COMPARISON OF FUSION TECHNIQUES APPLIED TO PRECLINICAL IMAGES: FAST DISCRETE CURVELET TRANSFORM USING WRAPPING TECHNIQUE & WAVELET TRANSFORM

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ABSTRACT

The term fusion means in general an approach to extraction of information acquired in several domains. The goal of image fusion (IF) is to integrate complementary multi sensor, multi temporal and/or multi view information into one new image containing information the quality of which cannot be achieved otherwise. The term "quality", its meaning and measurement depend on the particular application. In this paper, Fast Discrete Curvelet Transform using Wrapper algorithm based image fusion technique, has been implemented, analyzed and compared with Wavelet based Fusion Technique. Fusion of images taken at different resolutions, intensity and by different techniques helps physicians to extract the features that may not be normally visible in a single image by different modalities. This work aims at fusion of two images containing varied information. Proposed algorithm takes care of registration as well as fusion in a single pass. Attempt has been taken to fuse MRI with CT and MR/MR images of Preclinical data. In magnetic resonance imaging (MRI), there are three bands of images ("MRI triplet") available, which are T1-, T2- and PD-weighted images. The three images of a MRI triplet provide complementary structure information and therefore it is useful for diagnosis and subsequent analysis to combine three-band images into one. This fused image can significantly benefit medical diagnosis and also the further image processing such as, visualization (colorization), segmentation, classification and computer-aided diagnosis (CAD). This approach is is further optimized utilizing quantitative fusion metrics such as the Entropy, Difference Entropy, and Standard Deviation, image quality index (IQI) and ratio spatial frequency error (rSFe).

Key Words: *Fast Discrete Curvelet Transform, Wavelet Transform, Wrapping Technique, Image Fusion*

1. INTROUDUCTION:

To improve human health, scientific discoveries at the bench, where diseases are studied at a molecular or cellular level must be translated into practical applications. Basic research findings are translated into new tools for use in patients as well as the assessment of their impact which then result in novel observations being made by the clinical researchers about the nature and progression of disease that often stimulate basic investigations.

In this scenario, preclinical imaging provides a set of powerful tools that hold the promise to facilitate this translation from basic science to improved patient diagnostics and therapeutics at a far greater pace and in vivo the concept of molecular imaging probes, their uses in preclinical and clinical imaging along with specific applications with emphasis on cancer. Different types of probes based on ultrasound, radiopharmaceuticals and bioluminescence optical signaling as well as MRI will be discussed. The advantages and limitations of each of these different modalities will be presented in relation to the characteristics of signal generation, signal propagation in tissues and background levels.

Instrumentation technology for the design of small animal PET/PET, optical, MRI and ultrasound imaging systems, with emphasis on the issues of sensitivity, contrast resolution, doses of contrast agents required, presence or absence of radiation, as well as the spatial resolution and dynamic nature of the different imaging modalities will be discussed. In addition the development of other novel technologies used in preclinical imaging research will also be covered. The practical aspects of imaging experiments, including experimental design and data analysis and animal handling (including anesthesia, temperature monitoring and control, pathogen control, blood sampling and experiment reproducibility for multimodality imaging) will be presented. The Preclinical images are the animal images which are scanned using the Computed Tomography, Magnetic Resonance Imaging (MRI), and Single Photon Emission Tomography, etc. These modalities can be fused using the Fusion rule. The fusion rules used in this work is as follows:

- **(a) Selection rule** includes choosing the salient features of the image inputs. Higher absolute values of coefficients correspond to features such as edges or singularities.

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- **(b) Averaging** rule includes the averaging the coefficients.

As used here, most of the transform based techniques utilizes the transform coefficients of the input images are alone taken as an activity measure for the fusion rule criterion ,if prior knowledge of the source image is known, other characteristics of the image can also be included in the fusion rule.

Candes and Donoho justifies that ,though wavelet transform exhibits time frequency localization and yields acceptable fused output, the edges and singularities are not well represented .Also it suffers from limited directionality. The point singularity is better suited for wavelets in 1 dimensional signals ,but 2 dimensional signals like images have curve or line singularities where wavelets fails to approximate. Hence to process images of sparse nature, Fast Discrete curvelet are recommended by the researchers.

I thank the Philips Electronics India Ltd, for providing me the preclinical images which are obtained from the Beta sites.

2. FAST DISCRETE CURVELET TRANSFORM (FDCT):

The curvelet transform has gone through two major revisions. The first generation curvelet transform used a complex series of steps involving the ridgelet analysis of radon transform of an image. The performance was exceeding slow. The second generation curvelet transform[] discarded the use of the ridgelet transform, thus reduced the amount of redundancy in the transform and increased the speed considerably. Two fast discrete curvelet transform algorithm were introduced in. The first algorithm is based on unequally-spaced FFT while the second is based on the wrapping of specially selected Fourier samples. In this paper, we focus on the “wrapping” version of the curvelet transform ·

3. FUSION ALGORITHM BASED ON FDCT:

Among the fusion methods such as pixel level, feature level and decision level, pixel level fusion methods are the most mature ones. The algorithm in this paper is a pixel level fusion method. One of most important characteristic of Curvelet transform is anisotropy, which can represent the contour of image more sparsely and provide more information for image processing. At the same time, in order to compare the results of different methods, we will adopt means for the coefficients in high frequency, and adopt the maximal absolute value for the coefficients in low frequency in the wavelet transform. In the Curvelet transform, means will be adopted for the coefficients in the coarse scale, and maximal module absolute value for the coefficients in fine scale. The fusion procedure takes the following steps.

1. Let consider the fusion of MR/MR , the first dataset is MRI Triplet – T1,T2,T3 and the second dataset is the CoronalDT MRI. Convert the R, G, B component of CoronalDT MRI into I, H, S component.

2. Perform histogram matching of I component of CoronalDT MRI image and MRI Triplet image, and apply FDCT to the R, G, B component of CoronalDT MRI image and MRI Triplet image to obtain the curvelet coefficients in each scale.

3. Fuse the each component of CoronalDT MRI image and MRI Triplet image in each scale according to the fusion rule.

4. Apply the invert FDCT to the fused curvelet coefficients to obtain the fused I component.

5. Perform the invert IHS transform of the obtained I component and the H, S component in step 1 to get the fused image

4. WAVELET TRANSFORM:

In transform domain fusion, a transform is applied on the registered images to identify the vital details in the image. The technique is described in Figure1. Fusion rule is applied over the transform coefficients and fusion decision map is obtained. Inverse transform is applied over the decision map, yields the fused image. This fused image will have details of both the source images.

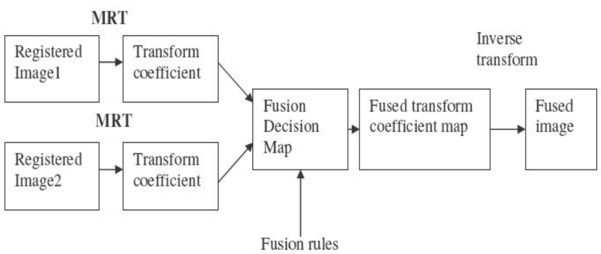


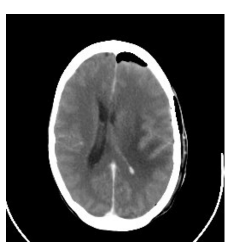
Figure 1: Block diagram of transform domain image fusion

Wavelets decomposes the image into low-high, high-low, high-high spatial frequency bands at different scales and the low –low band at the coarsest scale contains average image information[4] . The diagonal subbands of wavelet decomposition are further distinguished in to orientations ±15°, ±45°, ±75° by complex wavelets [5], but it adds redundancy. Till date various newer wavelets [6] with improved geometric features have been used for fusion.
The advancement of In order to compare the wavelet and curvelet based approaches; apart from visual appearance quantitative analysis is done over the fused images.

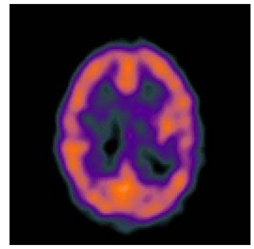
5. Results and Discussion :

The Analysis of the Transform is applied to the another set of medical Images which contains the T1, T2, PD (as shown in figure 8, 9, 10) to produce a Color Fused Image (figure 11 &12)

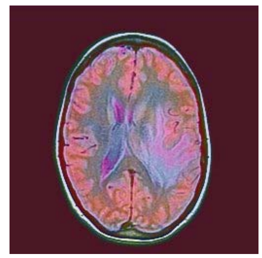
(8) T1 weighted



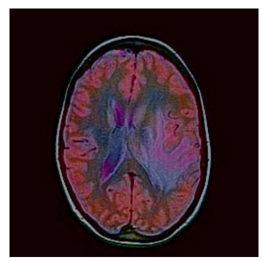
(9) T2 Weighted



(10) PD Image



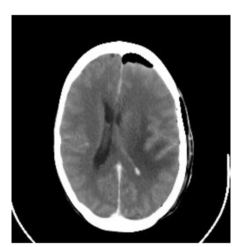
(11)Color Fused Image using Curvelet Transform using Fusion rule- Maximum of absolute value of ridgelet coefficients



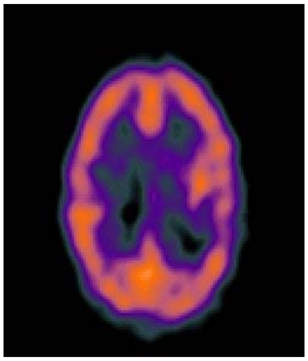
(12) Color Fused Image using Wavelet Transform using Maximum of absolute value of Wavelet Coefficients.

In Advancement of the Three Band Image Fusion is that the fused Images are combined with CT IMAGES of the same patient as shown in Figure(5). This will help Doctors for better diagnosis.

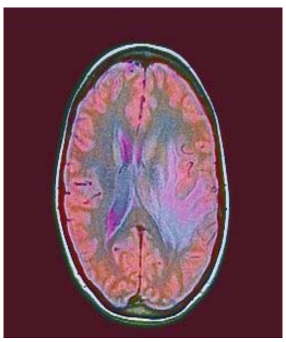
The Analysis of the Transform is applied to the another set of medical Images which contains the T1, T2 , PD (as shown in figure 8,9,10) to produce a Color Fused Image(figure 11 &12)



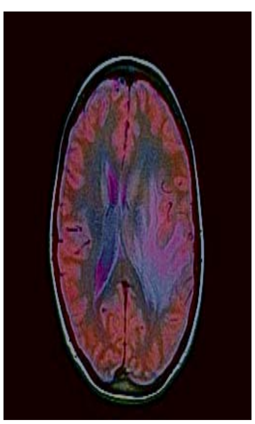
(8) T1 weighted (9)T2 Weighted



(10) PD Image



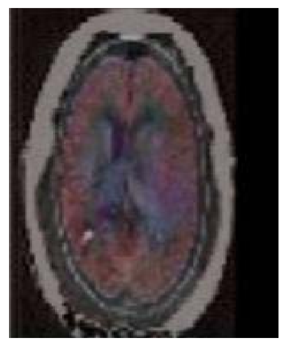
(11) Color Fused Image using Curvelet Transform



(12) Color Fused Image using Wavelet Transform

(13) CT Image

The Color Fused Image (Figure 12) is combined with CT to produce the resultant fused Image using Curvelet Transform is shown in figure 14 & 15.



(14) FUSION OF CT WITH T1, T2, PD using Curvelet Transform

(15) FUSION OF CT WITH T1, T2, PD using Wavelet Transform

Transform	Fusion rule	Entropy	Difference entropy	Standard deviation	Quality Measure Q	RMSE
Curvelet	Maximum absolute	5.832	5.361	69.29	0.900	1.530
	Addition	6.425	4.520	88.81	0.890	2.341
Wavelet	Maximum absolute	5.05	5.40	62.03	0.891	2.392
	Addition	5.79	4.76	87.34	0.879	2.413

Table 1: Entropy of source images

6. QUANTITATIVE ANALYSIS:

In order to compare the wavelet and curvelet based approaches; apart from visual appearance quantitative analysis is done over the fused images.

For the visual evaluation, the following criterion is considered: natural appearance, brilliance contrast, presence of complementary features, enhancement of common features etc.

The quantitative criterion [15] includes three parameters namely Entropy, Difference Entropy and Standard deviation. Each has its importance in evaluating the image quality.

1. Entropy: The entropy of an image is a measure of information content .The estimate assumes a statistically independent source characterized by the relative frequency of occurrence of the elements in X, which is its histogram. For a better fused image, the entropy should have a larger value.

2. Difference Entropy: It is calculated from taking the entropy of the image obtained from subtracting a source image from the fused image and the input source image.
Example: Fused image –CT Image=MRI Image
Entropy [obtained MRI Image –Input MRI] gives Difference Entropy. The difference entropy between two images reflects the difference between the average amounts of information they contained. Minimum difference is expected for a better fusion.

3. Standard deviation: The standard deviation (SD), which is the square root of variance, reflects the spread in the data. Thus, a high contrast image will have a larger variance, and a low contrast image will have a low variance.
The entropy is calculated individually for each source images (CT and Three Band MRI images) are tabulated in Table 1.

Entropy	**Image set 1**	
	CT	MRI
	4.202	4.866

Table 2: Quantitative analysis

These Quantitative measures are computed for the fused images (Three Band MRI Images) as well as CT with Fused Images (Three Band

MRI Images) and the result is given in Table2.Comparing the results in Table 1 and entropy of the fused images in Table 2, entropy of fused images shows an increase in the amount of information in both the transform approaches without any loss.

Quantitative analysis of the fused images indicates better results for curvelet transform based fusion with greater entropy, larger standard deviation and lower difference entropy than their wavelet equivalents. And among the curvelets, addition gives a better result.

7. CONCLUSION

In many important imaging applications, images exhibit edges and discontinuities across curves. In biological imagery, this occurs whenever two organs or tissue structures meet. Especially in image fusion the edge preservation is important in obtaining the complementary details of the input images. As edge representation in Curvelet is better, Curvelet based image fusion is best suited for medical images.

8. ACKNOWLEDGEMENT

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