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Image Enhancement with Medical Image Fusion using Multiresolution Discrete Cosine Transform*

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Abstract

Medical Image fusion by multi-resolution discrete cosine transform (MDCT) algorithm is one of the fusion techniques that has been implemented and evaluated. The performance of this algorithm as that of level 1 and level 2 MDCT image fusion techniques are compared. Here different methods of image enhancement have been implemented and the fusion metrics are evaluated. It is observed that image fusion by MDCT perform almost similar in both the levels but depending on the modality the enhancement varies. Depending on the real time applications the level of computation could be applied.

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***Keywords**: medical imaging ; fusion ; multiresolution DCT; discrete cosine transform; performance metrics; matlab;*

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1. Introduction

In today's world, Multi-sensor image fusion (MIF) [1] has emerged as an innovative and promising research area in image processing with a variety of applications ranging from military, remote sensing, machine vision, robotic, surveillance, enhanced vision system, and medical imaging, etc. [2]. The concept of this technique is that it combines two or more registered images. This process enables to increase the spatial resolution of acquired low detailed multi-sensor images thereby preserving their spectral information.

1.1. Discrete Cosine Transform

Discrete Cosine Transform is a much better transform than Discrete Fourier Transform. If the amplitude spectra of the image above under the DFT and DCT is compared it will show that the concentrated histogram obtained with the DCT is more concentrated than that of DFT [3]. Energy compaction is important the main reason being that image compression turns out to be beneficial in other applications. Block diagram of DCT is shown in figure 1 below:

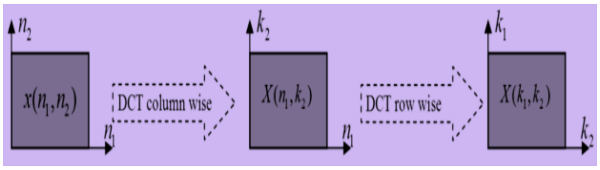

Figure 1: Schematic Representation DCT

1.2. Multi-Resolution DCT

Multi-Resolution DCT a way resembles wavelet transform in its approach i.e. low pass and high pass component of the signals are separated by the use of FIR filter. Decimation of the filtered outputs (both LP & HP) is by means of factor of two that enables in achieving the first level of decomposition. The two decimated outputs are again passed through for 2^{nd} level of decomposition. With is method any number of successive decomposition could be obtained by repeated decimations. Multi Resolution DCT (MDCT) basically acts as an effective tool in replacing the FIR filters with DCT [4]. The schematic flow of the MDCT (one level of decomposition) is represented in the figure 2 shown below:

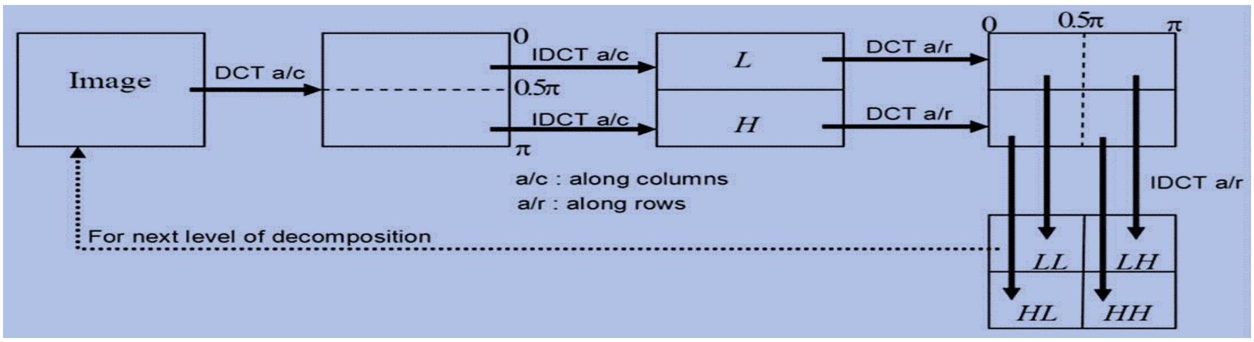

Figure 2: Schematic Representation of MRDCT decomposition Structure

1.3 Medical Imaging & Fusion

The field of medical imaging is rapidly growing with a lot of innovative techniques and methods. The modalities of nuclear imaging, MRI and ultrasound have emerged with high performance techniques alongside X-rays. These images thus obtained remain as the most important diagnostic tools in medicine today. Sensors used in the process of imaging are very unique and is a very important component of acquisition. A single sensor may not be enough to provide a complete comprehensive view of the environment under interest. The multimodal Medical imaging is the way forward for the best diagnostic & therapeutic purpose [5]. Hence in this paper the significance of fusion in medical imaging is well understood.

2. Methodology

The schematic diagram for the MDCT based pixel level image fusion scheme is shown in Fig. 3. It can be observed that the modification of the present scheme is by using MDCT instead of wavelets or pyramids. The images to be fused I_1 and I_2 are decomposed into D (d = 1, 2... D) levels using MDCT [6].
Hence with I_1 and I_2 as the source images and then by applying MRDCT the resultant fused image is given by I_f. The mathematical representation is given below:

$$I_1 \leftarrow \left\{ {}^1LL_D, \left\{ {}^1LH_d, {}^1HH_d, {}^1HL_d \right\}_{d=1,2,\ldots D} \right\}$$
$$I_2 \leftarrow \left\{ {}^2LL_D, \left\{ {}^2LH_d, {}^2HH_d, {}^2HL_d \right\}_{d=1,2,\ldots D} \right\}$$
$$I_f \leftarrow \left\{ {}^fLL_D, \left\{ {}^fLH_d, {}^fHH_d, {}^fHL_d \right\}_{d=1,2,\ldots D} \right\}$$

Where I_1 = source image 1; I_2 = source image 2 and I_f = fused output. The pictorial representation is shown below in figure 3

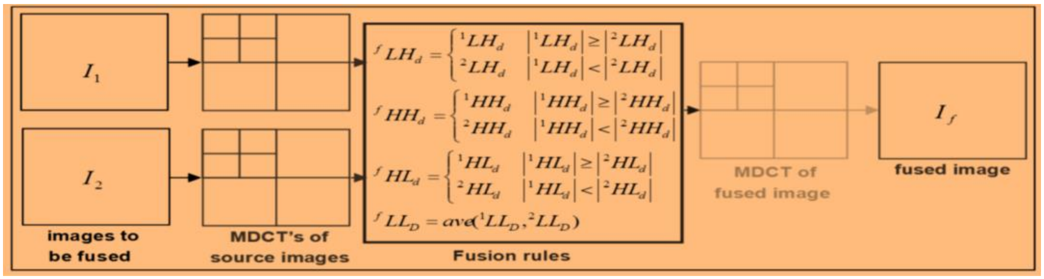

Figure 3: MRDCT Schematic Diagram

The significant concept is that at each decomposition level (d = 1, 2,...,D) , the fusion rule is such that it will select the larger absolute value of the two MDCT detailed coefficients. The sharper and the brightness changes in the images such as edges and object boundaries etc are due to the corresponding detailed coefficients. These coefficients fluctuate around zero. At the lowest level (coarest) (d = D), the fusion rule takes the average of the MDCT approximation coeficients as the approximation coeficients at coarser level are basically the smoothed and subsampled version of the original image [7]. The fused image If can be obtained using the above mentioned formula for I_f.

2.1 Implementation

The images taken here for fusion using multiresolution DCT are medical images.
The assumptions made are as follows:

- Images already registered
- Same specimen
- Acquired images of different modalities namely : CT,PET & MRI

The medical imaging is a comprehensive tool of image processing consisting of acquisition ,processing an reconstruction [8] .The planes used in medical imaging are three i.e : namely
Plane1: front to back; Plane 2: side to side; Plane 3: head to toe

One such plane is considered here for medical image fusion. Then four different filtering methods have been identified as image enhancement tool and its effectiveness on fusion has been analysed. The chosen enhancement methods are use of median filter, mean filter, log filter and Laplacian.
The flow of the methodology is given below in figure 4

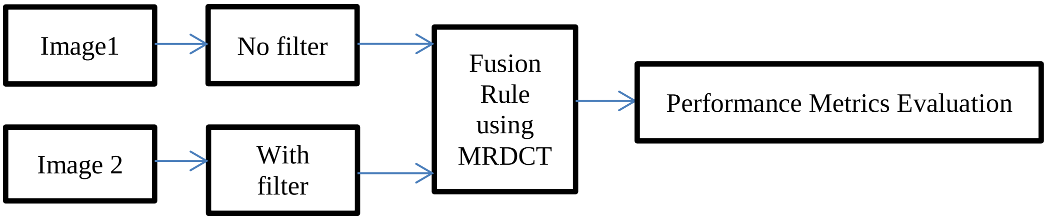

Figure 4: flow chart of implementation of MRDCT with image enhancement

2.2 Performance Metrics Evaluation

In general the outcome of the fusion method can be evaluated by two ways namely: objective and subjective. The subjective is dependent on the clinical acumen of the clinician whereas the objective in general is based upon the statistical parameters. They are also referred as qualitative analysis method and they do not depend on the individual evaluation skills. Also performance evaluation of the outcome can be done either with reference image or without reference image. More often medical images are done without reference image concept [9]. Based on this concept the metrics for the evaluation are chosen. Since medical images of two different modalities are the ones considered for the DCT based image fusion, the norm of evaluation of its performance is done without the use of reference image [10].
The metrics that have been considered for performance evaluation [ ] and discussed are :

- mean
- standard deviation
- entropy
- cross entropy
- Signal to noise ratio
- Peak signal to noise ratio

MEAN

$$\mu I_f = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} I_f(i, j)$$

STANDARD DEVIATION

$$\sigma = \sqrt{\sum_{i=0}^{L} h_{If}(i)(i-\bar{i})^2}, \bar{i} = \sum_{i=0}^{L} i h_{If}$$

ENTROPY

$H = -\sum_{i=1}^{L} P(i) log_2 P(i)$ where P(i) is the normalised histogram

CROSS ENTROPY

$$CE\left(I_1, I_2, I_f\right) = \left[CE\left(I_1, I_f\right) + CE\left(I_2, I_f\right)\right] / 2$$

SNR

$$SNR = 10\log_{10}\left[\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[I_{input}(i,j) - I_{fused}(i,j)\right]^2}{\sum_{i=1}^{M}\sum_{j=1}^{N} I_{input}(i,j)}\right]$$

PSNR

$$PSNR = 20\log_{10}\left[\frac{L^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} I_f(i,j)^2}\right]$$

The modality considered for the above are CT and MRI

The input images taken are CT image and MRI of a same specimen.
The fusion is done first without any enhancement [11]. Then the four types of filters chosen as enhancement have been implemented and the resultant image parameters are assessed.
The values thus obtained are tabulated in table1 below:

Table 1: Performance Metrics Evaluation

Modality / Metrics	CT	MR	FUSED				
			Without enhancement filter	with MEDIAN	With MEAN	With LOG	With LAPLACIAN
mean	0.1093	0.1068	0.1081	0.1058	0.1080	0.1058	0.1081
Std deviation	0.2184	0.1513	0.1511	0.1439	0.1421	0.1421	0.2400*
entropy	3.8314	4.8799	5.2480	5.1993	5.2470	5.1985	5.2502*
Cross entropy	0.7240	0.5261	0.6251	-	-	-	-
SNR	8.2696	5.8367	6.0558	5.7709	5.7049	4.0884	4.5578
PSNR	20.5140	20.4859	20.6755	20.7313	20.6735	14.2627	16.1506

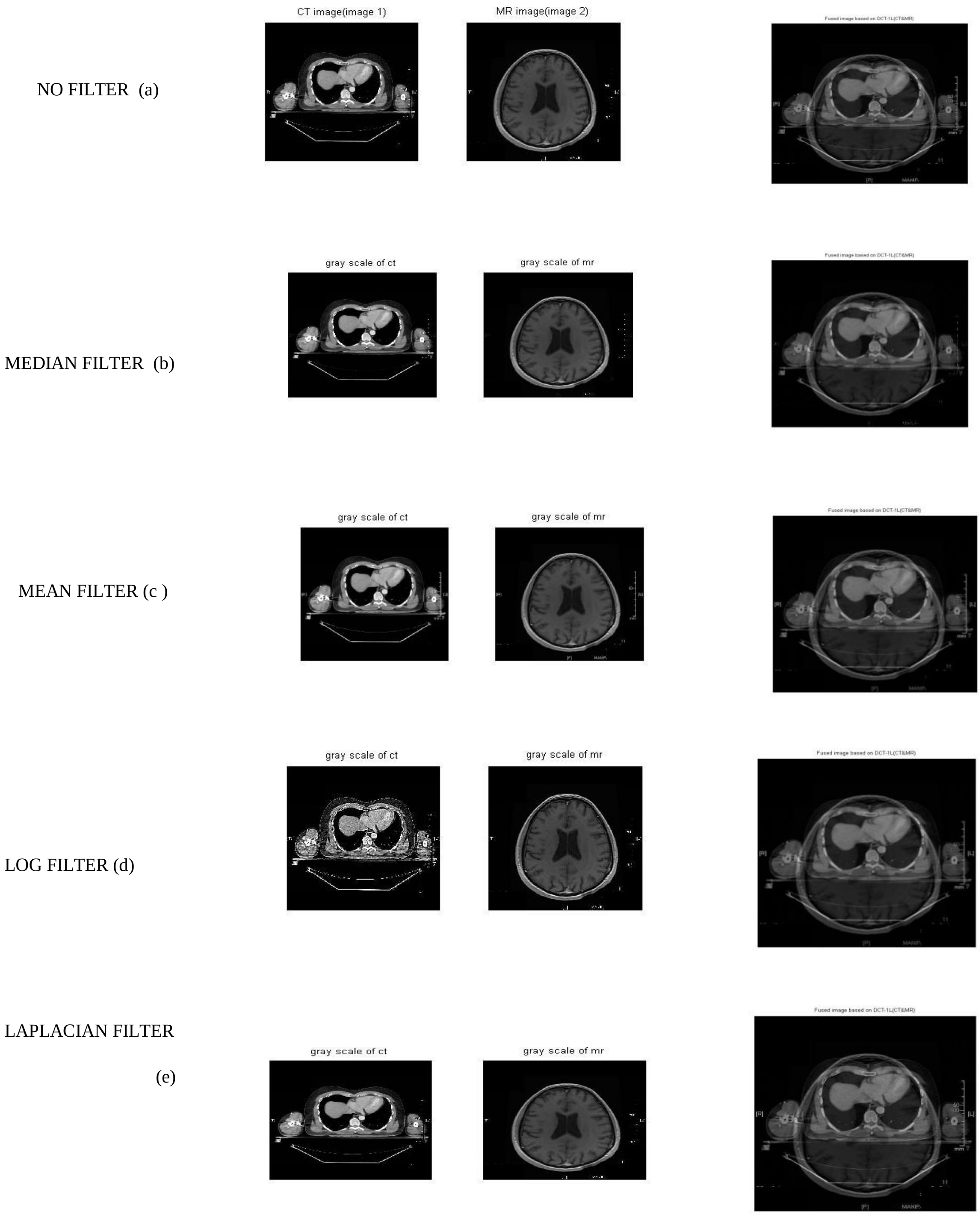

Figure 5 : outputs without & with image enhancement

3. Discussions

It is widely noticed that the DCT based methods of image fusion are proved to be more suitable and time-saving in real-time systems for still images or videos. The advantages of DCT being Efficiency, Complexity Reduction and decomposing images into series of waveforms it is well suited for real time applications [12] .In this paper an efficient approach for fusion of multi-focus images based on variance calculated in DCT domain has been presented. Based on the existing literature, the emphasis on random noise has been considered as it plays a vital role in medical imaging. Hence the presented paper focuses on fused image due to integration of two images.

It is always possible to do visual evaluation of Fusion quality by considering human judgment. This is basically subjective and has its own drawbacks mainly the assessment purely is dependent on the evaluator's ability to interpret, thereby raising the level of accuracy. To avoid these drawbacks, quantitative measures or objective measures provide greater level of accurate and meaningful assessment of fused images [13].

4. Results & Conclusion

Mean (μ) of an image indicates the average value of the information within the image. It is a pointer towards how the average value of the image behaves while the fusion technique is implemented [14]. It is known that standard deviation (SD) is composed of the signal and noise parts. This metric would be more efficient in the absence of noise. It measures the contrast in the fused image. An image with high contrast would have a high standard deviation. Entropy is used to calculate the amount of information. Higher value of entropy indicates that the information increases and the fusion performances are improved. High values of SNR show that the error of the estimation is small and therefore, among various image fusion methods the ones that exhibits higher SNR can be considered of better performance. The PSNR and MSE are measures similar to the SNR .When assessing the performance of an image fusion technique using the above mentioned measurements [15][16]

It isobserved that in fusion methods a single level of decomposition alnoe may not suffice though there is no significant advantage and no degradation of quality it will enable to act as an assistive way for clinical observation .

It is also observed that out of the various filters Laplacian is found to be of giving better quality image.

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