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A Review of Image Fusion Techniques

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***Abstract*— Image fusion is a process of blending the complementary as well as the common features of a set of images, to generate a resultant image with superior information content in terms of subjective as well as objective analysis point of view. Image fusion is to reduce uncertainty and minimize redundancy. It is a process of combining the relevant information from a set of images, into a single image, wherein the resultant fused image will be more informative and complete than any of the input images. Today the image fusion techniques are like DWT or pixel based. The conventional techniques are not that efficient and they did not produced the expected results as the edge preservance, spatial resolution and the shift invariance are the factors that could not be avoided during image fusion.**

***Keywords*— DWT (Discrete Wavelet transform), Image Fusion, Image processing.**

1. INTRODUCTION

Fusion of two or more images of the same scene to form a single image is known as image fusion. Image fusion process combines the relevant information from two or more images into single image therefore the resultant fused image will be more informative and having important features from each image. Image fusion is important in many different image processing fields such as satellite imaging, remote sensing and medical imaging. Several fusion algorithms have been evolved such as pyramid based, wavelet based, curvelet based, HSI (Hue Saturation Intensity), color model, PCA (Principal Component Analysis) method. All of them lacks in one criteria or the other. Wavelet method was supposed to be one of the most promising methods of image fusion due to its simplicity and ability to preserve the time and frequency details of the image to be fused. Wavelet Fusion transforms the images from spatial domain to wavelet domain. The wavelet domain represents the wavelet coefficient of the images. The wavelet decomposition is performed by passing the image into series of low pass and high pass filters. In this method the input signal goes through two digital filters. One of them performs high pass filtering and the other performs low pass filtering. The various filter bands are produced and each band producing images of different resolution levels and orientations. These sub bands are then combined using inverse wavelet transform.

In current image processing systems, the need for data fusion is increasing, mainly due to the increase of image acquisition techniques. Latest imaging technology sensors offer a wide variety of different information that can be extracted from an observed scene. This information is jointly combined to provide an enhanced representation of the scene.

Image fusion finds application in a very wide range of areas involving image processing. Some of the areas which find critical application of image fusion are:

• *Intelligent robots:* It requires motion control, based on feedback from the environment, from visual, tactile, force/torque and other types of sensors. Stereo camera fusion is required for intelligent viewing, control and automatic target recognition and tracking.

• *Medical Imaging:* Fusion of X-ray CT and MRI images enable doctors to carry out computer assisted surgery. A 3D reconstruction of the fused result will aid in better visualization of the internal organs.

• *Remote Sensing:* Arial images of a particular scene are taken using various parts of the electromagnetic spectrum. Sensors ranging from black-and-white photography to multi-spectral active microwave space-borne imaging radar are used. Various fusion techniques are used to combine the information obtained from each sensor to a single composite image.

Combining low quality images into a single image, which has a higher quality than either of the input images is the crux behind image fusion. Image fusion aims at integrating the complementary information from the input images, so that the fused image is more suitable for visual perception and computer processing. However, with rapid development in image fusion techniques, the need for objective evaluation of the fusion methods is needed. The required quality of the fused image varies with each application and hence, image quality metrics allow us to choose from the various fusion techniques, the best one for a particular application.

Medical imaging has gained more prominence in the healthcare industry. There are many imaging techniques available to acquire images from a human body. CT scanners allow doctors to visualize dense structures like bones, while MRI scanner is used for visualizing soft tissues. Yet another technique, PET, helps in providing better information about the blood flow activity taking place inside the blood vessels.

All these techniques aid medical practitioners to better visualize the internal organs of the patients and thereby assure an accurate treatment. The various modality images obtained from the varied imaging techniques, give different information regarding the same organ being studied. This is normally quite uncomfortable for doctors, as they have to analyze multiple images of different modalities in order to correctly diagnose the problem associated with a patient. This problem gave rise to promising research in the field of multimodal image fusion. Image fusion techniques have seen extensive research and various fusion algorithms have been developed for medical image fusion. Image fusion techniques are broadly classified as: pixel based, feature based and decision based. Medical image fusion techniques commonly employ pixel level fusion. It includes spatial domain techniques like principal component analysis (PCA) and Brovey transform method and spectral domain techniques like pyramid methods, discrete wavelet transform (DWT), complex wavelet transform (CWT), curvelet transform, slantlet transform and countourlet transform based methods. Spectral domain fusion techniques have proven to give better fusion performance when compared to the spatial domain techniques, due to the fusion of information involved in the former at multiple resolutions.

2. EVOLUTION OF IMAGE FUSION RESEARCH

The evolution of the research work into the field of image fusion can be broadly put into the following three stages:

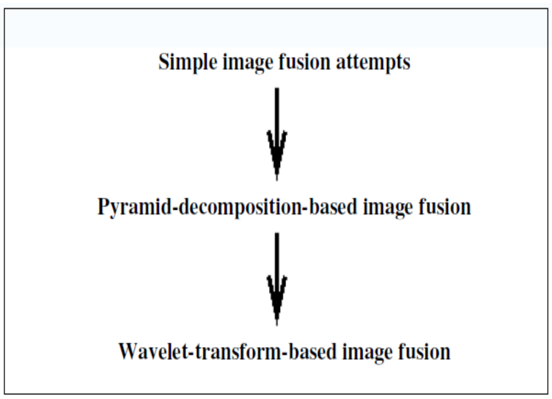

Figure 1: Evolution of Image Fusion Research.

The primitive fusion schemes perform the fusion right on the source images. This would include operations like averaging, addition, subtraction/omission of the pixel intensities of the input images to be fused. These methods often have serious side effects such as reducing the contrast of the image as a whole. But these methods do prove good for certain particular cases wherein the input images have an overall high brightness and high contrast. With the introduction of pyramid transform in mid-80's, some sophisticated approaches began to emerge. People found that it would be better to perform the fusion in the transform domain. Pyramid transform appears to be very useful for this purpose. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images, and then the fused image is obtained by taking inverse pyramid transform. Here are some major advantages of pyramid transform:

- It can provide information on the sharp contrast changes, and human visual system is especially sensitive to these sharp contrast changes.
- It can provide both spatial and frequency domain localization.

Several types of pyramid decomposition are used or developed for image fusion, such as:

- Laplacian Pyramid
- Ratio-of-low-pass Pyramid
- Gradient Pyramid
- FSD Pyramid
- Morphological Pyramid etc.

More recently, with the development of wavelet theory [2] [6] [7] [9] [12], people began to apply wavelet multiscale decomposition to take the place of pyramid decomposition for image fusion. Actually, wavelet transform can be taken as one special type of pyramid decompositions. It retains most of the advantages for image fusion but has much more complete theoretical support. A lot of research is happening in this field and even advance multi wavelets are applied for fusing images.

3. IMAGE FUSION ALGORITHMS

In the techniques discussed here, fusion is performed directly on the source images. This includes operations like averaging, addition, subtraction or omission of pixel intensities of the input images to be fused. These methods have serious side effects such as reducing the contrast of the whole image. However, these methods do prove satisfactory for certain cases, where the input images have high brightness and high contrast.

3.1 Averaging Method

This is the simplest method of fusing images. Here, the corresponding pixel intensities of the input images are averaged. The fused image thus obtained has both good and bad information present in the input images. Since an averaging operation is done, both the good and bad information in the input images are minimized. Though an averaged image is obtained, this technique is an imperfect method of image fusion.

3.2 Select Maximum Method

In this technique, of every corresponding pixel in the input images, the pixel with the maximum intensity is selected and is taken as the resultant pixel of the fused image. Since it doesn't make any compromise on the good information available in the input images, it is better than the averaging method. However, it has a drawback that it always considers the higher pixel intensity as the better information. So, either the entire information is taken or it is totally avoided.

3.3 Select Minimum Method

This method picks up the pixel with the minimum intensity as the resultant pixel value for the fused image. Thus, for each location of the fused image, the pixel value will be the minimum value from the input set of images at the corresponding locations. This technique also has the problem of either completely considering or discarding information. Images with dark shades normally give good results with this fusion technique.

3.4 Principal Component Analysis Method

PCA is a vector space transform, often used to reduce the dimensionality of datasets for data analysis. PCA is the simplest and most useful method for Eigen-vector based multivariate analysis, since its operations reveal the internal structure of the data. The PCA is used extensively in image compression and image classification. The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. It computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first. Within this subspace, this component points the direction of maximum variance. The third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. and its basis vectors depend on the data set.

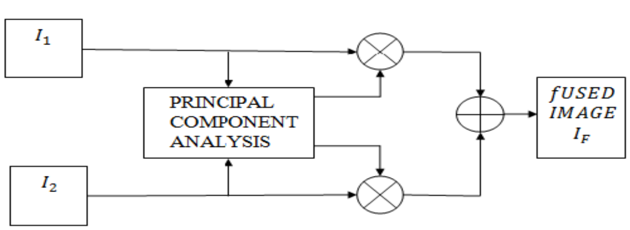

Figure 2: Flow diagram of image fusion scheme employing PCA.

Steps involved in PCA

- From the input image matrices produce the column vectors.

- Compute the covariance matrix of two column vectors formed before.

- Compute the Eigen values and Eigen vectors of the covariance matrix.

- The column vector corresponding to the larger Eigen value is normalized by dividing each element with mean of Eigen vector.

- Normalized Eigen vector value act as the weight values which are respectively multiplied with each pixel of the input images.

- The fused image matrix will be sum of the two scaled matrices.

4. DISCRETE WAVELET TRANSFORM (DWT)

Discrete Wavelet Transform can be derived from the Continuous Wavelet Transform (CWT). The discrete wavelet transform (DWT) is in literature commonly associated with signal expansion into (bi-) orthogonal wavelet bases. Thus, as opposed to the highly redundant CWT, there is no redundancy in the DWT of a signal; the scale is sampled at dyadic steps a $\in \{2^j : j \in Z\}$, and the position is sampled proportionally to the scale b $\in \{k2^j : (j, k) \in Z^2\}$.

By no means can a DWT be understood as a simple sampling from a CWT. In the first place, the choice of a wavelet is now far more restrictive: if we are dealing with finite-energy signals $f(x) \in \mathbf{L}^2(R)$, the wavelet $\psi(x)$ has to be chosen such that $\{\psi(2^{-j}(x - 2^j k))\}$ $(j,k) \in Z^2$ is a basis of $\mathbf{L}^2(R)$. The systematic framework for constructing wavelet bases, known as the multiresolution analysis.

The orthogonal wavelets are rarely available as closed form expressions, but rather obtained through a computational procedure which uses discrete filters. The term "wavelets" refers to a orthonormal basis function that is generated by the translation and dilation of scaling function Φ and the mother wavelet ψ. A discrete wavelet transform is a finite scale multi resolution representation of a discrete function. Discrete wavelet transform is orthogonal and invertible where the inverse transform is expressed as the matrix is the transpose of the transform matrix. The wavelet function is localized in space, unlike sines and cosines in Fourier transform. Similar to sines and cosines the individual wavelet functions are localized in frequency. The wavelet basis is defined a

$$\psi_{(j,k)}(x) = 2^{j/2}\psi(2^j x - k)$$

The scaling function is mathematically given by

$$\phi_{(j,k)}(x) = 2^{j/2}\phi(2^j x - k)$$

Where ψ is the wavelet function and j and k are integers that scale and dilate the wavelet function. Factor 'j' in Equations is known as the scale index, which represents the width of the wavelet. The location index k gives the position. The wavelet function is dilated by powers of two and is translated by k which is an integer. In terms of the wavelet coefficients, the wavelet equation is

$$\psi(x) = \sum_{k}^{N-1} g_k \sqrt{2\phi(2x-k)}$$

The function *Φ(x)* represents a scaling function and the coefficients h0, h1,….. are low pass scaling coefficients. The wavelet and scaling coefficients are related by the a quadrature mirror relationship which is given as

$$g_n = (-1)^n h_{1-n+N}$$

Where N is the number of vanishing moments.

The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:-

(1) It is a multi scale (multi resolution) approach well suited to manage the different image resolutions. Useful in a number of image processing applications including the image fusion.

(2) The discrete wavelets transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information. Such coefficients coming from different images can be appropriately combined to obtain new coefficients so that the information in the original images is collected appropriately.

(3) Once the coefficients are merged the final fused image is achieved through the inverse discrete wavelets transform (IDWT), where the information in the merged coefficients is also preserved.

Three previously developed fusion rule schemes were implemented using discrete wavelet transform based image fusion:

- *Maximum Selection (MS) scheme*: This simple scheme just picks the coefficient in each subband with the largest magnitude;
- *Weighted Average (WA) scheme*: This scheme developed by Burt and Kolczynski uses a normalised correlation between the two images' subbands over a small local area. The resultant coefficient for reconstruction is calculated from this measure via a weighted average of the two images' coefficients;
- *Window Based Verification (WBV) scheme*: This scheme developed by Li *et al.* creates a binary decision map to choose between each pair of coefficients using a majority filter.

Image fusion process using DWT is described below:

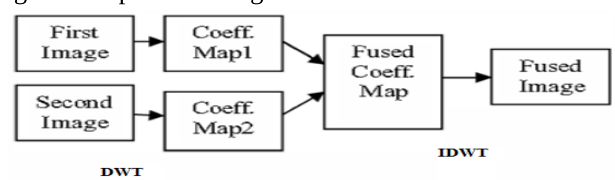

Figure 3: Image fusion process using DWT.

Wavelet transform is first performed on each source images to generate a fusion decision map based on a set of fusion rules. The fused wavelet coefficient map can be constructed from the wavelet coefficients of the source images according to the fusion decision map. Finally the fused image is obtained by performing the inverse wavelet transform.

5. COMPARISON OF DIFFERENT IMAGE FUSION TECHNIQUES

S.No	Fusion Algorithm	Domain	Advantages	Disadvantages
1	Simple Average	Spatial	This is the simplest method of image fusion.	The main disadvantage of Pixel level method is that this method does not give guarantee to have a clear objects from the set of images.
2	Simple Maximum	Spatial	Resulting in highly focused image output obtained from the input image as compared to average method.	Pixel level method are affected by blurring effect which directly affect on the contrast of the image
3	PCA	Spatial	PCA is a tool which transforms number of correlated variable into number of uncorrelated variables, this property can be used in image fusion.	Spatial domain fusion my produce spectral degradation.
4	DWT	Transform	The DWT fusion method may outperform the slandered fusion method in terms of minimizing the spectral distortion. It also provide better signal to noise ratio than pixel based approach.	In this method final fused image have a less spatial resolution.

6. CONCLUSION

Several fusion algorithms have been evolved such as pyramid based, wavelet based, curvelet based, HSI (Hue Saturation Intensity), color model, PCA (Principal Component Analysis) method. All of them lacks in one criteria or the other. Wavelet method was supposed to be one of the most promising methods of image fusion due to its simplicity and ability to preserve the time and frequency details of the image to be fused.

REFRENCES

[1]. Abhinav Krishn, Vikrant Bhateja, Himanshi, and Akanksha Sahu , *"PCA Based Medical Image Fusion in Ridgelet Domain",* © Springer International Publishing Switzerland 2015. S.C. Satapathy et al. (eds.), Proc. of the 3rd Int. Conf. on Front. of Intell. Comput. (FICTA) 2014 – Vol. 2, Advances in Intelligent Systems and Computing 328, DOI: 10.1007/978-3-319-12012-6_52.

[2]. Gagandeep kaur , Anand Kumar Mittal , *"A New Hybrid Wavelet Based Approach for Image Fusion",* International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 1, January 2015

[3]. Kaushal Mehta1, Dr. Dilbag Singh, *"Designing of Technique of Image Fusion and Comparison with the Existing Techniques",* International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264) Vol. 3, No. 2, April 2015.

[4]. M.D. Nandeesh and Dr.M. Meenakshi, *"Image Fusion Algorithms for Medical Images-A Comparison",* Bonfring International Journal of Advances in Image Processing, Vol. 5, No. 3, July 2015.

[5]. Manpreet Kaur1, Dr. Shiv Kumar Verma2, Gagandeep Kaur3, *"Medical Image Fusion Using Wavelet Transform",* International Journal For Technological Research In Engineering Volume 2, Issue 11, July-2015.

[6]. Jyoti Agarwal1 and Sarabjeet Singh Bedi, *"Implementation of hybrid image fusion technique for feature enhancement in medical diagnosis",* Agarwal and Bedi Human-centric Computing and Information Sciences (2015) 5:3 DOI 10.1186/s13673-014-0020-z.

[7]. Deepali Sale1, Pallavi Sonare2, Dr.M.A.Joshi, *"PCA Based Image Fusion for Multispectral Palm Enhancement",* International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 2, February 2014.

[8]. Nayera Nahvi, Deep Mittal, *"Medical Image Fusion Using Discrete Wavelet Transform",* Nayera Nahvi Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 9(Version 5), September 2014, pp.165-170.

[9]. Xin Zhou*, Wei Wang and Rui-an Liu, *"Compressive sensing image fusion algorithm based on directionlets",* Zhou et al. EURASIP Journal on Wireless Communications and Networking 2014, 2014:19.

[10]. Nisha Gawari, Dr. Lalitha.Y.SComparative, *"Analysis of PCA, DCT & DWT based Image Fusion Techniques",* International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-3, Issue-5)May201.

[11]. Dr. S. Narayana Reddy,C. Chandrasekhar, *"Design and Implementation of Image Fusion Technique Using DWT for Micro Air Vehicle",* IJECT Vol. 5, Issue spl-1, Jan - MarCh 2014.

[12]. Vadher Jagruti, *"Implementation of Discrete Wavelet Transform Based Image Fusion",* IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 2, Ver. VIII (Mar - Apr. 2014), PP 107-109 www.iosrjournals.org

[13]. Sweta K. Shah, Prof. D.U. Shah, *"Comparative Study of Image Fusion Techniques based on Spatial and Transform Domain",* International Journal of Innovative Research in Science, Engineering and Technology Vol.3, Issue 3, March2014.

[14]. Laxman Tawade1, Abida Bapu Aboobacker2 and Firdos Ghante, *"Image Fusion Based on Wavelet Transforms",* International Journal of Bio-Science and Bio-Technology Vol.6, No.3 (2014), pp.149-162 .

[15]. Xu, Z., *"Medical Image Fusion Using Multi-Level Local Extrema.", Elsevier-Information Fusion"* 19, 38–48 (2014).

[16]. Singh, R., Khare, *"A Fusion of Multimodal Images using Daubechies Complex Wavelet Transform",* A Multiresolution Approach. Info. Fusion. 19, 49–60 (2014)

[17]. Huaxun Zhang , and Huaxun Zhang, *"A Way of Image Fusion Based on Wavelet Transform",* 2013 IEEE 9th International Conference on Mobile Ad-hoc and Sensor Networks.

[18]. A., Singh, S., Bhateja, V, *"A Robust Approach for Denoising and Enhancement of Mammographic Breast Masses"*, International Journal on Convergence Computing, Inderscience Publishers 1(1), 38–49 (2013).

[19]. Kusum Rani1, Reecha Sharma, "*Study of Different Image fusion Algorithm",* International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 5, May 2013).

[20]. Kusum Rani1, Reecha Sharma, *"Study of Image Fusion using Discrete wavelet and Multiwavelet Transform",* International Journal of Innovative Research in Computer and Communication Engineering Vol. 1, Issue 4, June 2013.

[21]. A. Sasi, L. Parameswaran, Sruthy S, "*Image Fusion technique using DT-CWT"* IEEE, 2013.

[22]. R.Desale, S.Verma, *"Study and Analysis of PCA,DCT & DWT based Image Fusion Techniques",* International Conference on Signal processing, Image Processing and Pattern Recognition 2013.

[23]. K.Rani,R.Sharma, *"Study of Different Fusion Algorithm",* International journal of Emerging Technology and advanced Engineering , Vol.3, May 2013.

[24]. Gagandeep Kour1, Sharad P. Singh *"Image Fusion Parameter Estimation And Comparison Between SVD And DWT Technique"* International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 2, Issue 11, November 2013.

[25]. Dr.S. S. Bedi, Rati Khandelwal, *"Comprehensive and Comparative Study of Image Fusion Techniques",* International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-1, March 2013.

[26]. A.Ufade, M.Kawade, *"Comparision of spatial domain and transform domain image fusion technique for restoration of blur images",* International Conference on Recent Trends in engineering & Technology, 2013.

[27]. M.Pradnya,S.Ruikar, *"Image Fusion Based On Stationary Wavelet Transform",* International Journal on Advanced Engineering Research and Studies 2013.

[28]. Dr.S.S.Bedi, Mrs.Jyoti Agarwal, Pankaj Agarwal, *"Image Fusion Techniques and Quality Assessment Parameters for Clinical Diagnosis: A Review",* International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 2, February 2013.

[29]. Nirosha Joshitha J, R. Medona Selin, *"Image Fusion using PCA in Multifeature Based Palmprint Recognition",* International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-2, May 2012.

[30]. Dasarathy, B.V, *"Information Fusion in the Realm of Medical Applications – A Bibliographic Glimpse at its Growing Appeal"*, Information Fusion 13(1), 1–9 (2012).