International Journal of Scientific & Engineering Research, Volume 7, Issue 2, February-2016
ISSN 2229-5518

MULTIMODAL IMAGE FUSION: A SURVEY

C.N. DESHMUKH, *PROFESSOR, PRMIT&R, BADNERA*

K.D.DHORE, *STUDENT, M.E, PRMIT&R, BADNERA*

***Abstract*— The quality of information offered by the medical images for diagnosis support can be increased by combining images from different compatible medical devices. Medical image fusion has been used to derive useful information from multimodality medical image data. Image fusion is the process by which two or more images are combined into a single image retaining the important features and information from each of original images ,so image become more interpretable, reliable and much easier to understand by people. Fused image will be represented in format capable for computer processing. Image fusion can be performed by using wavelet transform, complex wavelet transform, non sub sampled contourlet transform, etc. The resulting image possesses more information compared to individual images. This paper describes different techniques and related research for image fusion for multimodal medical imaging.**

.

***Index Terms*— Image fusion, wavelet transform, complex wavelet transform, non-sub sampled contourlet transform.**

I. INTRODUCTION

IMage fusion is one of the most fruitful, precise and useful diagnostic techniques in medical imaging now a days. The new skill has made a clear difference in patience care by reducing the time between diagnosis and treatment. Image fusion is the progression by which two or more images are combined into single image retaining the important features from each of the original images.

Image fusion aims at extracting information from multiple source images to obtain to obtain a more accurate, complete and reliable fusion image for the same scene or targets. Compared with original inputs, the fused image is more suitable for observation, analysis, understanding and extracting information. With advantages in technology, more and more imaging modalities are available for research and clinical studies, for example structural images like Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Magnetic Resonance Angiography (MRA), Ultrasonography (USG), etc provide high resolution images with anatomical information, While Functional images such as Position Emission Tomography (PET), Functional MRI (fMRI), and Single Photon Emission Computed Tomography (SPECT), etc, provide low resolution images with functional information. Each of these modalities provides some unique and very often complementary characterization of the underlying anatomy and tissue microstructure. Hence combining these different modalities images provides more useful information through image fusion.

The image fusion is classified into three level first pixel level second feature level and third decision level.

a) Pixel Level Fusion

It produces a fused image in which information content related with each pixel is concluded from a set of pixels in source images. Fusion at this level can be carried out either in spatial or in frequency domain. However, pixel level fusion may be conducted for contrast reduction.

b) Attribute Level Fusion

Attribute level fusion requires the extraction of salient characteristics which are depending on their surroundings such as pixel intensities, edges or textures. These analogous attribute from the input images are fused. This fusion level can be used as a means of creating supplementary amalgamated attributes. The fused image can also be used for classification or detection.

c) Decision Level Image Fusion

Decision-level fusion is the superior level fusion. All decision and control are decided according to the output of decision-level fusion. It uses the data information extracted from the pixel level fusion or the feature level fusion to make optimal decision to achieve a specific objective. Moreover the redundancy and uncertain information can help in systems stoutness.

The advantage of multi-modal image fusion Comprise of:

i. Improved reliability – The fusion of different measurements can diminish noise and consequently develop the steadfastness of the measured quantity.
ii. Robust system performance – Redundancy in various measurements can help in systems stoutness. In case one or more sensors fail or the performance of a meticulous sensor deteriorates the system can depend on the other sensors.
iii. Compact representation of information – Fusion leads to condensed representations. For example, in remote sensing, instead of storing imagery from numerous spectral bands, it is moderately more proficient to store the fused information.

iv. Extended range of operation – Multiple sensors that function under different operating conditions can be deployed to expand the effective range of operation. For example, different sensors can be used for day/night operation.
v. Extended spatial and temporal coverage – Joint information from sensors that diverge in the spatial resolution can increase spatial coverage. The identical is true for the secular dimension.
vi. Reduced uncertainty – Joint information from several sensors can diminish the vagueness associated with the sensing or decision process.

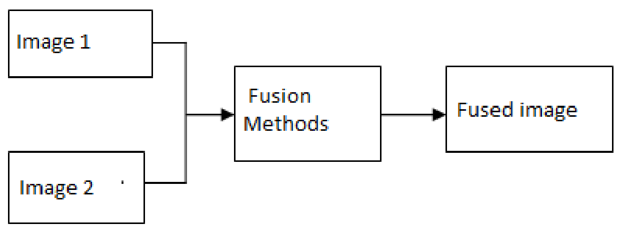

Figure 1.Image Fusion

Two images image 1 and image 2 of same or different modalities are taken and by applying various fusion methods final fused image is derived which is more informative than single image.

II. IMAGE FUSION TECHNIQUES

Image fusion is one of the significant processes to acquire essential features from the common images, in which images from different modalities are fused to get the most desired results in a single output image. The information content and its information richness vary for the different techniques that are used for the purpose.
Image fusion technique can be broadly classified into two methods.

- Spatial domain fusion method
- Transform Domain Fusion

In Spatial domain technique, we directly indulge with the image pixels. The pixel values are manipulated to achieve desired enhancement. The fusion methods such as averaging, principle component analysis (PCA), the brovey method and HIS based methods falls under the spatial domain approaches.

A. Spatial Domain Fusion Techniques

1. *Average Method:*

This method takes the average of two images pixel by pixel. This method work well when the image which are to be fused are from the same type of sensor and contains additive noise. One limitation is that some noise may introduce into fused image which reduce the final image quality [1].

2. *Brovery Transform:*

This method maintains the relative spectral contribution of each pixel but replaces the overall brightness by high resolution panchromatic images. This is a real fast and simple method. One disadvantage is it produces spectral distortion [2].

3. *Intensity Hue Saturation:*

This method uses three low resolution multispectral images in different bands and transforms them into IHS space, which is replaced by the high resolution panchromatic image and transformed back into original RGB space along with previous H as well as S components. This method gives good visual effect but produces colour distortion [3].

4. *Simple Maximum Method:*

In this image fusion method, the resultant fused image is obtained by selecting the maximum intensity corresponding pixels from both the input image.

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \max A(i,j)B(i,j)$$

A(i,j), B(i,j) are provided input images and F(i,j) is output fused image. The advantage is that it results in highly focused output image obtained from input image as compared to average method. The disadvantage is that the pixel level method is affected by the blurring effect which directly affect on to the contrast of the image.

5. *Simple Minimum Method:*

In this fusion method, the resulting fused image is obtained by selecting the minimum intensity of corresponding pixels from both the input image [4].

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \min A(i,j)B(i,j)$$

A(i,j), B(i,j) are input images and F(i,j) is fused image.

6. *Principle Component Analysis (PCA):*

It is a mathematical tool from applied linear algebra. It is a simple parametric method for extracting necessary information from confusing data sets. PCA is a technique involving numerical procedure for transforming the correlated variables to uncorrelated variables called principal component. Compact and optimal data set is computed. PCA is the simple technique which reveals the internal structure of data in balanced way but it may develope spectral degradation. Application areas for using PCA are image classification and image compression [5].

The origin of PCA lie in multivariate data analysis, it has a wide range of other application PCA has been called, „one of the most vital results from applied linear algebra and perhaps its most common use is as the first step in analysing large sets. In general, PCA uses a vector space transform to reduce the dimensionality of large data sets. By using the mathematical projection, the original data set, which may have involved many variables, can often be interpreted by just a few variables.

The major advantage if this method is that it prevents certain features from dominating the image because of their large digital numbers. The disadvantage is that it suffers from spatial degradation.

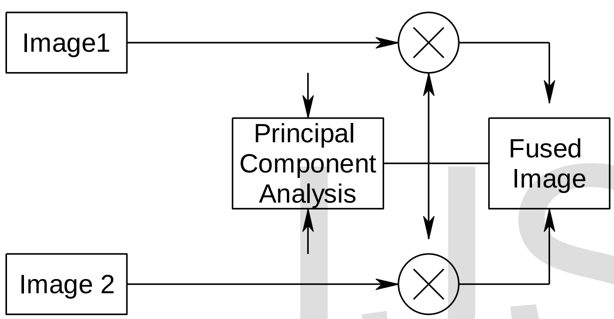

Fig.2. Image Fusion Process Using PCA

7. IHS Transform

It is one of the mainly used popular methods by many researchers for blending Panchromatic and Multispectral images. The fusion is based on the RGB-IHS conversion model. In this method, the principle is based on the fact that the IHS color space is catered to cognitive system of human and that the transformation owns the ability to separate the spectral information of an RGB composition into two components H and S, while isolating most of the spatial information in the I component. In this technique three MS bands R, G and B of low resolution image are first transformed into the IHS color coordinates, and then only the histogram - matched high spatial resolution image substitutes the intensity image and that describes the total color brightness and exhibits as the dominant component a strong similarity to the image with higher spatial resolution. At last, an inverse transformation from IHS space back to the original RGB space yields the fused RGB image and spatial details of the high resolution image incorporated into it. This method provides a better visual effect and high spatial quality for the fused image. Limitation of this method is that it produces a significant color distortion with respect to the original image [6].

B. Transform Domain Fusion Techniques

The multi resolution techniques involve two kinds, one is Pyramid transform and other is Wavelet Transform

[1] Pyramid Transform

In this fusion method of transform domain. Various Pyramids based fusion techniques proposed are FSD Pyramid, Laplacian Pyramid, Ratio-of-low-pass Pyramid, Gradient Pyramid, and Morphological Pyramid contrast providing the image fusion based on different fusion rules. In pyramid approach, pyramid levels obtained by the down sampling of source images are fused at pixel level depending on fusion rules. The fused-image is obtained by reconstruction of the fused image pyramid. An image pyramid consists of a set of low pass or band pass copies of an image, each single copy representing pattern information of a different scale. At every level of fusion using pyramid transform, the size of the pyramid would be half the size of the pyramid in the preceding level and the higher levels will gather upon the lower spatial frequencies. The main idea is to construct the pyramid transform of the fused image by the pyramid transforms of the source images and then the fused image is obtained by taking inverse pyramid transform[7].

[2] Discrete Wavelet Transform

Wavelets are finite duration oscillatory functions with zero average value [8]. They have finite energy. They are suited for analysis of transient signal. The irregularity and the good localization property make them better basis for analysis of signals with discontinuities. Wavelets can be stated having two functions viz. the scaling function f (t), also known as "father wavelet" and the wavelet function or "mother wavelet". Mother wavelet (t) undergoes translation and scaling operations to give self similar wavelet families as given by Equation.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\,\psi\left(\frac{t-b}{a}\right), \ (a, b \epsilon R), \ a > 0$$

The wavelet transform decomposes the image into high-low, low-high, high-high spatial frequency bands at different scales and the low-low band at the coarsest scale. The L-L band contains the average image information whereas the other bands contain directional information because of spatial orientation. Higher absolute values of wavelet coefficients in the high bands correspond to salient features such as edges or lines [1][9][10]. The basic steps performed in image fusion given in fig. 3.

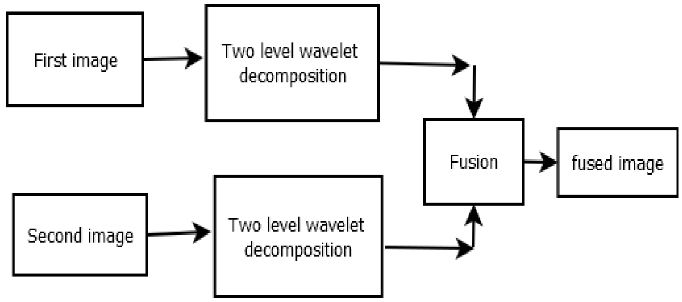

Fig.3. Image Fusion Process Using DWT

[3] Curvelet Transform

Curvelet transform is based on segmentation of the whole image into small overlapping tiles and then, the ridgelet transform is applied on each tile. The purpose of the segmentation process is to approximate curved lines by the small straight lines. The overlapping of tiles aims at avoiding edge effects. The ridgelet transform itself is a 1-D wavelet transform applied on the Radon transform for each tile, which is a tool of shape detection. The curvelet transform was firstly proposed for image denoising [11–13]. Because of its ability to deal with curved shapes, the application of the curvelet transform in medical science image fusion would result in better fusion results than that obtained using the wavelet transform.

The curvelet transform has evolved as a tool for the representation of curved shapes in graphical applications. Then, it was used in the fields of edge detection and image denoising [11, 12]. Recently, some authors have proposed the application of the curvelet transform in different areas for image fusion [14, 15]. The algorithm of the curvelet transform of an image *P* is expressed in the following steps:

A) The image *P* is split up into three subbands $\Delta 1$, $\Delta 2$ and $P3$ using the additive wavelet transforms

B) Tiling is performed on the sub bands $\Delta 1$ and $\Delta 2$.

C) The discrete ridgelet transform on each tile, of the subbands $\Delta 1$ and $\Delta 2$, is performed.

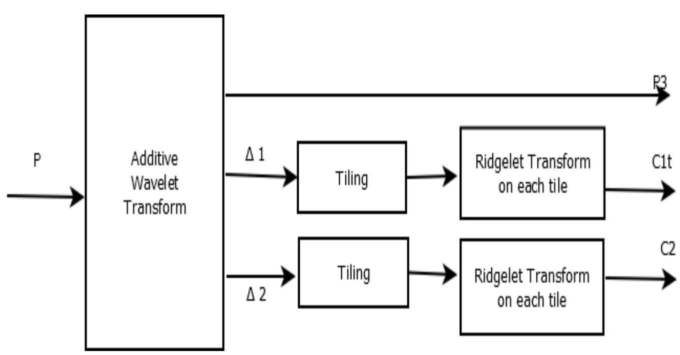

Fig. 4: Curvelet transform

[4] Contourlet Transform

The wavelet transform is best at isolating the discontinuities at object edges, but cannot detect the smoothness along the edges. Moreover, it can only capture limited directional information. The contourlet transform can effectively overcome the disadvantages of wavelet; contourlet transform is a multi-scale and multi-direction framework of discrete image. In this transform, the multi-scale analysis and the multi-direction analysis are separated in a serial way. The Laplacian pyramid (LP) [16] is first used to get the point discontinuities, then followed by a directional filter bank (DFB) [17] to link point discontinuities into linear structures. The total outcome is an image expansion using basic elements like contour segments.

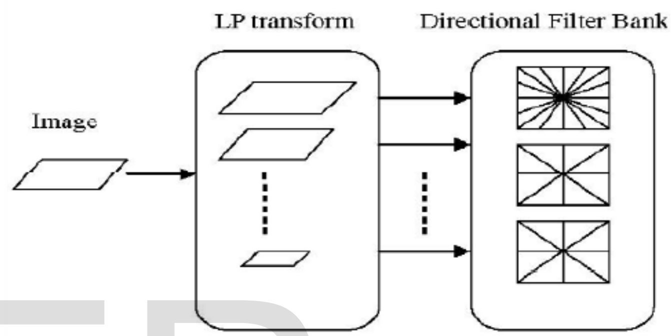

Fig.5: The framework of contourlet transforms

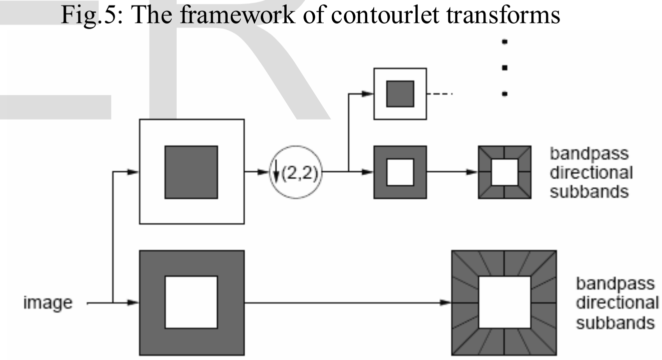

Fig. 6: Contourlet filter bank

Figure 6 shows the contourlet filter bank. First, multi scale decomposition by Laplacian pyramid, and then a directional filter bank is applied to each band pass channel. In addition to retaining the multi-scale and time-frequency localization properties of wavelets, the contourlet transform offer high range of directionality. Contourlet transform adopts nonseparable basis functions, which makes it capable in capturing the geometrical smoothness of the contour along any possible direction.

[5] Nonsubsampled Contourlet Transform (NSCT)

Nonsubsampled Contourlet Transform is similar with Contourlet Transform, which also do multi-scale and directional decomposition respectively. Firstly, nonsubsampled pyramid filter bank (NSPFB) is used to do multi-scale decomposition with input images. Then, nonsubsampled directional filter bank (NSDFB) is used to do directional decomposition with band pass images of each scale prepared by the first step. Finally, different scale and directional images are obtained [13].

The subsampled procedure after analyzing filtering and upsampled procedure before integrated filtering are removed in laplacian pyramid and directional decompositions of NSCT. These procedures are changed to do upsampled operation to the corresponding filter and the signal is filtered after that. Since it has no upsampled and subsampled procedure, the size of all sub-bands is the same with original images. Because of these reason, NSCT has a character of translation invariance [19].

The proposed algorithm is follows:

1) Suppose the original images are A and B then do NSCT transform respectively to them. A series of directional sub-bands and a low frequency one are obtained.

2) Perform fusion rules to low-frequency sub-band and high-frequency directional sub-bands. The rules could be different to each band to reconstruct image.

3) Reconstruct image using fused coefficients and get the fusion result F.

III. CONCLUSION

In this paper different multimodal image fusion techniques have been reviewed. The image fusion techniques are used to create a single enhanced image which is more suitable for the purpose of human visual perception, object detection. Each technique has its own merits and demerits. These techniques improve the clarity of the images to some extent. Spatial domain provides high spatial resolution. The advantage of simple average technique is that it is the simplest method of image fusion, while its disadvantage is that this method does not give guarantee to have clear objects from the set of images. The transform domain methods provide a high quality spectral content. We have described the wavelet based (DWT), curvelet based, counterlet based which are more impressive over the other respectively. But NSCT in transform domain is found to be more fruitful than the preceding technologies; it is fully shift-invariant, multiscale, and multidirectional expansion that has a fast implementation. In future, the method will be helpful in the field of medical image fusion to get information rich fused image and to get cent percent of the information from image of different modalities in to the fused image.

REFERENCES

[1] SABARI .BANU, R. (2011), ―"Medical Image Fusion by the analysis of Pixel Level Multi-sensor Using Discrete Wavelet Transform", Proceedings of the National Conference on Emerging Trends in Computing Science, Pp.291-297.

[2] Nupur Singh, Pinky Tanwar (2012), "Image Fusion Using Improved Contourlet Transform Technique", IJRTE Volume-1, Issue-2.

[3] Tu, Su, Shyu, Huang (2001) "Efficient intensity-hue saturation-based image fusion with saturation compensation", Optical Engineering, Vol. 40 No. 5.

[4] S. Shah, D. Shah, "Comparative study of image fusion techniques based on spatial and transform domain", *IJIRSET*,vol.3,issue 3,pp. 10168-10175,MARCH 2014

[5] Shalima, R. Virk, " Review of image fusion Techniques", *IRJET*, vol.2, issue 3,pp. 333-339, JUNE 2015

[6] S. panwar,S. Malwadkar, "A review:Image fusion techniques for multisensory Images*", IJAREEIE*,vol.4,pp. 406-410,JAN 2015

[7] P. Kaur, M. Kaur, "A comparative study of various digital image fusion techniques: A review", *IJCA,* vol. 114,pp. 26-31,MARCH 2015

[8] Deepali A.Godse, Dattatraya S. Bormane (2011) **"**Wavelet based image fusion using pixel based maximum selection rule" International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 7 July 2011, ISSN : 0975-5462

[9]Gonzalo Pajares , Jesus Manuel de la Cruz "A wavelet-based image fusion tutorial" 2004 Pattern Recognition Society.

[10] Stavri Nikolov Paul Hill David Bull Nishan Canagarajah "WAVELETS - FOR IMAGE FUSION.

[11]Saevarsson, B. B., J. R. Sveinsson, and J. A. Benediktsson, "Combined wavelet and curvelet denoising of SAR images," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium, (IGARSS)*, Vol. 6, 4235–4238, 2004.

[12] Saevarsson, B. B., J. R. Sveinsson, and J. A. Benediktsson, "Translation invariant combined denoising algorithm," *IEEE International Symposium on Circuits and Systems, (ISCAS 2005)*, Vol. 5, 4241–4244, 2005.

[13] Saevarsson, B. B., J. R. Sveinsson, and J. A. Benediktsson, "Time invariant curvelet denoising," *Proceeding of the Nordic Signal Processing Symposium, (NORSIG 2004)*, 117–120, 2004.

[14] Choi, M., R. Y. Kim, and M. G. Kim, "The curvelet transform for image fusion," *International Society for Photogrammetry and Remote Sensing, ISPRS 2004*, Vol. 35, Part B8, 59–64, Istanbul, 2004.

[15] Choi, M., R. Y. Kim, M. R. Nam, and H. O. Kim, "Fusion of multispectral and panchromatic satellite images using the curvelet transform," *IEEE Geosci. Remote Sensing Lett.*, Vol. 2, No. 2, 136–140, Apr. 2005.

[16] Burt P J., "Merging images through pattern decomposition", Proceedings of SPIE, 575: 173-18, 1985.

[17] Bamberger R H., "A filter bank for the directional decomposition of images: Theory and design", IEEE Trans. Signal Processing, 40 (4): 882 -893, 1992.

[13] Da Cunha A L , Zhou J , Do M N, "The nonsubsampled contourlet transform: theory , design , and applications", IEEE Trans . Image Proc., 15 (10) : 308923101, 2006.

[19] Huang Qingqing et al. , "Improved Fusion Method for Infrared and visible remote sensing imagery Using NSCT", 6th IEEE conference on industrial electronics and applications, pp. 1012-1015, 2011.