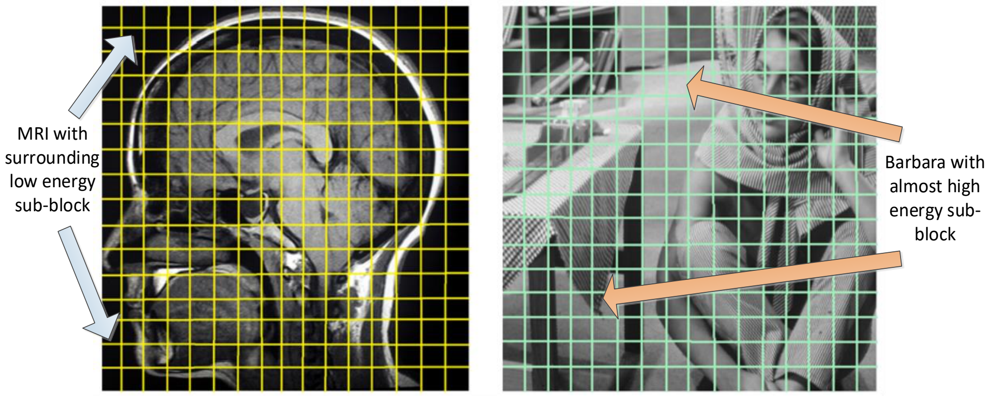


a b

Figure *3*. – The standard deviation variations: a – standard image [barbara], b – X-RAY image

Blocking operation. Blocking Algorithm has been used in the proposed system, instead of using the hole image, the sub-band of contourlet transform (with multi dimension arrays) instead of the sub-band wavelet transform (with two-dimension arrays). It is a new technique for maximizing signal to noise ratio.

For overall image size, (512x512) pixels, it can be use the block size of (32x32) pixel size, it means that the hole image will divide into (16x16) or 256 sub-image (block), as shown in figure 4.



a b

Figure *4*. a – X-RAY image blocking, b – Barbara image blocking

The analysis of preprocessing by using the mentioned techniques (wavelet, contourlet- with and without blocking) are achieved by applying the system shown in the figure 5.

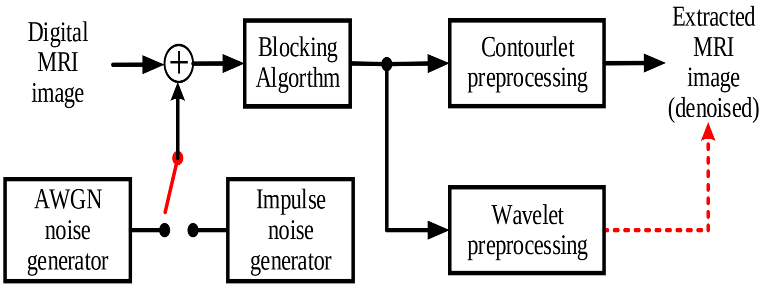


Figure 5. –The proposed system (CTB)

From the figure 4. It can be observe that the surrounding blocks, in figure 4a has lower energy (more darkness) as compared with the blocks inside the X-RAY object (skull), while there is a little difference in energy concentration of the blocks everywhere at the image of standard image (such as Barbara), figure 4b, as well seen in the figure 3(a,b) the standard deviation variation values of both, observe the more randomness of variation with the X-RAY than standard image. Whereas Do and Veterreli had proposed new multi-dimensional method for image denoising called contourlet transform this method is effectively able to find the contours and edges, its constructed of Laplacian pyramid (cluster) and filter banks [6,7,8]. The contourlet coefficients are generated by passing the bandpass output, then directed them to directional filter bank, the Laplacian pyramid is again received the output of lowpass in clustered manner till obtaining the image details like LL (Low-Low), LH (Low-High), HL (High-Low), and HH (High-Low). the schematic diagram of contourlet transform explained briefly in the Figure 6.

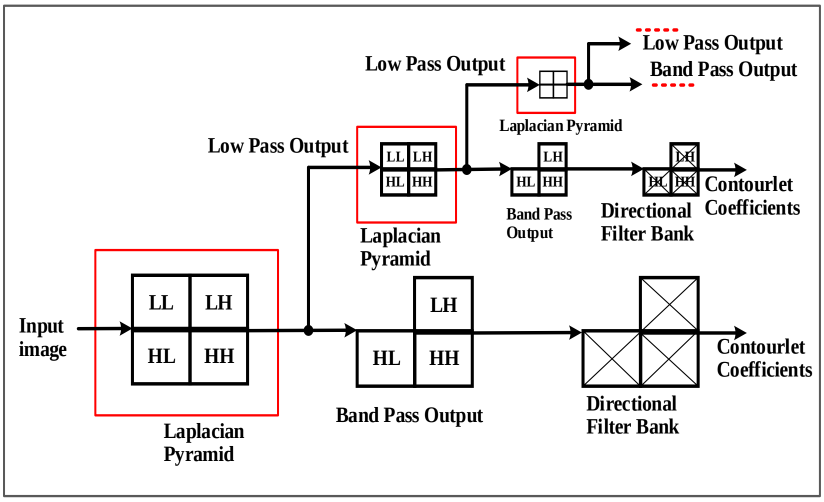


Figure 6. – Block diagram of Contourlet transform

The threshold value choosing for contourlet represents a problem in which solved in this work in automated choosing of the value of σ_x:

It means that, it should estimate the variance of noise value, and to find the optimal threshold value to be used in Contourlet transform with blocking technique. The variance of noise is calculated by:

$$\sigma_x^2 = \left\{\frac{med(K_{i,j})}{C}\right\}^2 \ldots\ldots \quad (2)$$

Where K, is the contourlet coefficients of the image, C, constant calculated by normalized mean value of individual block, the threshold value used for extracting contourlet coefficients is calculated by [6].

$$Th = \frac{3}{4} M \left(\frac{\sigma_x^2}{\sigma_d} \right) \; ..... \qquad (3)$$

Where M= the number of pixels in each individual block (x*y), σ_d is the standered deviation of noisy source image.

The experimental results. 1- The results of menual methods of measuring and controlling image quality of Radiation Doses.

Radiation doses were evaluated in this paper using an RMI 240 device designed for X-Ray devices. The reading rate for the three tablets that represent the Entrance Surface Dose (ESD pp) is taken in the presence of the patient, and this dose is the dose that the patient receives and the dose resulting from X-Ray scattering from the patient's body, and these doses can be compared to the global dose limits for each type of examination And for every hometown. As in the figure (7). Table (2) represents the surface potions before and after the factory reset, it is noted that the resulting images differ in their accuracy due to human errors in reading, therefore for the mentioned reasons a method was proposed in the image processing that greatly reduces reading errors Image.

Figure *7.* – X-ray measuring device RM 240

Table 1. **–** Represents surface doses of several parts of the body (A)PA: Posterior (B) LAT: Lateral AP: Projection Projection (C)

Projection Types						
Hospital	Chest	Skull		Lumber Spine		Pelvis
	PA	PA	LAT	AP	LAT	AP
before Noise removal						
A	0.27	3.81	3.53	12.36	14.88	11.70
B	0.28	5.05	4.02	7.00	15.70	2.6
C	0.38	4.32	5.14	6.54	13.50	7.16
After Noise removal						
A	0.29	3.58	2.84	8.39	8.03	9.74
B	0.09	4.7	3.74	3.9	8.4	1.2
C	0.24	5.12	4.37	5.78	11.26	6.42

The experiment has been done, mainly at X-RAY images, with the use of contourlet pre-processing and blocking algorithm, wavelet (2D) transform used for comparison of results for both, the standard image and blocking image. It is observed that the SNR has been improved when apply contourlet transform [10,11,12]. Figure (8, 9) represent Knee (X-RAY) with wavelet and AWGN [11] and Head (X-RAY) images.

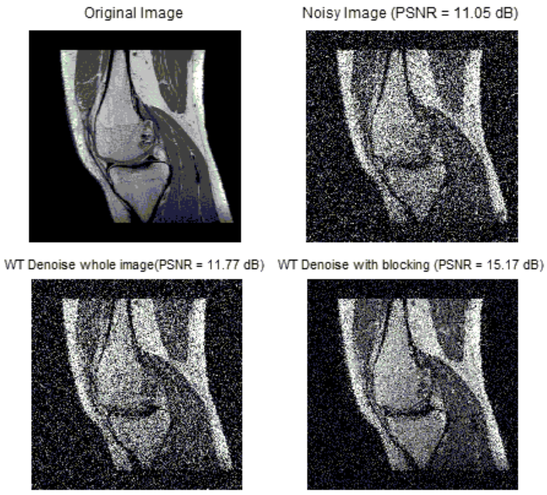


Figure *8.* – Contourlet denoising for AWGN filtering (denoising) - with Barbara

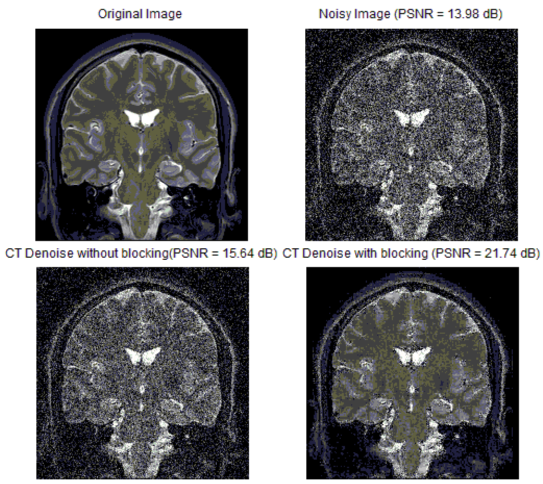
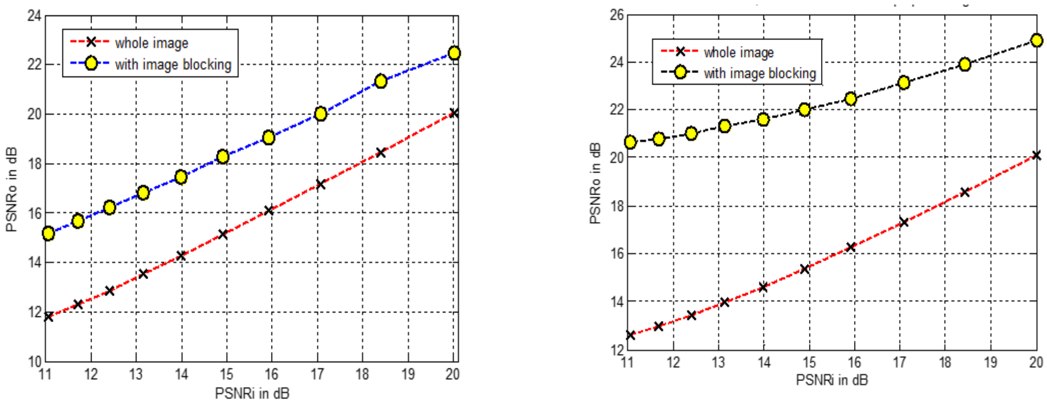


Figure *9.* **–** Contourlet denoising for AWGN filtering (denoising)- with Head(X-RAY)

From these figures, it's very clear visually that the contourlet transform has more PSNR gain comparing the blocking method used, and hole image without blocking. For the figure 8, the noisy Barbara image with 13.98 dB, the contourlet denoising results of 19.84 dB, while it was without blocking results only a 15.22 dB, but with X-RAY images, got more visual clear effect and higher PSNR with blocking algorithm for 21.74 (for Head X-RAY). The noise added for the recent three examples was only AWGN. As compared with the wavelet transform, it is observed that got only a 15.17 dB PSNR with Knee (X-RAY). It's clear that the best image media for the best PSNR using for the proposed method are X-RAY images, with contourlet transform and blocking method (CTB).

For ensure the robustness of the CTB, in addition of adding AWGN, the impulsive noise also used, the salt& pepper (a type of impulse noise) has been added to test the system. It is more difficult in remove than the white noise, in the figure 10(a), it's clear that when comparing the results by using blocking algorithm, with the hole image denoising (without blocking), got advantage of 3 dB PSNR difference with wavelet, and about 10 dB with contourlet preprocessing for AWGN removal, Figure 10(b), thus, it is so clear that the wavelet is weak in this application and there is no sense to continue with it.

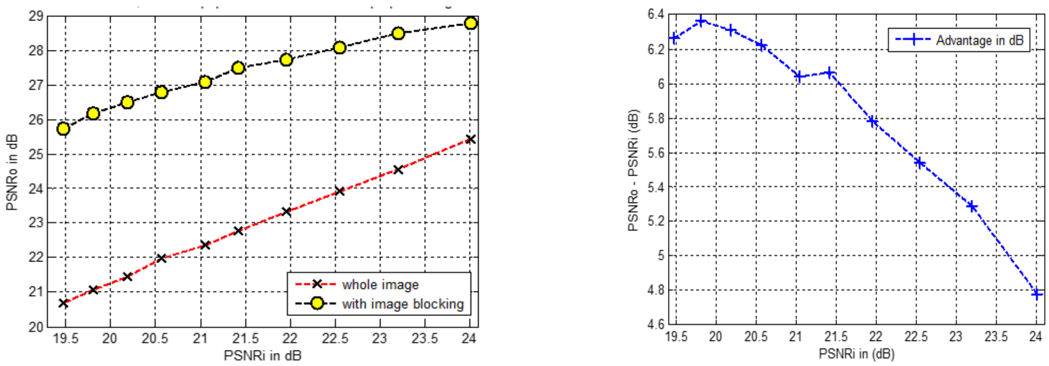


a b

Figure *10.* a – wavelet denoising for AWGN, b – contourlet denoising (both with blocking method)

Figure 11(a) shows good performance of removing salt and pepper noise, about 5 dB difference in PSNR by average, figure 11(b) shows the advantage of PSNR for MRI- Knee image.

$$APSNR = PSNR_o - PSNR_i \quad \ldots.. \quad (4)$$



a b

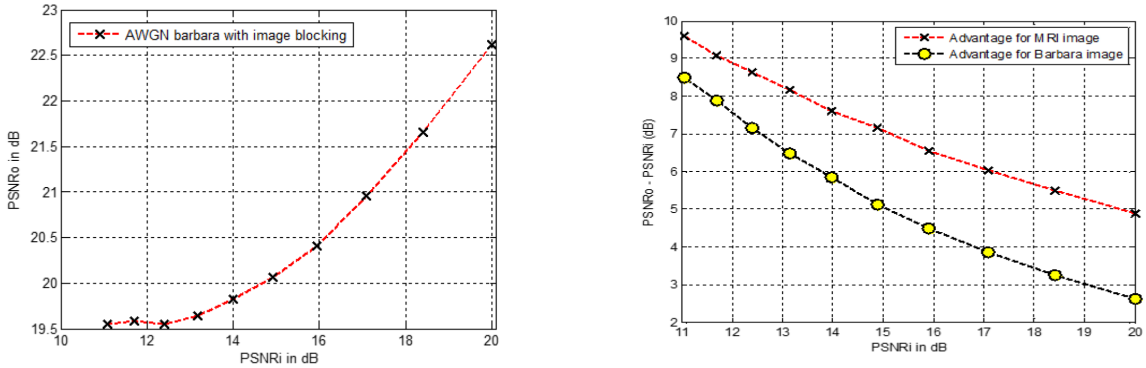
Figure *11.* a – salt & pepper with contourlet preprocessing, b – PSNR advantage with salt and pepper with contourlet preprocessing (both for MRI- Knee image)

From the above figures clarify that the new method is more adequate for denoising to MRI image than other type of images such as (portrait, texture, and landscape images), because of high gain PSNR resultant of MRI compared with other types. Figure 12 (a) shows the $PSNR_o$ with $PSNR_i$ for Barbara, and figure 12 (b) shows the advantage of PSNR≈ 3 dB between Barbara (an example for slandered image) and Knee (an example for MRI image) by applying CTB.

Table 2 shows the effect of changing the block size of MRI image to the PSNR improved in dB.

Table 2. – The effect of Block size for (MRI) image by using contourlet preprocessing

Block size (x*y)	32*32	64*64	128*128	256*256
PSNR improvement in dB	9.19	5.87	5.79	5.15



a b

Figure *12.* a – AWGN for Barbara with contourlet preprocessing, b – Advantage of PSNRo of MRI image with Barbara image using CTB

From the table shown, it can declare that as much as block size be smaller, the improvement of PSNR will be better, although there is a limitation below:

$$Bs \geq \sqrt[2]{2d} \ldots \qquad \ldots \quad . \quad .(6)$$

While Bs is the minimum block size, d is the x dimension of original image, therefore, for a (512x512) image, the minimum block size will be (32x32) pixels. This limitation cause by the 3rd level cluster of contourlet transform.

Discussion. The average dose measured in this research for all devices in this study compared to the reference dose of the International Atomic Energy Agency (IAEA), but it is generally greater than the reference doses with a range of (1.7 - 1.2) as in Table (1), although this increase does not It poses a great risk to patients, but it is preferable that the dose be less than that according to leveles in radiation protection, because the increase in the dose is not justified due to human errors and this increases are:

1. The age some devices used in this study.
2. The heavy operation load on the device during working hours.
3. Some radiographers, has low experience or insufficient training.
4. The psychological conditions of the medical staff will negatively affect quality.

As mentioned in Table (1), the quality assurance tests show that the devices (a, b) have succeeded in these tests and they work within the international specifications, while the device (C) has failed in most of the tests, therefore the proposed method, with image processing with contourlet transform and image blocking technique has been proposed. It shows that dividing the image into blocks improves the denoising process using Wavelet or Contourlet transforms. However, Contourlet transform denoising behavior outperforms the wavelet behavior. Simulation results on both ordinary and medical X-Ray images showed that the proposed blocking method is more powerful in medical X-Ray and MRI images than in ordinary images. Also, the results showed that the denoising improvement depends on the block size and the less block size is, the more PSNR advantage is. However, due the limited size of the LL band in Contourlet transform, there is a minimum block size to be used. This minimum block size depends of the size of the original image and number of levels in Contourlet transform.

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