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New Method for Low Vision JPEG Medical Images Enhancement with Modified Quantization Table

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Abstract

The purpose of this work is to reduce the data volume and to achieve a low bit rate in the digital representation of Low vision medical digital images (X-ray & MRI), without a perceived loss of image quality. In JPEG compression, it is possible to control the compression ratio and image quality by controlling quantization table values. Thus an attempt is made to standardize the JPEG quantization table for medical images by statistical methods. The resulted compressed images show low bit rates with approximately little degradation in their visual quality PSNR (Peak Signal to Noise Ratio). Then the resulted quantization table is used as a standard quantization table for enhancement technique in DCT (Discrete Cosine Transform) domain. The level of enhancement is adjusted by a parameter λ which can be setted to any desired level. The resulted medical images resulted at the output of presented system show high visual quality.

Keywords: DCT- transform,Low vision,Image Enhancement.

طريقة جديدة لتعزيز الصور الرقمية الطبيةمنخفضة الوضوح نوعJPEG باستخدام جدول تكميم محور

الخلاصة

الغرض من هذا البحث هو تقليل حجم المعلومات و الوصول إلى معدل معلومات(bit rate) منخفض لتمثيل الصور الطبية المنخفضة الإضاءة كصور (X-ray & MRI) بدون خسارة كبيرة في جودة الصورة. للصور الرقمية المضغوطة بشكل (JPEG) وجد انه من الممكن السيطرة على نسبة ضغطها وعلى جودتها وذلك بتغيير قيم التكميم القياسية في جدول التكميم ليكون أكثر ملائمة لخاص الصور الطبية.حيث استعملت الطريقة الإحصائية الموضحة في وهكذا فان الصور المضغوطة باستخدام جدول التكميم المقيس أعطت نتائج أفضل لتخفيض معدل المعلومات مع تراجع قليل في (PSNR). و من ثم تم استخدام جدول التكميم المقيس كجدول قياسي في الطريقة المقدمة لتعزيز الصور الرقمية أثناء ضغطها. أظهرت الصور الطبية المعززة جودة عالية مما يؤكد ملائمة جدول التكميم المقيس مع متطلبات الصور الطبية.

Introduction

The trends in medical imaging are increasely digital [1]. The quantities and quality of medical imaging data are forcing consideration of compression and as result enhancing the compressed images by lossy compression techniques can achieve much higher compression ratio through it doesn't permit the exact recovery of the original image. In image compression with JPEG baseline system its possible to control the compression ratio and the quality by controlling values in the quantization table [1,2]. This table contains 8*8 coefficients and each coefficient determines the bit allocation in the frequency domain [3]. Generally, medical images has

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significant values (these values that contains most of image details), in much higher frequency components [3]. Consequently, the compression with a low bit rate and without perceived loss of diagnostic quality is achieved by modifying the quantization table Q, as a pre-processing to obtain modified quantization table Q_s before performing the new scheme of enhancing low quality medical images via weighting quantization table Q_s with redesigned array to obtain new quantization table Q_s^w which includes the modified values this scheme is illustrated in the fig (1) below:

JPEG BASLINE SYSTEM

In image encoding with JPEG baseline system lossy image compression is achieved as follows:

1- Image data in the spatial domain (X) is grouped in to the non overlapping 8*8 blocks (X_p) [4,5].

2- The 2-D DCT is performed on each 8*8 block of the source image to obtain transformed coefficients, hence in the JPEG domain there are 64 basis function or images for 8*8, image data in spatial domain, this is illustrated in Fig (2). The actual formula for 2-D DCT is as follows.

$$F(u,v) = 1/4 * C(u) * C(v) * \left[\sum_{x=0}^{7} \sum_{y=0}^{7} f(x,y) \cos\frac{(2x+1)u\pi}{16} * \cos\frac{(2y+1)v\pi}{16} \right] \quad (1)$$

The inverse DCT is obtained using the same basis function as[2,5].

$$f(x,y) = 1/4 C(u) C(v) F(u,v) * \left[\sum_{u=0}^{7} \sum_{v=0}^{7} \cos\frac{(2x+1)u\pi}{16} * \cos\frac{(2y+1)v\pi}{16} \right] \quad (2)$$

where $C(u), C(v) = 1/\sqrt{2}$ for u,v=0. and $C(u), C(v) = 1$ otherwise.

3-After output from the DCT each of 64 DCT coefficients is uniformly quantized in conjunction with 64 element quantization table, which is specified by the application (or user) as an input to the encoder [4,5]. The purpose of quantization is to achieve further compression by representing DCT coefficients with no greater precision than is necessary to achieve desired image quality. Quantization is defined as division of each DCT coefficients by its corresponding quantized step-size followed by rounding to the nearest integer as below [4,5].

$$F_p^Q(u,v) = \mathrm{INT}(\mathrm{ROUND}(\frac{F(u,v)}{Q(u,v)})) \quad (3)$$

In the JPEG standard, the same table is used to all blocks of JPEG image see Table (1). The dequantizer formula is as:

$$\tilde{F}_p^Q(u,v) = F_p^Q * Q(u,v) \quad (4)$$

where $Q(u,v)$ is the array of elements of quantization table. If there is no loss of information in the DCT process quantization process results in loss of information in JPEG compression standard [5]. Quantization in transformed domain means reducing the magnitude of the component. If the quantization error is not large, inverse quantization may produce the similar values as the one before quantization [4,5,6].The quantization table plays a vital role in this presented scheme for compression and enhancing medical images .

Enhancement In Jpeg Domain

(A) The Standrization Of Jpeg Quantization Table For Medical Image

It is possible to control JPEG image quality by controlling values in quantization table; hence a preprocessing for the images (medical images) is done to enhance their quality before introducing the input image to the proposed enhancement system presented in [1]. This process is attempted by using statistical method [3]. The standardized quantization table is determined by using the following steps:

1-10,465 of (8*8) blocks are extracted from 23 medical images (455 blocks/image). Some of these images, (chest, brain, bone…etc)

2-Each (8*8) block is transformed with 2-D DCT (Two-dimensional Discrete Cosine transform) transform.

3-The resulted (8*8) blocks are averaged. Therefore each frequency component of the resulting (8*8) blocks is average of 10,465 values.

$$F_{av}(\hat{u},\hat{v}) = \sum_{al\,lim\,ages} F(\hat{u},\hat{v})/T_{nb} \quad (5)$$

where T_{nb} is the total number of blocks.

4-Each quantization value of the table is determined on the reciprocal value of each value of the frequency distribution.

Table (2) gives the experimental result of standardized quantization table for image called chest of size 192*192 (8) bit/pixel give. The flow chart of standardization process is depicted in fig.(3)

(B) General Frame Work For Algorithm

After the previous standardization to the quantization table the modified JPEG receiver is illustrated in fig (4) below. The compressed image is decoded and dequantized using quantization table Q_s that is transmitted with the compressed image. The inverse 2-D DCT (2-D IDCT) is applied to the image resulted from dequantizer to obtain the reconstructed blocks. The image enhancement algorithm operates in the decompression stage by weighting the modified quantization table Q_s with a pre-designed array to obtain new weighted and standardized quantization table Q_s^W that includes the enhancement function. Note that the multiplication operation presented in fig (4) is a point by point multiplication.

(C) Weighting Of Quantization Table

Image enhancement implies contrast modification and thus requires a measure of contrast. Contrast measure can be used to determine the parameters in an image enhancement algorithm [3,6].One method of contrast measurement is local contrast measure by using equation .

$$\sigma_g = \sqrt{\sum_{g=0}^{L-1} (g-\overline{g})^2 p(g)} \qquad (6)$$

where L= gray level range, g=gray level value in any region of interest in image, p (g) =probability of occurrence of that gray level in region of interest, $\overline{g}$ = Mean value of gray levels in region of interest, finally σ_g = standard deviation of gray levels in region of interest. Human contrast sensitivity varies as a function of spatial frequency, therefore the spatial frequency content of an image should be considered in the definition of contrast .In[1]a definition is proposed of local band-limited contrast in images that assigns a contrast value to every point in the image as a function of the spatial frequency band .For each frequency the contrast is defined as the ratio of the band pass-filtered image at that frequency to the low-pass images filtered to an octave below the same frequency[3]. Let F be an 8*8 block which is composed of DCT coefficients where $F_{u,v}$ are DCT coefficients(as illustrated in equations 1,2).

$$F=\begin{bmatrix} f_{00} & f_{01} & f_{02} & f_{03} & f_{04} & f_{05} & f_{06} & f_{07} \\ f_{10} & f_{11} & f_{12} & f_{13} & f_{14} & f_{15} & f_{16} & f_{17} \\ f_{20} & f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & f_{26} & f_{27} \\ f_{30} & f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} & f_{37} \\ f_{40} & f_{41} & f_{42} & f_{43} & f_{44} & f_{45} & f_{46} & f_{47} \\ f_{50} & f_{51} & f_{52} & f_{53} & f_{54} & f_{55} & f_{56} & f_{57} \\ f_{60} & f_{61} & f_{62} & f_{63} & f_{64} & f_{65} & f_{66} & f_{67} \\ f_{70} & f_{71} & f_{72} & f_{73} & f_{74} & f_{75} & f_{76} & f_{77} \end{bmatrix} \quad (7)$$

The value of $(f_{u,v})$ represents the value of each of DCT coefficients .Corresponding local band-limited image contrast can be defined ,following[1]as:

$$\widetilde{C}_n = \frac{E_n}{\sum_{i=0}^{n-1} E_i} (1 \le n \le 14) \quad (8)$$

Or following [5]:

$$\widetilde{C}_n = \frac{\sum_{i=0}^{n} E_i}{\sum_{i=0}^{n-1} E_i} \quad (9)$$

where

$$E_n = \frac{1}{N} \sum_{i+j=n} \left| f_{i,j} \right| \quad (10)$$

In above i,j represents the row and column number respectively in (7).and E_n is a spatial frequency band illustrated in equation (7)also. Finally:

$$N = \begin{cases} n+1 \ldots\ldots n<8 \\ 14-n+1 \ldots\ldots n \ge 8 \end{cases} \quad (11)$$

Here, for simplicity, the following measure will be employed.

$$\widetilde{C}_n = \frac{E_n}{E_{n-1}} \quad (12)$$

Equation (12) is employed as definition of contrast measure, because, as shown below, it results in a very simple form of the function for uniform enhancement [5].

Contrast Enhancement In Dct Domain

Let the contrast of the original block be $\widetilde{C} = (\widetilde{c}_1, \widetilde{c}_2, \ldots \widetilde{c}_{14})$, where $\sim$ the contrast is specific frequency band E_l, and let contrast of the enhanced block be $\overline{C} = (\overline{c}_1, \overline{c}_2, \ldots, \overline{c}_{14})$. If for example one wishes to enhance the contrast uniformly for all frequencies, then.

$$\overline{c}_n = \lambda * \widetilde{c}_n \quad (13)$$

Leading to :

$$\frac{\overline{E}_n}{\overline{E}_{n-1}} = \overline{c}_n = \lambda * \widetilde{c}_n = \frac{\lambda * \widetilde{E}_n}{\widetilde{E}_{n-1}}) \quad (14)$$

which when rearranged yields.

$$\overline{E}_n = \frac{\lambda * \widetilde{E}_n}{\widetilde{E}_{n-1}} * \overline{E}_{n-1} =$$

$$\frac{\lambda \widetilde{E}_n}{\widetilde{E}_{n-1}} * \frac{\lambda \widetilde{E}_{n-1}}{\widetilde{E}_{n-2}} * \overline{E}_{n-2} \qquad (15)$$

$$= \lambda^2 * \frac{\widetilde{E}_n}{\widetilde{E}_{n-2}} * \overline{E}_{n-2} =$$

$$\lambda^n * \frac{\widetilde{E}_n}{\widetilde{E}_0} * \widetilde{E}_0 = \lambda^n * \widetilde{E}_n$$

Thus the enhanced DCT coefficients $\bar{f}_{ij}$ are:

$$\bar{f}_{ij} = \lambda^{i+j} \bar{f}_{ij} \qquad (16)$$

The above processing can be realized by weighting the standardized quantization table Q_s.

$$\overline{q}_{s(i,j)} = \lambda^{i+j} * \widetilde{q}_{s(i,j)} \qquad (17)$$

where $\widetilde{q}_{s(i,j)}$ are the elements of Q_S, and $\overline{q}_{s(i,j)}$ are the elements of the weighted and standardized quantization table Q_S^W. The above processing requires only 64 multiplications [1], and can be implemented with a single parameter control.

Experimental Results

Good diagnosis is achieved by subjective assessment of the quality of pictures. Table (3) shows the experimental results for the presented medical images chest and brain (PSNR and the bit rate) .The PSNR is approximately the same for the images quantized by the standard and standardized quantization table. However 4.1% in the chest image and about 4.5% in brain image improves the bit rate. The chest image with (35.7dB) and brain image with (35.9dB) were enhanced by using method described in section 3.3. The enhancement effects were evaluated visually. The level of enhancement was controlled by factor λ. Fig(5) and fig(6) illustrate how the enhancement can be adjusted by controlling a single parameter λ, for two images with λ selected to be (1.3,1.7,1.9), as seen from these two figures that the sharpness of image is increased so the doctor can adjust the input λ, to specific level of sharpness for any medical image. Fig (8) and fig(9),illustrate the histograms of each image that emphasize the visual results from which it is clear that increasing the value of λ results in more spreading (reduction in peaks) of the histogram shapes. The same system was applied on other two images (brain 2,and bone)as illustrated in fig.(9)and in fig.(10) with (34.6 dB, and 38, 3 dB) respectively with their histograms illustrated in fig.(12) and in fig.(13), the result previously presented are emphasized in these new groups of images.

Conclusions

The proposed JPEG quantization for lossy medical compression performs well in the new enhancement system that works on the compression domain directly unlike other compression technique which works on the decompressed image resulting in increasing blocks and other artifacts. Table (3), present the gain in (bit/sample) for two images with average gain of about 4% for image called chest and image called Brain, with negligible degradation in PSNR.

Thus the standardized quantization table plays a vital role in the presented enhancement technique that can be adjusted for medical image by a doctor to the desired level by adjusting λ. Figures (5) to (12) illustrate the application of proposed enhancement technique with histograms. It is seen that increasing λ leads to more image sharpness, this is proved with more spreading the histograms.

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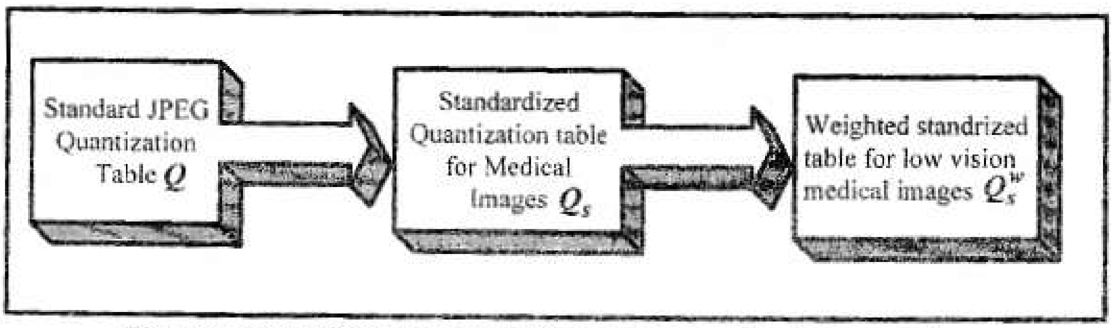

Fig (1): Stages of modified Quantization table generation for proposed scheme

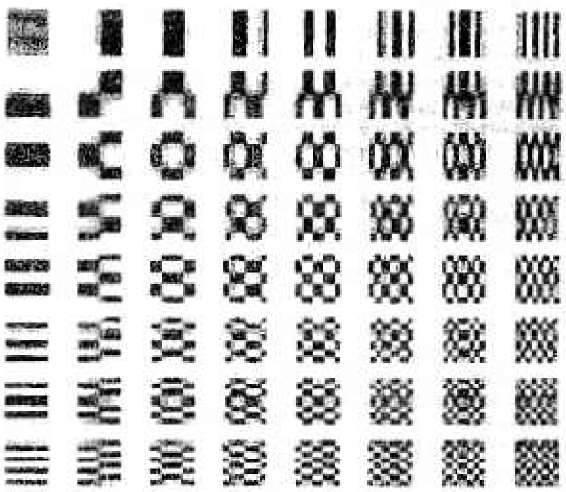

Fig.(2): Basis Image of 8* 8 DCT

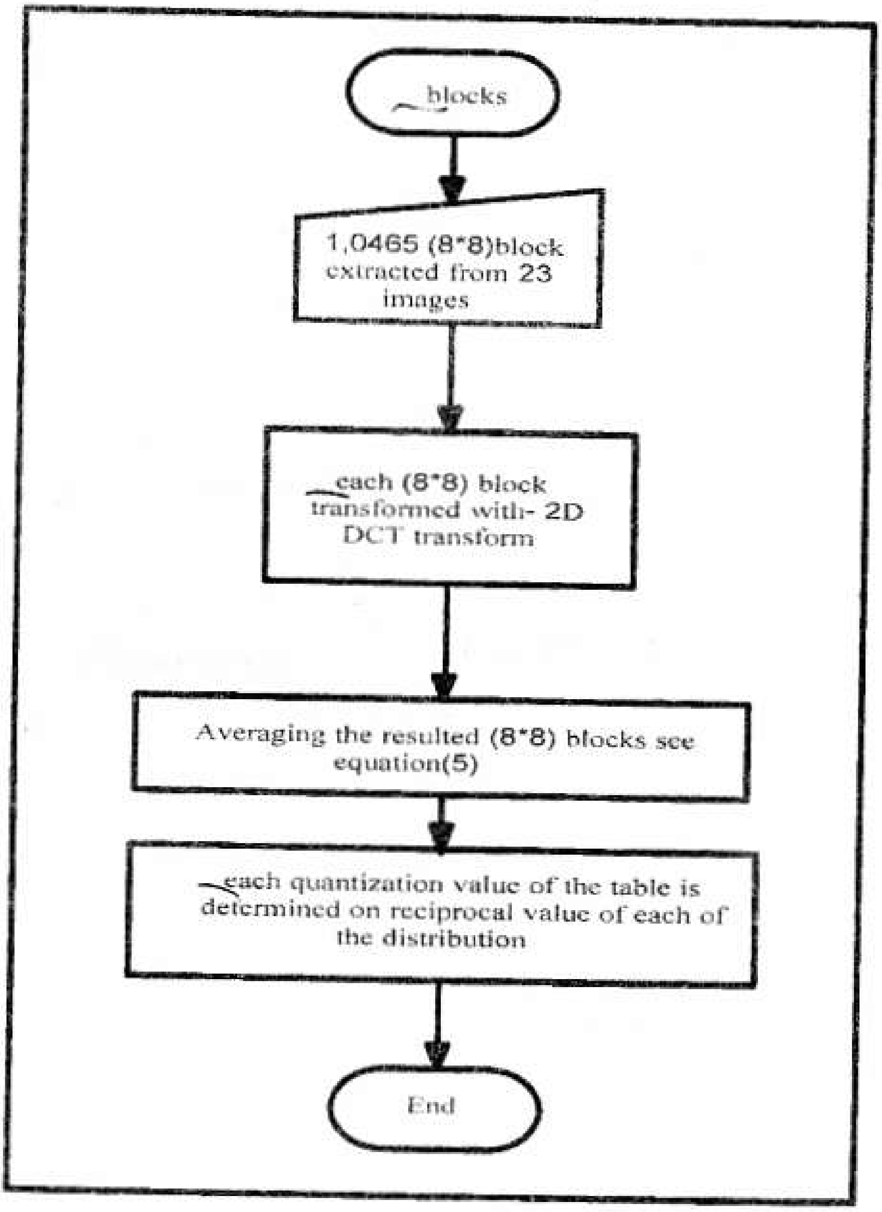

Fig.(3): The flow chart of standardization process

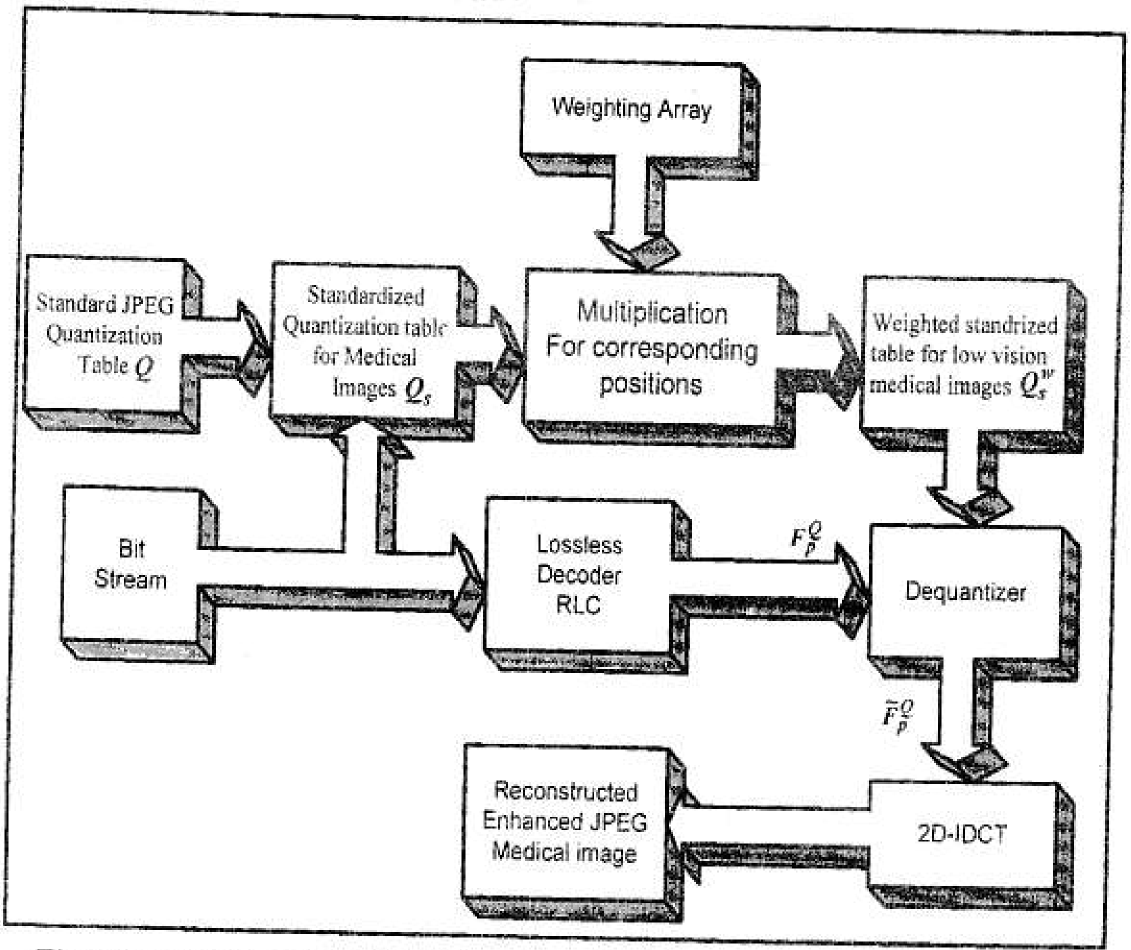

Fig (4): The Modified JPEG Decoder with image enhancement function.

Table (1): Standard Quantization table for JPEG image compression

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Table (2): The standardized quantization table for JPEG medical images

8	16	24	40	81	97	72	145
8	16	24	40	89	162	194	283
16	16	24	40	89	170	194	283
16	24	24	40	89	170	194	291
24	24	32	48	89	162	194	275
24	32	32	48	105	178	202	299
48	48	48	72	121	194	210	291
81	81	81	89	145	202	210	292

Table (3): Comparison between standard and standardized quantization tables.

JPEG Q_table	Bit rate (bit/sample)		PSNR (dB scale)	
	Chest	brain	chest	brain
Q	0.740	0.675	36.0	36.3
Q_s	0710	0.646	35.7	35.9

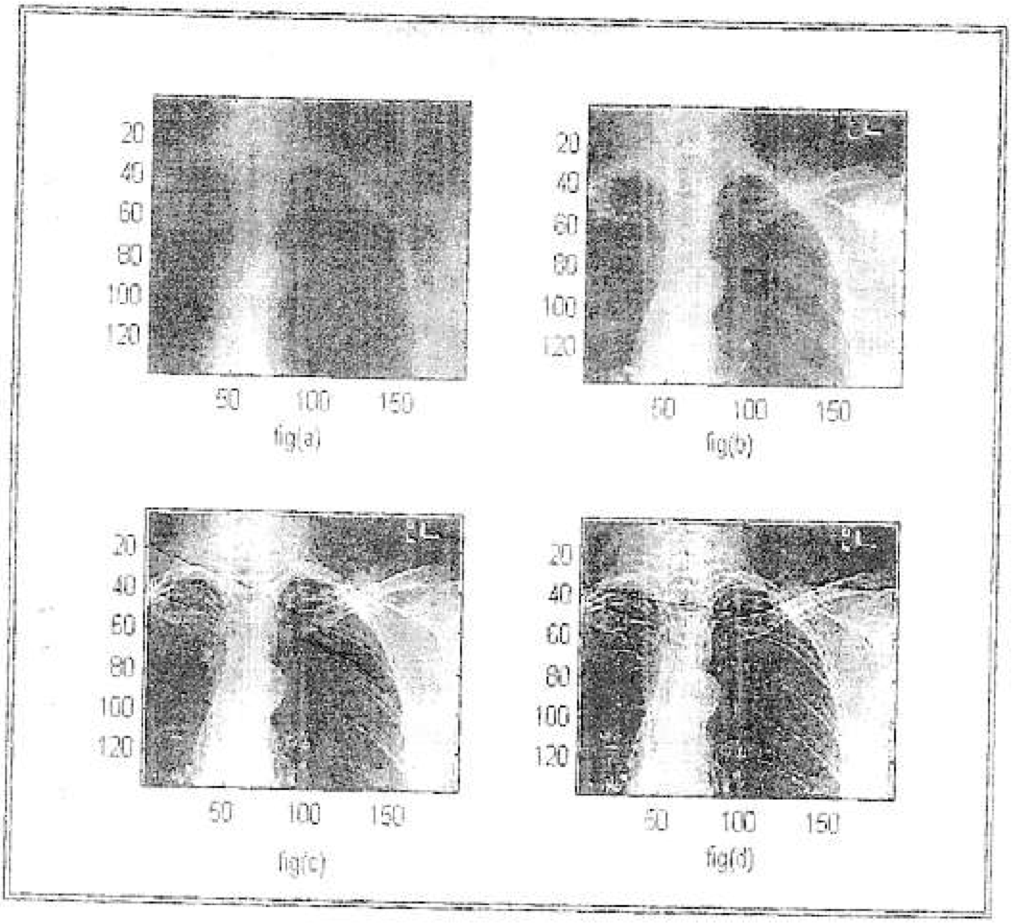

Fig.(5) (a,b,c,d): Original image called Chest ,enhanced images with λ =(1.3,1.7,1.9) respectively

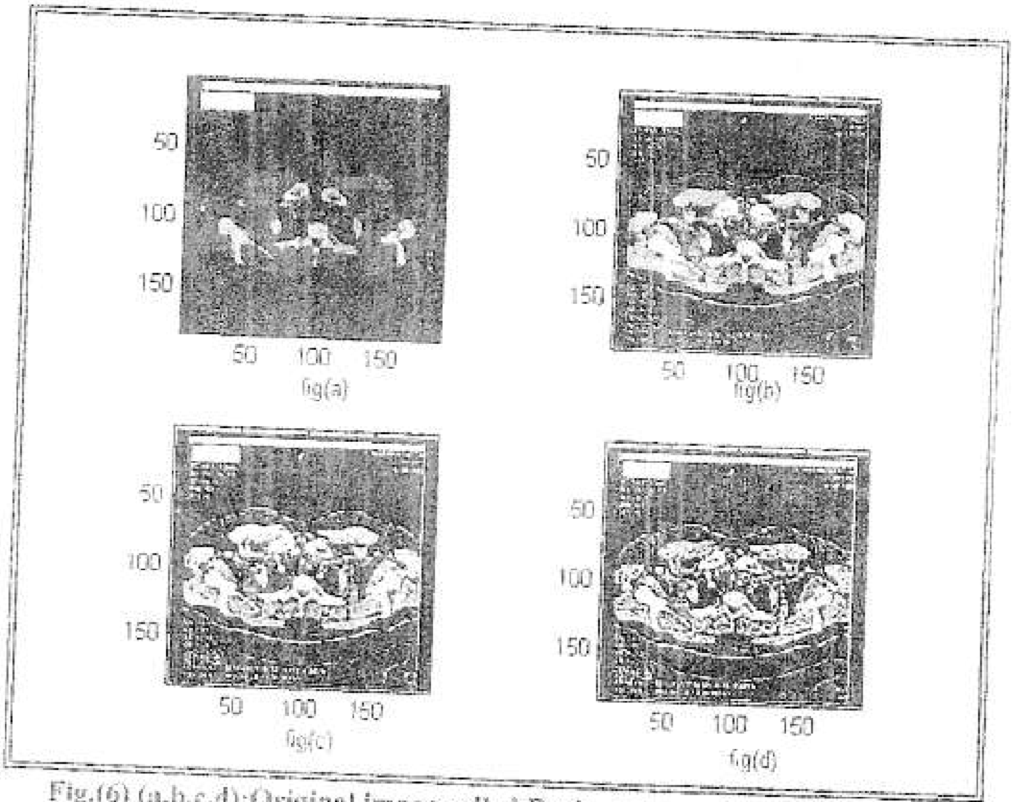

Fig.(6) (a,b,c,d):Original image called Brain ,enhanced images with λ=(1.3,1.7,1.9) respectively

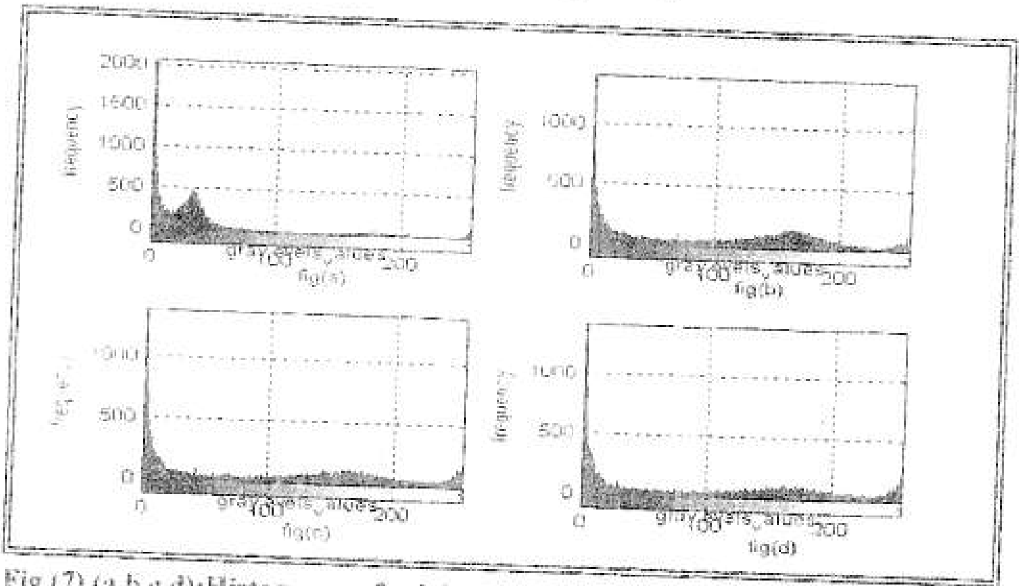

Fig.(7) (a,b,c,d):Histograms of original image called Chest ,and enhanced images with λ=(1.3,1.7,1.9) respectively

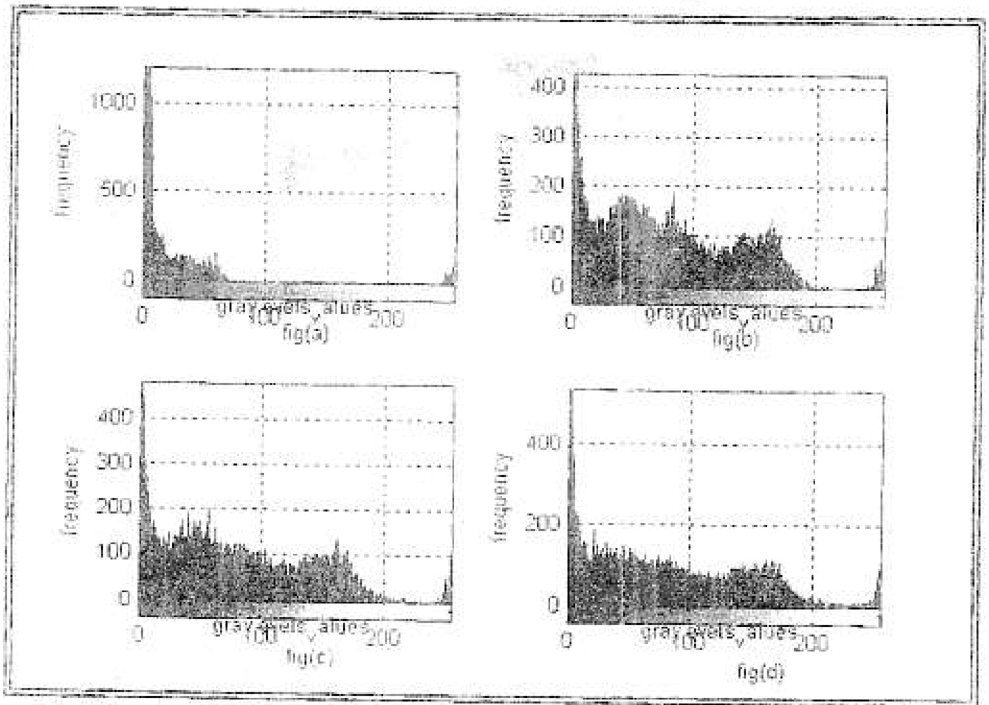

Fig.(8) (a,b,c,d):Histograms of original image called Brain ,and enhanced images with λ =(1.3,1.7,1.9) respectively

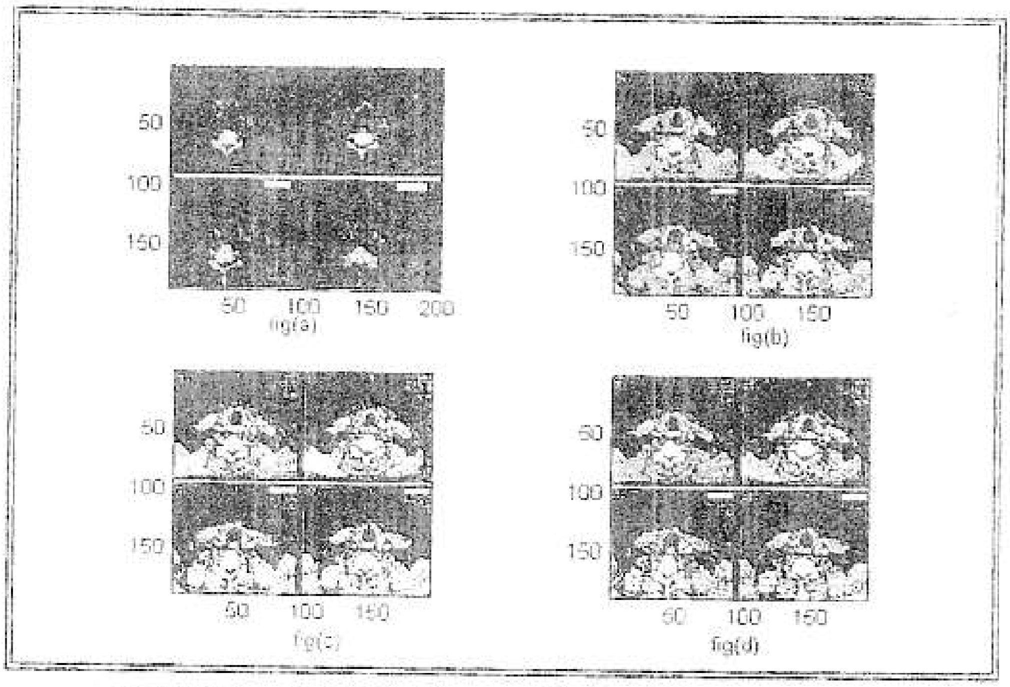

Fig.(9) (a,b,c,d): Original image called Brain2 ,enhanced images with λ =(1.3,1.7,1.9) respectively

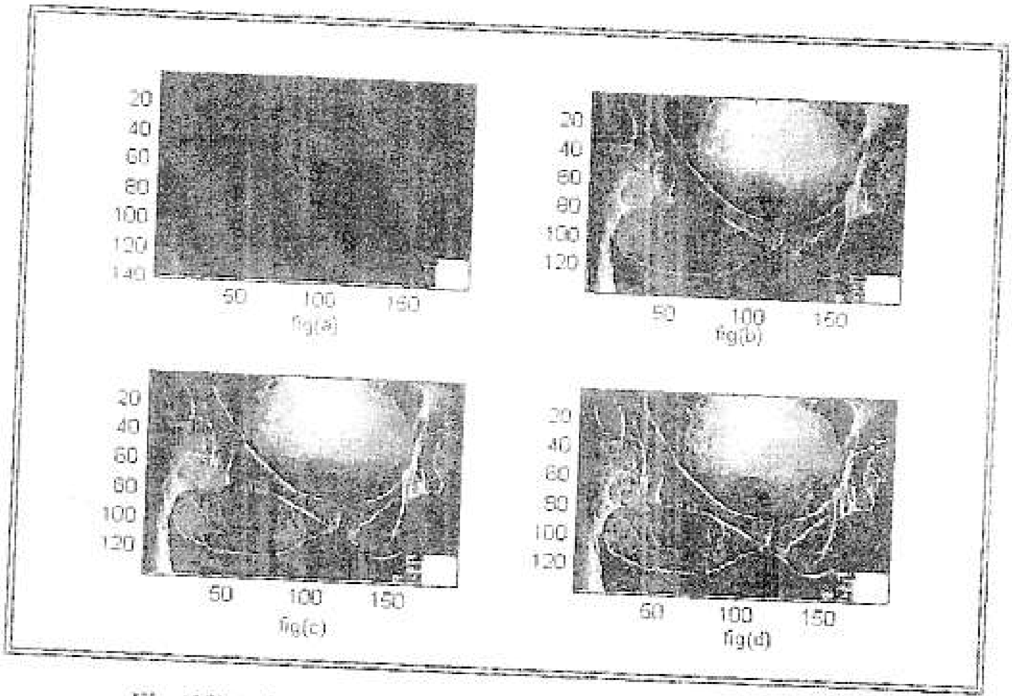

Fig.(10) (a,b,c,d):Original image called Bone ,enhanced images with λ =(1.3,1.7,1.9) respectively

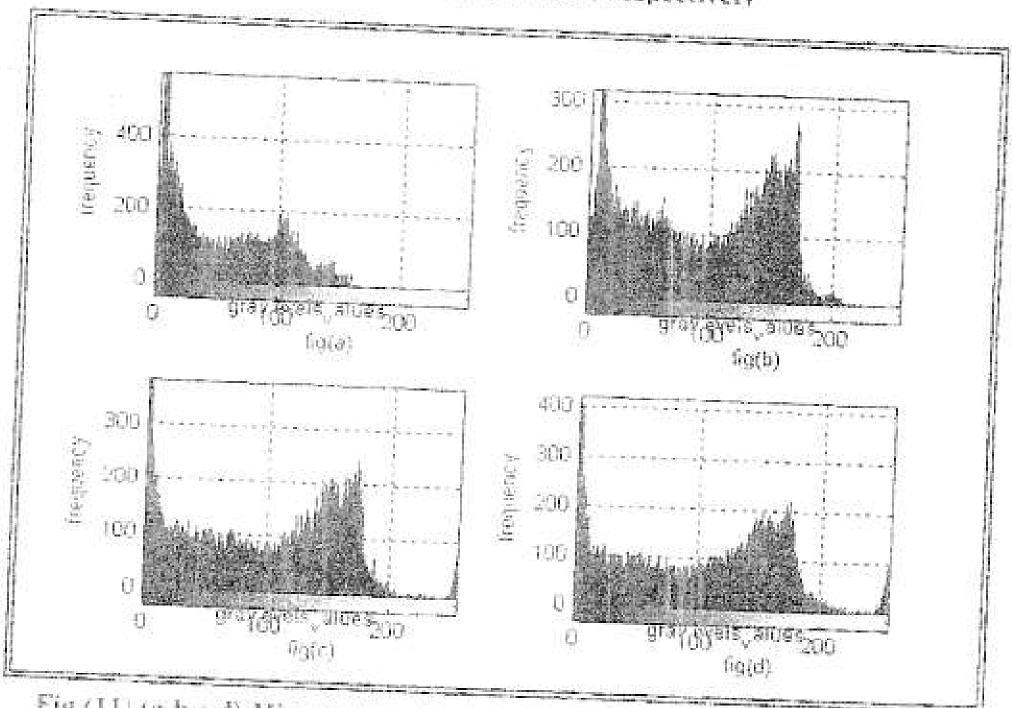

Fig.(11) (a,b,c,d):Histograms of original image called Brain2 ,and enhanced images with λ =(1.3,1.7,1.9) respectively

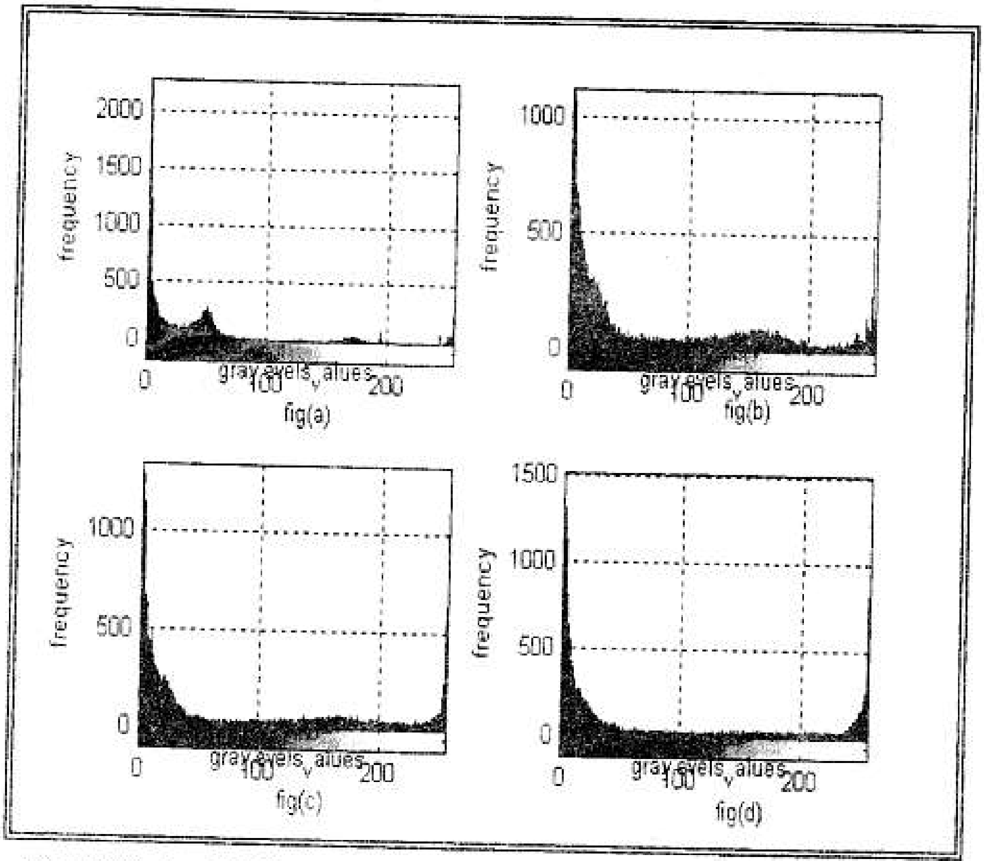

Fig.(12) (a,b,c,d):Histograms of original image called Bone ,and enhanced images with λ =(1.3,1.7,1.9) respectively