Medical Image Fusion in NSST Domain utilizing Laplacian Low Energy and Average Fusion Rule

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Abstract. Digital photography is a very powerful and widely used form of communication. They represent the most complex details of the world around us in a simple, coherent, and easily accessible way. Due to the natural advances in the acquisition of devices such as bio-sensors and remote sensors, large amounts of data are available for further processing and extraction of data. In this proposed research study of Image fusion, The NSST method is applied for the decomposition of two medical Images into Low-Frequency Sub-band and High-Frequency Sub-band. Low pass frequency sub-bands are combined using an average filter and a modified Low pass sub-band is created. The modified high pass sub-band is created using intermediate high pass sub-bands with local laplacian. The final image is calculated by applying inverse NSST on Modified low pass sub-band and modified high pass sub-bands. Results are calculated that show this methodology Increases image fusion efficiency and able to remove the noise artifacts with increased information transfer rate.

Keywords*:* NSST, Laplacian, Image Fusion, CT, MRI, PET

1 Introduction

Image processing can be used to perform specific mathematical operations in pixels of the image, to obtain an improved visual quality and to extract certain useful information. Image integration is an effective way to retrieve information from multiple sources into a single image. Combined details enable visual representation of the wider image.

Recommendation derived from multiple senses; multiple foci or multiple views are grouped together to produce a new image that can be assigned to each image or set of data. The concept of image integration finds its application in various fields such as in Remote Sensing A variety of data is obtained through various sensors to obtain an integrated image with a higher resolution and spectral resolution. Other areas of image fusion use are surveillance, biometrics, defense systems and medical imaging. Many applications for image integration have been found in the field of medical imaging. Medical images obtained by various sensors are linked together to enhance the diagnostic quality of the image. With advances in the field of medical science and technology, medical imaging is able to provide a wide range of imaging information. The various medical images have specific features that need to be monitored simultaneously for clinical diagnosis. Multi-digit image processing is therefore

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done to combine the sensory properties of different images into a single image. the image integration process enhances the integrated image with enough data that can be supplied to each optical sensor. The source of the information to be entered can be made available from the same source at different times or from multiple sensory numbers at a regular time.

In Multi focus Fusion image integration, simultaneous images of the same location with different locations or focus objects are inserted to obtain all the information in a single image [1]. For example, an image of a single-centered object is combined with an image that contains other parts of the focus.

Multi-view Fusion: It is a combination of one type of behavior taken at the same time but in different situations and in different parts. It is intended to provide information from additional perspectives. For example, location views can be taken from the front and back views and can be grouped together to get a single multiple view image.

Multi-modal Fusion: In this case, the input of various sensors is put together to integrate the existing information into the recommended images.

1.1 Types of Images used in Fusion

In medical field different types of medical Data can be analyzed in the image format as DICOM Medical Images examples are CT scan, MRI Scan and PET, SPECT Image Scan. Image Fusion provides dedicated software for aligning location alignment (matching) and viewing of image data from a variety of modes (CT, MR, NM, PET) or from the same scenario but from multiple diagnostic tests for the same patient. It supports a positive diagnostic effect (a combination of morphological and functional information) and treatment planning. CT, MR, or PET images are accepted as input of image imaging [2]. In this Paper the comparative work is proposed using MR Image with PET and CT Image.

CT (Computer Tomography) Imaging is done with a CT scan process used to identify diseases or injuries, tissues, clots that lead to strokes, bleeding, and other conditions in various parts of the body in CT Scan Image scanning computer-assisted scanning and rotating X-ray machines are used to create distinct images of the body. These images provide more detail than conventional X-ray images. They can show soft tissues, blood vessels, and bones in various parts of the body.

MR (Magnetic Resonance) Image Scan test is also used to diagnose diseases or Injuries on Different Parts of the Body. An MRI scanner uses a large magnet, radio waves, and a computer to create a detailed, concise image of internal organs and structures.

PET (Positron Emission Tomography) is a Medical Imaging test that uses a radioactive drugs to show the activity and Changes in metabolic processes and in other physiological activities including blood flow, regional chemical composition, and absorption into the body.

1.2 Type of Image fusion method Image

Fusion Method is divided into spatial domain and Frequency domain. In spatial domain the pixel value of the images are modified to get the fused Image but the drawback of this method is reduction in sharpness and contrast which may not be accepted in medical Image processing.

Frequency Transformation Based techniques gives better image quality in the Image Fusion process where frequency transformation is used to change the images into coefficients. The techniques for image fusion used into frequency domain is FRFT (Fractional Fourier transform), DWT (discrete wavelet transform), Laplacian Pyramid based decomposition, NSCT (Non sub-sampled Counterlet Transform), NSST (Non Sub-sampled Shearlet Transform) etc. In this paper NSST is used to decompose images into Low Frequency and High Frequency sub-bands.

NSST (Non Sub-band Shearlet Transform): The NSST is a directional representation system that adds to the geometrical information employed in this method. Shearlet transform is a multi-scale geometric analysis algorithm based on composite wavelength that inherits the benefits of contourlet and curvelet transforms. The NSST [3] discretization technique involves two phases: multi-scale factorization and multi-orientation.

$$\Omega_{AB}(\Psi) = \begin{cases} \Psi_{j,l,k}(x) = |\det(A)|^{\frac{j}{2}} \Psi(B^l A^j_{x-k}) \\ \qquad j, l \in Z, \;\; k \epsilon Z^2 \end{cases} \qquad (1)$$

Where $\Psi \; \epsilon L^2(R^2), A, B$ are the two invertible matrices of 2x2 size and $|detB|$=1

2. Related Work

A single fusion process is usually deficient in one way or another. As a result, there is a need to build a system that takes into account the benefits of several distinct fusion rules. As a result, hybrid image fusion is employed. It processes the image using various fusion criteria before combining the results to create a single image [4]. In this section the related study of previous work using NSST is shown below.

"K. Vanitha, D. Satyanarayana, et al, 2021" [5] (included) SF-PAPCNN is a novel approach for integrating multimodal medical pictures. Low Pass and High Pass frequency terms are decomposed using NSST on multimodal pictures. The maximal rule is used to select the coefficients of the Low Pass sub-band. SF-PAPCNN combines the coefficients of high-frequency bands. If you apply the Inverse-NSST-rule, you'll get the combined medical image. Validating the usefulness of Fusion Method requires the use of quality measures such as entropy ENT, Fusion Symmetry FS, deviation STD, mutual information QMI, and edge strength QAB/F.

P. Ganasala and Prasad 2020 [6]. In this Paper the NSST on YIQ Color mode of functional information Based technique is applied which can be used to preserve anatomical details on the Data set of SPECT and MRI images of Brain tumor. Fused Images are quantitatively measured by five image fusion quality indices such as Mutual Information, Visual Information fidelity, Similarity Index Matrix (SSIM), Spatial Frequency and Edge Intensity. These results of quality indices shows that this method of fusion on SPECT and MRI is better in preserving the anatomical details.

2019 [7] C. S. Asha et. al By using a chaotic Grey Wolf optimization method, we propose a weighted blending of high-frequency sub-bands of the non-subsampled shearlet transform (NSST) domain. A multi-scale and multi-directional decomposition of the raw pictures is first performed using the NSST. As a result of a simple maximum rule, the low-frequency bands are fused together to sustain an individual's energy. To reduce the distance between the fused pictures, an adaptively weighted combination of high-frequency images is utilised. Finally, the fused image is formed Using inverse NSST of merged low and high-frequency bands.

Y. Liu, D. Zhou, R. Nie, R. Hou, Z. Ding and R. Xie, 2018 [8]. In this Research Paper the Author Proposed a technique based on NSST to get low frequency coefficients and the high frequency coefficients. In the next step the high frequency coefficients are merged using the absolute-maximum rule while the low frequency coefficients are fused with a SR-based fusion approach. Then a fused image is obtained by inverse NSST. The results show that the proposed method achieves the best performance in both subjective and objective evaluation.
Z. Song and co-authors (9) New fusion method for PET/CET images of the whole body using pulse coupled neural networks and non-sampled shearlet transforms (NSST). Images are first decomposed into Low Pass and Several High Pass Sub-bands, and then PCNN is employed in High Pass Sub-bands in the work described above. Rule of maximum energy fusion applies to high pass sub-bands as well as a rule of maximum selection. The Fused Image is obtained using the Inverse Method of NSST.
2016 [10], J. Yang et. al According to a study published in this journal, researchers have developed a non-subsampled shearlet transform (NSST) and compressive sensing (CS) medical picture fusion technique. There are two sub-bands in this method, one low pass and the other high pass. Weighted fusion rule is used to enhance weights using low pass sub-band coefficients, and CS is used to improve fusion rule by allowing observations to participate in the computation of the fusion. This will be followed by obtaining the final fused picture using the inverse NSST method. Experimental results demonstrate that the suggested technique not only enhances the fusion image's details, but also decreases the computation time.

3 Proposed Work

NSST-based Image Fusion Algorithm for CT and MRI: In this article, we apply NSST-based Image Fusion for medical imaging. Decomposing the pictures A and B is first done with NSST, followed by getting the low-pass sub-band and high pass sub-band for each image. In order to fuse low frequency sub-band coefficients, the average fusion rule is utilised, whereas the Laplacian fusion rule is used to fuse high frequency sub-band coefficients with a high degree of complexity. This technique may extract more detailed information from the original picture in the last phase by performing Inverse NSST. The Flow chart of proposed fusion scheme is shown as Fig.1. And steps are as follow:
STEP 1: Select pair of medical images, one of the image is named as Image A (CT Image) and other as Image B (MR Image), Apply NSST technique to decompose these images into low pass ‘L’ and high pass ‘H’ sub-bands as LA, LB and HA HB.

STEP 2: Combining low pass sub-band of Image A and low pass sub-band of Image B using average filter and generating a modified low pass sub-band of Both the Images as LAB.

STEP 3: Integrating High pass sub-band of Image A and high pass sub-bands of Image B with local laplacian and then output is modified in High pass sub-band.

STEP 4: Final image is formed as a fuse Image by applying inverse NSST on Modified low pass sub-band and modified high pass sub-bands.

For the PET and MR Images same algorithm is applied on the sub-bands of PET Image and sub-bands of MR Image after decomposition into Low Frequency and High Frequency by using NSST (Non sub-band shearlet transform technique). Different Parameters are calculated and compared which is shown in table 1. Function loss (LABF) Results shows that MR-CT Image fusion gives the good quality image with minimum loss as compare to PET-MR Image.

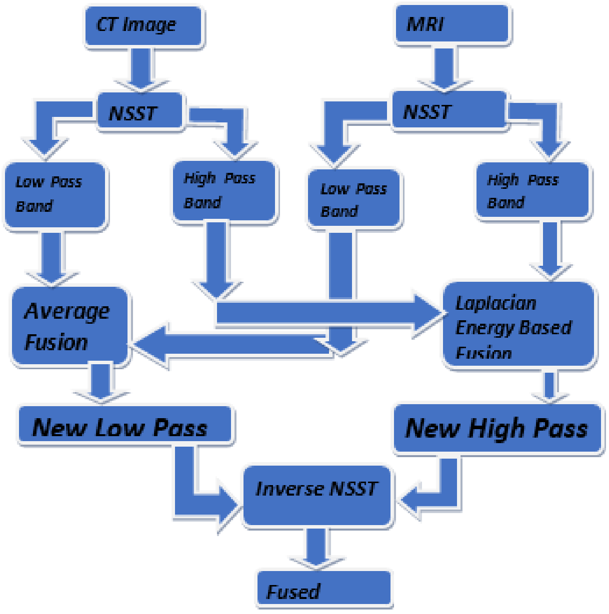

Figure 1. Flow Chart of Our Proposed Method

4 Image Fusion Parameters

For calculating all the parameters, let us assume that weights of Image A and B on pixel position (i,j) is to be considered as w_A *and* w_B. Then fused pixel value $f(i,j)$ is shown below

$$f(i,j) = \frac{(A(i,j)\times w_A + B(i,j)\times w_B)}{w_A + w_B} \qquad (1)$$ 2

Where $A(i,j)$ *and* $B(i,j)$ are the intensity value of Pixels at Position (i,j) of Image A and Image B respectively and $f(i,j)$ is the Intensity of fused pixel Image.
(a) Average Pixel Intensity (API) or mean (F): an index of contrast.

$$API = \overline{F} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} f(i,j)}{M \times N}$$ 3

Where $f(i,j)$ is a pixel intensity for position (i,j) of an image F.
(b) Average Gradient (A. G): a measure of sharpness and clarity degree.

$$AG = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}[(f(i,j) - f(i+1,j))^2 + \left(f(i,j) - f(i,j+1)\right)^2]^2}{M \times N}$$ 4

(c) Spatial Frequency (S. F): a measure of sharpness and clarity degree. The larger value of SF gives more clarity in image.

(d) Standard Deviation (S. D): this is the square root of the variance, which reflects the spread in the data.

(e) Entropy or Information index (H): Entropy is a measure index to evaluate the information quantity of an image. If the entropy value is higher in the fused image then it indicates that fused image carrying greater information compare to the source image. If value of entropy is higher than better will be the fusion result.

$$Entropy = -\sum P_F(f)\log_2 P_F(f) \quad 5$$

Where $P_F(f)$ stands for Probability distribution function of the intensity of an image F.
(f) Mutual Information (M. I. F) or Fusion Factor: Fusion factor is a measure of correlation between information content of fused image with respect to the source images.
M.I.F. of source image A and Fused Image F is represented as MI_{AF} and Mutual Information for source image B and Fused Image F is representedMI_{BF}.
Overall Mutual Information for source image A and source image B with the fused image is:

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$$MI_{AB}^{F} = MI_{AF} + MI_{BF} \quad 6$$

(g) Fusion Symmetry (F S) or Information fusion symmetry: FS is a measure of finding symmetry between the two images fused image and source image with respect to information.

$$FS = 2 - \left|\frac{MI_{AF}}{MI_{AF} + MI_{BF}} - 0.5\right| \quad 7$$

(h) Normalized Correlation (CORR): a parameter to find degree of similarity of fused image with respect to source image.
(i) QABF (Fusion image quality): QABF is an index of measuring edge information or common information in fused images. Highest value of QABF shows better fusion quality of image that is called total fusion performance of the fused Image.
(j) LABF (Function Loss): this LABF parameter value shows lowest value with minimum loss.
(k) NABF (Fusion Artifacts): NABF is parameter to measure noise artefacts into the fused image added due to fusion. For the better fuse image NABF value should be low.
(l) Mean Square Error (MSE) or Measure of Image Compression Quality: Mean square error (MSE) is a parameter to measure image compression quality index measure of fused image with the source image to know how close is fused image with the original Image. Lower the MSE index value, lower will be the error between original image and fused image.

5 Results

For assessing our proposed technique using image fusion process, The size of all the source images CT Scan Image, MRI Image and PET Images are taken as the size of 256x256. Proposed algorithm is implemented with the combination of CT, MR Images and PET, MR Images. Parameters such as Mutual Information, Entropy, Standard Deviation, QABF, LABF, NABF, AG calculated for the validation of this algorithm. CT-MR and PET-MR fusion method is compared which is shown in table 1.

Table 1. CT-MR and PET-MR Parameters value table

S. No.	Table Column Head		
	PARAMETERS	CT-MRI Data	PET-MRI Data
1	QABF	0.8964	0.8340
2	LABF	0.0968	0.1649
3	NABF	0.1144	0.0120
4	API	32.4874	20.4407
5	S. D.	43.4752	40.3794
6	A. G	9.0428	8.7386
7	Entropy	6.2135	3.4335
8	M.I.F	2.0790	2.0669
9	S. F.	16.6122	24.7427
10	FS1	1.7024	1.9921

Simulations Results:
In the simulation Results visual performance of Images is shown, In Fig. 2 (a) MRI Image and CT Scan Image is taking and after applying our proposed algorithm the Fused Image is generated. Fig. 2 (b) shows that MRI Image and PET image is taken as input image, after applying proposed algorithm a resultant Fused Image is generated which can be used in many applications in the medical imaging.

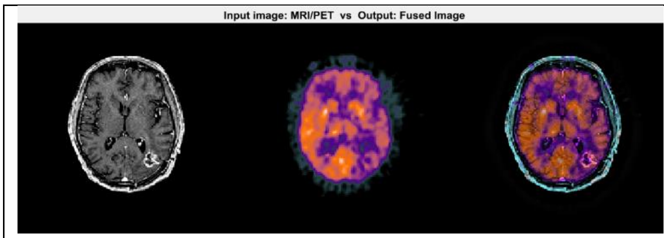

Fig. 2 (a): ME-PET image resulting Fused Image

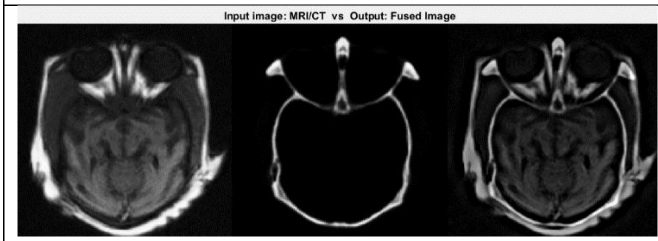

Fig. 2 (b): MR-CT image resulting Fused Image

Figure 2. Input Image MRI/PET Vs Fused Output Image

6 Conclusion

In this research study, we propose an Image Fusion approach based on NSST, Laplacian, and Averaging for CT-MR and PET-MR images. The non-sub-sampled shearlet transformations are an excellent technique for image fusion because they provide high quality spectral content, more anisotropic direction selectivity, and higher computational efficiency, all of which provide additional information about the geometry of the images. laplacian is found to be a better technique for image fusion in medical image processing. After Implementation the results suggests us that NSST with averaging and Laplacian is better approach in the image fusion processing.

References

[1] G. Easley et. al ,"Sparse directional image representation using the discrete shearletstransform" Applied and Computational Harmonic Analysis Vol. 25, Issue 1 ,2008,pp. 25-46

[2] Jacobs et. al., "Fine particles, thin films and exchange anisotropy," Magnetism, Vol. 3, , 1963, pp. 271–350.

[3] Tamilselvan et.al, "Survey and analysis of various image fusion techniques for clinical CT and MRI images", IJEST Vol. 24, Issue 2, 2014, pp. 193-202.

[4] Liu Z et. al " A novel multi-focus image fusion approach based on image decomposition" Inf Fus, Vol.1,Issue 35,2017 pp.102–116.

[5] Liu, X, et.al. " Image fusion based on shearlet transform and regional features" International Journal of Electronics and Communications, Vol. 68,Issue 6,2014,pp. 471–477.

[6] K. Vanitha et.al "Multi-modal Medical Image Fusion Algorithm Based on Spatial Frequency Motivated PA-PCNN in the NSST Domain", Current Medical Imaging, 2021, Vol 17,Issue 5 pp. 1-20.

[7] Ganasala, P et.al (2020). "Functional and Anatomical Image Fusion based on Texture Energy Measures in NSST Domain (ICPC2T)

[8] C. S. Asha et. al "Multi-Modal Medical Image Fusion With Adaptive Weighted Combination of NSST Bands Using Chaotic Grey Wolf Optimization," IEEE Access, Vol. 7, pp. 40782-40796, 2019

[9] Y. Liu et. al , "Brain CT and MRI medical image fusion scheme Using NSST And Dictionary Learning," (ICCC), 2018, pp. 1579-1583.

[10] Song, Z et. al (2017). "An Improved Medical Image Fusion Method Based on PCNN in NSST Domain" . 2017 ICVRV

[11] J. Yang et. al "A novel fusion technique for CT and MRI medical image based on NSST," (CCDC), 2016, pp. 4367-4372

[12] Raju et.al. (2018). "Comparison of Medical Image Fusion Methods using Image Quality Metrics". 2018 IC3IoT

[13] Guru Prasad et. al., "Fusion of CT and PET Medical Images using Hybrid Algorithm DWT-DCT-PCA", vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[14] Yagnik Trivedi "IMAGE FUSION USING HYBRID WAVELET TRANSFORM'' IJARIIE, Vol-2 Issue-3 2016

[15] W. Kong et. al, "Technique for image fusion between gray-scale visual light and infrared images based on NSST and improved RF," Electron Optics, Vol. 124, no. 23, pp. 6423-6431, 2013.

[16] Y. Yang et.al "Medical image fusion via an effective wavelet-based approach," Journal on Advances in Signal Processing, Vol. 2010, pp. 1–13, 2010.

[17] R. Singh et. al , "Fusion of multimodal medical images using daubechies complex wavelet transform–a multiresolution approach," Information Fusion, Vol. 19,2014, pp. 49–60.

[18] G. D. Patne et. al, "Review of CT and PET image fusion using hybrid algorithm," I2C2, 2017, pp. 1-5.

[19] Cao Y et. al ," Multi-focus image fusion by nonsubsampled shearlet trans-form" ICIG 2011 .IEEE, 2011. pp. 17–21.

[20] Shi Z et.al , Adaptive image fusion algorithm based on shearlettransform. Acta Photonica Sinica 2013;Vol. 42 Issue1 pp.115–20.

[21] Wang L et.al ,"Multi-modal medical image fusion using the inter-scale andintra-scale dependencies between images shift-invariant shearlet coefficients".Information Fusion, 2012, pp 1-12.