Novel Approach for Iterative Image Fusion using Fuzzy and Neuro Fuzzy Logic

Rao, D, S.,[1] Seetha, M.[2] and Krishna Prasad, M.H.M.[3]
[1]VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India
E-mail: srinivasarao_d@vnrvjiet.in
[2]Department of Computer Science and Engineering, G. Narayanamma Institute of Technology and Science Hyderabad - 500008, Telangana State, India, E-mail: seetha.maddala@gmail.com
[3]Jawaharlal Nehru Technological University, Kakinada, Andhra Pradesh 533003, India
E-mail: hazarath.munaga@gmail.com

Abstract
Image fusion may be defined as an approach of merging two or more input images in to a single fused image which is comparatively more informative than all the input images. Image fusion aims to reduce the redundancy and uncertainty in the output and aims to maximize application related significant information. Fused images are used in diverse applications such as remote sensing, machine vision, biometrics, medical imaging and military domain. In this paper, we carry out iterative image fusion through fuzzy logic and neuro fuzzy logic techniques by fusing satellite images obtained from two or more image sensors to improve visualization capability. We also compare the proposed iterative image fusion approach based on fuzzy logic and neuro fuzzy logic with two more approaches like Principal component analysis (PCA) based fusion and the wavelet transform based image fusion. Fused images obtained from iterative image fusion using fuzzy and neuro fuzzy and other comparative methods are assessed through typical quality evaluation metrics. The proposed iterative fusion based on fuzzy logic approach divulges better values in some metrics whereas iterative image fusion based on neuro fuzzy logic technique provides better values in other metrics. Due to the potentiality of the fuzzy logic and neuro fuzzy logic. The overall experimental results generated from suggested approach substantiate that the utilization of the iterative image fusion using fuzzy logic and neuro fuzzy logic techniques would efficiently improve the quality grade of the fused image with concurrent confinement of spectral and spatial information.

1. Introduction

The authors consider the kalman algorithm to perform pixel level based image fusion is performed using Kalman algorithm (Quadric and Othman, 013). The fused image is obtained from the fusion of optimal estimates of pixel values and strives to defend the capability of proposed Kalman filter for data fusion. A hybrid image fusion technique is proposed by combining self-fractional Fourier function (SFFF) decomposition and multivariate empirical mode decomposition. The fused image is obtained by applying inverse transformation on fused intrinsic mode functions (IMF) images (Sharma et al., 2014). An efficient approach for image fusion of multi-focus images based on variance calculated in DCT domain is proposed to apply for real time applications (Mohammad et al., 2011). A novel image fusion technique is proposed that combines information from different spectral bands with a Wavelet transform from various sub-bands and subsequently make the statistical dependency analysis between sub-bands to obtain fusion either by selection or by weighted fusion (Raghavendra and Christoph, 2014).

A new method is proposed for fusion by decomposing input images using direction let transform and the fused image is obtained with the specified procedure for fusion. (Xin et al., 2014). A novel approach is furnished (Balasubramaniam and Ananthi, 2014) for image fusion by intuitionistic fuzzy sets (IFS) and the proposed fusion technique attempts to improve the quality of the image by eliminating uncertainties and vagueness. Thus, (Christinal and Jebaseeli, 2013) proposed a method for image fusion which transfers color from the reference image to the output image using Color Transfer Technology; and a scaling factor is incepted in the b channel to obtain hot targets which are popped out with intense colors while the background details are present with the natural color appearance. By combining curvelet and wavelet transform approaches (Shutao and Bin, 2008) multifocus image fusion is proposed, where curvelet

transform is used to decompose each of the input images and the wavelet-based image fusion approach is used to fuse coefficients and the output fused image is obtained by performing the inverse curvelet transform.

The authors (rameshet al., 2004) , propose image fusion for video surrealism and context enhancement based on a gradient domain approach that preserves important local perceptual cues while removing regular difficulties like aliasing, ghosting and haloing. Image fusion approach (Min et al., 2011) which is based on the principle of Markov Random Fields makes use of the fact that the decision making in the fusion process has a significant correlation within its neighborhood and assumed that it can be modeled as an MRF. A new image fusion approach (Anjali et al., 2013) is proposed based on the integration of wavelet and fast discrete curvelet transform, which describes curved shapes of the images and remarkably analyses various feature of images. A new approach called multiscale image fusion method (Rajiv and Ashish, 2013) for multimodal medical images employed DWT and input images are fused at multiple scales from level 2 to level 8 scales with maximum fusion rule. Conclusively, the multi scale image fusion method enables the selection of suitable fused image with better flexibility. A novel image fusion using compressed sensing (CS) technique decomposes two or more input images using directionlet transform approach and produces the sparse matrix and also fuses the obtained sparse matrices along coefficient sheer value maximum scheme. Later fused image is from the reduction samples through resolving the optimization approach (Zhou et al., 2014)

Multi-objective optimization based image fusion uses multi-objective optimization strategy and a key energy function where first strategy ensures improvement in spatial information obtained from gradient delegation to fuse the image and the other one ensures that the image spectral information is retained by a data fitting (Xie et al., 2014)

Image fusion problem solved by (Qiwei et al., 2014) applies the multi-object optimization strategy and uses a key energy function, which ensures injection of more correlated detailed spatial information by assuring that the spectral information is preserved by a data fitting term. The fusion result can be obtained by minimizing the proposed energy function. A novel fusion method (Peiguang et al., 2013) based on FRFT (fractional Fourier transform) –NSCT (nonsub sampled Contourlet transform) is proposed where NSCT has features like multiscale, multi-direction, shift invariance. FRFT transforms the signal analysis into fractional domain and can simultaneously reflect the signal information in both the time domain and frequency domain. After the individual comparison of Discrete Wavelet Transform (DWT) and PCA, a new method is proposed for image fusion by combining DWT (transform domain) and PCA (spatial domain) methods (Mitra, 2014). Based on human visual system and back propagation (BP) technique a novel multi focus image fusion method where three traits considered to reflect the quality of a image pixel are chosen first and used to instruct a BP neural network approach to decide which image pixel is clearer. Later those pixels are used to build the fused image (Yong Yong et al., 2014).

2. Wavelet Transform Based Image Fusion

Image fusion using discrete wavelet transform (DWT) converged with a different coefficients selection approach is proposed and using DWT input images are decomposed and two disparate window-based image fusion rules are distinctly engaged to combine high and low frequency coefficients. Later the low frequency domain coefficients with higher intensity measure are elected as coefficients of the fused image (Yang et al., 2014)

Wavelet transform (Mary, 2009) is a type signal representation that can give the frequency content of the signal at a particular instant of time. The block diagram of a generic wavelet based image fusion approach is shown in the Figure 1.

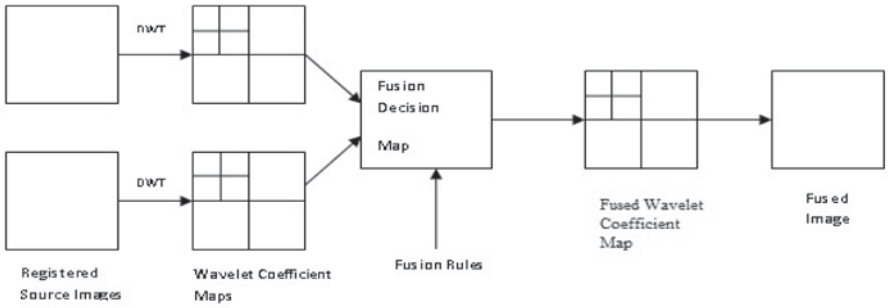

Figure 1: The generic structures of the image fusion using wavelet transform

Wavelet based fusion (Godse and Bormane, 2008) process performs wavelet decomposition of source images and the fusion is performed based on taking maximum valued pixels from approximation. Later, binary decision map is generated which gives the decision rule for fusion of approximation in the input images. Through maximum selection pixel rule, final fused transform corresponding to approximations are obtained. Concatenation of fused approximations is regarded to obtain new coefficient matrix and fused image is generated by applying inverse wavelet transform.

3. Principal Component Analysis Based Image Fusion

A mathematical approach that converts a number of associated variables into a number of unassociated variables through the Principal Component Analysis (Naidu and Rao, 2008).

3.1 Steps in Principal Component Analysis (PCA) Algorithm

1. Source image are converted in to column vectors
2. From two column vectors obtained from step 1, covariance matrix is computed.
3. From the covariance matrix calculate the characteristic values and the corresponding characteristic vectors
4. Both the column vector and Eigen vectors got normalized
5. By fusing the two scaled matrices obtained fused image matrix is computed

3.2 Image Fusion by PCA

We consider the input images denoted by $I_1(x, y)$ and I_2 (x, y) and convert these images in to equivalent two column vectors and subtract their means. The dimension of the output vector is n x 2, where n is the length of the image vector. The Eigen values and conform Eigen vectors for this output vector is computed and also compute the Eigen vectors correlated to the larger Eigen values. P_1 and P_2 are normalized components computed from covariance matrix to obtain Eigen vector and the fused image is obtained from it (Naidu and Rao, 2008).

$$I_f = P_1 I_1(x, y) + P_2 I_2(x, y) \quad \text{Equation 1}$$

4. Fuzzy Logic Based Image Fusion

So many classic methods for image fusion are proposed for image fusion includes, Multiplicative Transform, Brovey Transform, and HIS Transform, DWT, PCA etc., In this paper we propose the Iterative Image Fusion using fuzzy and neuro fuzzy logic as an alternative approach to the existing conventional methods so as to improve the fused image quality even in the situations to model uncertainty. Fuzzy logic can design the fusion process using fusion rules. Fuzzy logic will also simulate, debug and implement the fusion process very effectively. In fuzzy logic we view each item as a subject of degree and we can also fuzzify any reasoning system. We can also interpret comprehension as a fuzzy constraint over a collection of parameters or variables. Similarly the Deduction process in Fuzzy approach is like diffusion process.

4.1 Fuzzy Logic in Image Processing

Fuzzification (Maruthi and Sankarasubramanian, 2008) is used to convert the gray-level plane of input image to the membership plane and also to decode the data. On Contrary, Defuzzification is used to obtain the fused image with fuzzy methods. To modify the membership values, suitable fuzzy techniques may be applied.

4.2 Fuzzy Inference System (FIS)

FIS deals with determining membership functions, fuzzy operators and fuzzy rules. Mamdani's FIS is the popular FIS and it assumes that the membership functions of the output to be fuzzy sets. To model any inference system Sugeno's FIS can be used where either linear or constant output membership functions may be present.

4.3 Steps in Fuzzy Image Fusion

Fuzzy image fusion includes:

1. Fuzzification process
2. Membership values modification
3. Defuzzification process

The fuzzification and defuzzification approaches are used to encode and decode the image data respectively and the modification of membership values is the major role here. Initially source images are converted from gray-level scale to the membership plane through fuzzification step and we use suitable fuzzy techniques to modify the membership values as illustrated in the Figure 2. The algorithm (dammavalam and Maddala, 2012) ome fusion is to repeat the fusion process steps reiteratively, where fused image obtained from the first time fusion process will be the one of the input images for the second iteration.

In proposed method, we use 3 membership functions and 6 fuzzy rules. We use the notations MSF_i to denote i^{th} membership function.

For example, MSF_1 indicates first membership function; MSF_2 denotes second membership function etc. Similarly Input_i indicates ith input function and Output_i indicates i^{th} Output function. The rules are listed below.

Rule-1:
[Input_1 is MSF _3] or [Input_2 is MSF _3] → [output1 is MF _2]

Rule-2:
Input_1 → MSF_1] or [Input_2 is MSF_3] → [output1 is MF_1]

Rule-3:
[Input_1 → MSF_ 3] or [Input_2 is MSF_2] → [output1 is MF_ 3]

Rule-4:
[Input_1 → MSF_2] or [Input_2 is MSF_2] → [output1 is MF_2]

Rule-5:
[Input_1 → MF_2] or [Input_2 is MF_2] → [output1 is MF_ 2]

Rule-6:
[Input_1 → MSF_1] or [Input_2 is MSF2] → [output1 is MSF_ 1]

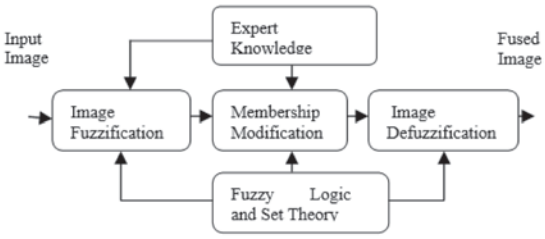

Figure 2: The general structure of the fuzzy image processing

5. Image Fusion using Neuro-Fuzzy Logic

Neuro-fuzzy logic can manipulate any kind of information and can also manage faulty information, resolve conflicts by coalition and aggregation. Neuro fuzzy logic has the capabilities like, self-insight, self-ordering and self-integration without the demand for previous education of underlying data relations. It is also expert in imitating human resolution making process and fast data processing using fuzzy number operations.

5.1 Adaptive Neuro-Fuzzy Inference System (ANFIS)

ANFIS approach implements a process for the fuzzy making scheme to attain knowledge about to image data set. The ANFIS function achieves membership function parameter adjustment.

5.2 Algorithm for Neuro-Fuzzy Based Image Fusion

The algorithm (dammavalam and Maddala, 2012) for reiterative image fusion process using neuro-fuzzy logic repeats the fusion method procedure iteratively, where the output fused image obtained from the previous step employed as one of the source input images to be fused from second iteration onwards. Fuzzy logic method is combined with neural networks to instrument the fusion process with neuro-fuzzy logic. Satellite image fusion approach using fuzzy logic and neuro-fuzzy logic techniques are compared, the results of the same are discussed in the previous work (Srinivasa et al., 2012).

6. Quality Evaluation Parameters for Image Fusion

In order to assess the quality of the output fused image obtained from the fusion process evaluation measures are utilized.

6.1 Image Quality Index (IQI)

Degree of similarity between any two images treated as image quality index. Maximum value for IQI indicated better fusion conclusion. IQI determined through (mumtaz and Masjid, 2008) equation 1.

$$IQI = \frac{m_{ab}\ 2xy\ 2m_a m_b}{m_a m_b x^2 + y^2 m_a^2 + m_b^2}$$

Equation 2

Where mean values of I_1, I_2 images are denoted by x and y and m_a^2, m_b^2 and m_{ab} indicates the variance of I_1, I_2 and covariance values of I_1 and I_2 respectively.

6.2 Mutual Information Measure (MIM)

The amount of information of one image contained in another image is known as mutual information measure. A greater value for MIM indicates better fusion process of the two source images and is determined through:

$$I_{MN} = \sum_{x,y} P_{MN}(x,y) \log \frac{P_{MN}(x,y)}{P_M(x) P_N(y)}$$

Equation 3

Where P_M (x) and P_N (y) denotes density functions of individual source images are and $P_{MN}(x, y)$ represents joint probability density function respectively.

6.3 Fusion Factor (FF)
A and B are two given input images and F denotes the fused image, the Fusion factor (FF) is computed as (Seetha et al., 2005).

$$FF = I_{AF} + I_{BF}$$

Equation 4

Where MIM values between each input image and fused image represented through I_{AF} and I_{BF} respectively.

6.4 Fusion Symmetry (FS)
The implication of degree of symmetry in the information satisfied from source and fused images is computed through fusion symmetry (FS):

$$FS = abs\left(\frac{I_{AF}}{I_{AF} + I_{BF}} - 0.5\right)$$

Equation 5

6.5 Fusion Index (FI)
The fusion index is computed as:

$$FI = I_{AF} / I_{BF}$$

Equation 6

Where I_{AF} indicates MIM between multispectral and fused image and I_{BF} indicates MIM between panchromatic and fused image. A greater value of fusion index indicates the better fusion process of the two source images.

6.6 Root Mean Square Error (RMSE)
Difference per image pixel by cause of the fusion process is measured by the root mean square error (RMSE). A lesser value for RMSE represents better fusion process of the two source images. RMSE is given by:

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(R(i,j) - F(i,j)\right)}$$

Equation 7

6.7 Peak Signal to Noise Ratio (PSNR)
A higher value of Peak signal to noise ratio represents better fusion results. MSE value indicates the mean square error and L denotes number of gray levels in the image.

$$PSNR = 20\log_{10}\left[\frac{L^2}{MSE}\right]$$

Equation 8

6.8 Entropy
The information content an image is measured through entropy and a greater value for entropy indicates improved fusion results. Entropy computed from:

$$E = -sum(p * \log_2(p))$$

Equation 9

Where fused image histogram counts obtained from imhist function indicated through p.

6.9 Spatial Frequency (SF)
The SF defined as count of cycles that fall inward one degree of visual angle [17]

$$SF = \sqrt{(RF)^2 + (CF)^2}$$

Equation 10

7. Results and Discussions
In this paper, satellite input images are iteratively fused using fuzzy logic and neuro fuzzy logic approaches. The fusion of multispectral and panchromatic images are fused and fusion results are also compared among PCA, wavelet and proposed techniques. The study have been carried out by using 3 sample images for example obtained from IRS 1D LISS III sensor (Ex.1, Ex.2 and Ex.3) over Hyderabad (Ex.1 and Ex.3), India and Ex. 2 satellite images are obtained from the Online Resource f-http://www.metapix.de/examples_r.htm. The proposed iterative image fusion using fuzzy logic and neuro fuzzy logic techniques are implemented through Matlab. The proposed method is scalable and may also be applied for various application domains like remote sensing applications, biometric applications, medical imaging and video surveillance. Membership functions and rules are determined for processing input images through fuzzy inference system (FIS) to implement image fusion using fuzzy logic. The assessment measures are employed to evaluate and compare the fusion results obtained from different methods. The value for each evaluation parameter for various fusion methods are depicted in Table 1.

Table 1: Evaluation indices for image fusion based on fuzzy, neuro fuzzy, iterative fuzzy, iterative neuro fuzzy logic, PCA and wavelet based fusion respectively

Method	IQI	MIM	FF	FS	FI	RMSE	PSNR	Entropy	SF
Fuzzy Fusion									
(Ex 1)	0.9758	0.4628	1.0965	0.0779	0.7303	44.8400	15.1306	7.9873	10.4567
(Ex 2)	0.9942	0.9582	2.1379	0.0518	0.8122	48.9935	14.3687	7.3129	16.9749
(Ex 3)	0.9491	1.4662	2.9949	0.0104	0.9591	37.2497	16.7423	7.1232	9.7307
Neuro Fuzzy Fusion									
(Ex 1)	0.9999	1.4656	2.8115	0.0213	1.0889	14.9554	24.6348	7.2757	25.5698
(Ex 2)	0.9829	1.5076	3.3427	0.0490	0.8215	34.4618	17.4180	7.3202	37.1225
(Ex 3)	0.9712	1.3084	3.6863	0.1451	0.5502	27.4634	19.3897	7.2678	16.7716
Iterative Fuzzy Fusion		0.5775							
(Ex 1)	0.9889	1.0613	1.5993	0.1389	0.5652	35.5359	17.1175	7.9873	9.2448
(Ex 2)	0.9808	0.7794	2.6136	0.0939	0.6837	48.0757	14.4923	7.3129	13.7455
(Ex 3)	0.9690		3.7627	0.2929	0.2613	35.6428	17.0914	7.2371	10.3945
Iterative Neuro Fuzzy Fusion									
(Ex 1)	0.9994	2.0385	3.1153	0.1544	1.8931	13.0681	25.8405	7.3442	34.9067
(Ex 2)	0.9978	1.7930	3.2733	0.0478	1.2112	11.8959	26.6568	7.3202	34.8753
(Ex 3)	0.9993	1.4218	3.3984	0.0816	0.7193	38.6540	16.4209	7.2678	28.1023
PCA based fusion									
(Ex 1)	0.9990	1.6640	2.8864	0.0765	1.3613	9.7165	28.3806	7.3521	25.9833
(Ex 2)	0.9976	1.6146	3.3085	0.0120	0.9532	18.440	22.8129	7.3129	32.4423
(Ex 3)	0.9839	1.4458	3.1947	0.0152	1.0626	19.3668	22.3896	7.3404	12.6803
Wavelet based fusion									
(Ex 1)	0.9997	1.4475	2.6247	0.0515	1.2296	12.5861	26.1330	7.3816	31.6700
(Ex 2)	0.9969	1.0722	2.1878	0.0099	0.9611	30.5298	18.4363	7.2948	34.9314
(Ex 3)	0.9842	1.4122	2.7832	0.0074	1.0301	19.0864	22.5163	7.3380	17.0501

The fusion results obtained from the fusion process emphasize that our proposed method, iterative image fusion approach using fuzzy logic and neuro fuzzy logic techniques improved the image content and quality to interpret easily when compared to the fused images obtained from wavelet and PCA based fusion methods. Image quality index (IQI) value is higher (0.9999) in Ex.1 in neuro fuzzy logic based image fusion technique compared to IQI values (0.9990 and 0.9997) from PCA based fusion and wavelet based fusion respectively. The IQI value (0.9978) obtained from iterative neuro fuzzy based fusion for Ex.2 is better compared to PCA and wavelet based fusion methods with IQI values (0.9976 and 0.9969). In Ex. 3, the IQI value (0.9993) is better value from iterative neuro fuzzy fusion compared to IQI values (0.9839 and 0.9842) PCA and wavelet based fusion techniques consequently. Better MIM values (2.0388, 1.7930 and 1.4662) are gained from iterative image fusion using neuro fuzzy logic and fuzzy logic correspondingly compared to PCA based image fusion values (1.6640, 1.6146 and 1.4458) for examples 1, 2 and 3 respectively. In Ex.1 the higher values of (3.1153, 3.3427 and 3.7627) fusion factor (FF) computed from the neuro fuzzy logic based iterative fusion, neuro fuzzy logic based image fusion and fuzzy logic based iterative fusion techniques consequently intimates that fused image comprises considerably valuable volume of image content; currently available in both the source images contrast to FF values (2.8864, 3.3085 and 3.1947) computed from image fusion using PCA technique. The iterative image fusion using fuzzy

logic and iterative neuro fuzzy logic produces improved amount for one more assessment parameter, peak signal to noise ratio in the 3 examples considered. The higher values for another evaluation measure like fusion index reveal that fusion results obtained from the proposed iterative image fusion using fuzzy and neuro fuzzy logic approaches are improved compared to PCA based and wavelet based fusion results. The values for Entropy (34.9067, 37.1225 and 28.1023) obtained from fusion process using neuro fuzzy logic and iterative image fusion based on fuzzy logic approach are improved contrast to (25.9833, 34.9313 and 17.050) values produced from PCA based fusion and image fusion using wavelet transform approach. The entropy value is good improvement for images obtained from the proposed method in 3 examples considered. Through greater values for one more assessment indices, spatial frequency that fusion result obtained from the neuro fuzzy logic retains more image content contrast to other fusion approaches. The quality of fused image is determined based on choosing of compatible membership functions and suitable fuzzy rules for the implementation of fusion process. Absolute membership values for input images consistently provides better fusion results. Therefore, it is completed that results generated from the proposed method iterative image fusion using fuzzy logic and neuro fuzzy logic approaches outperforms PCA and wavelet based fusion techniques respectively (Figures 3, 4, 5 and 6).

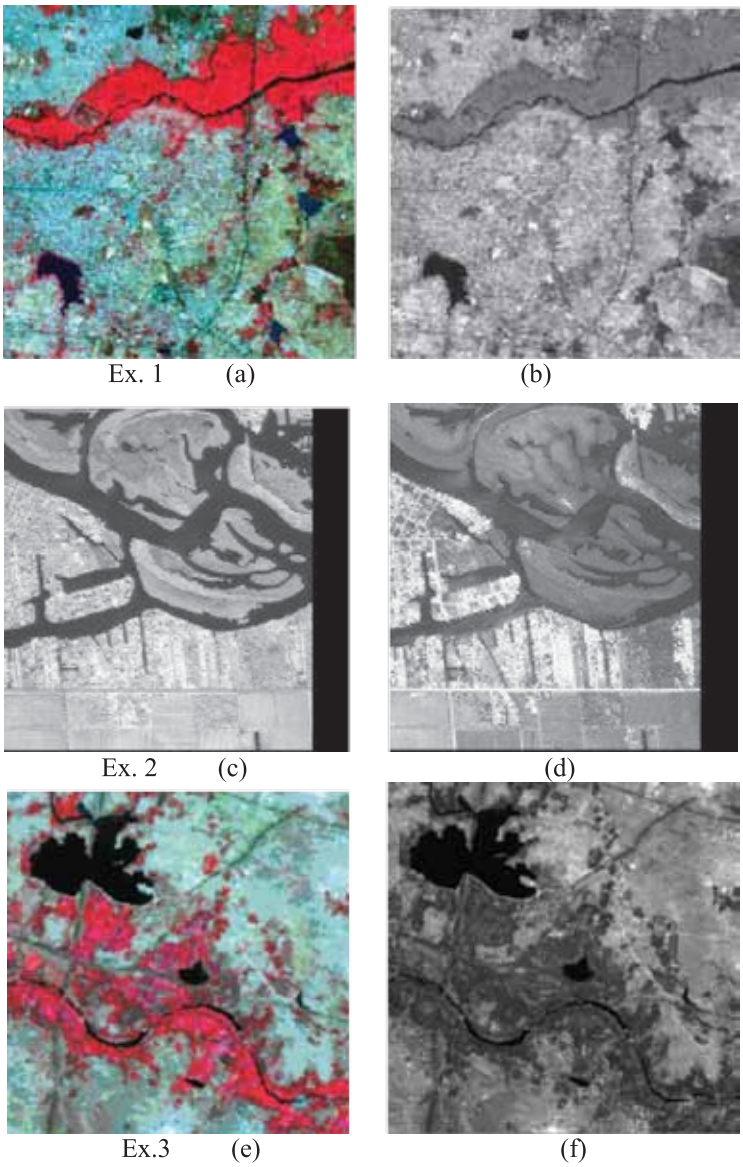

Figure 3: Original images: (a), (c), (e) are multispectral and (b), (d), (f) are panchromatic images

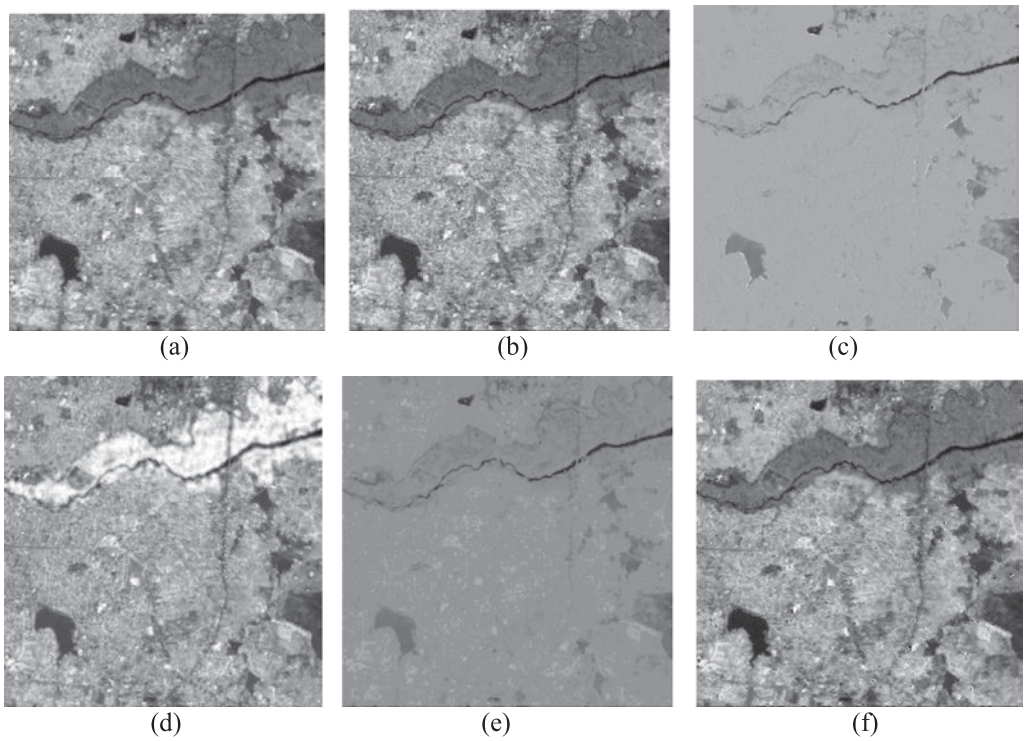

Figure 4: Fused images (a) PCA (b) wavelet (c) fuzzy based (d) neuro fuzzy bsed (e) iterative fusion based on fuzzy logic and (f) iterative fusion based on neuro fuzzy logic respectively

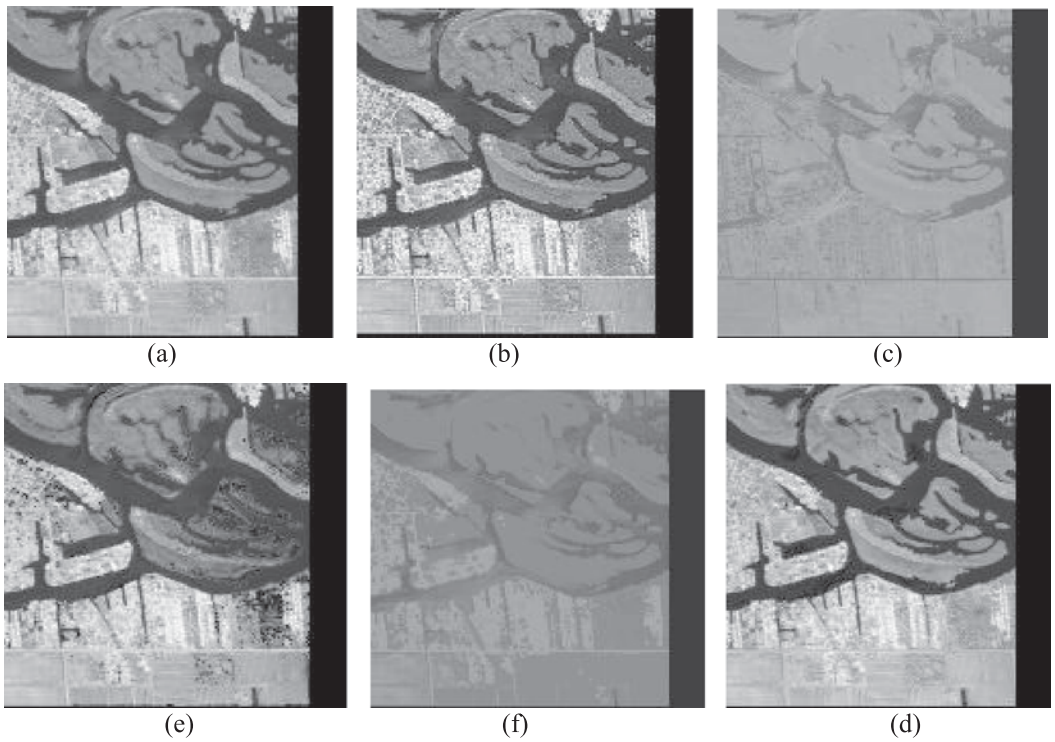

Figure 5: Fused images (a) PCA (b) wavelet (c) fuzzy based (d) neuro fuzzy bsed (e) iterative fusion based on fuzzy logic and (f) iterative fusion based on neuro fuzzy logic respectively

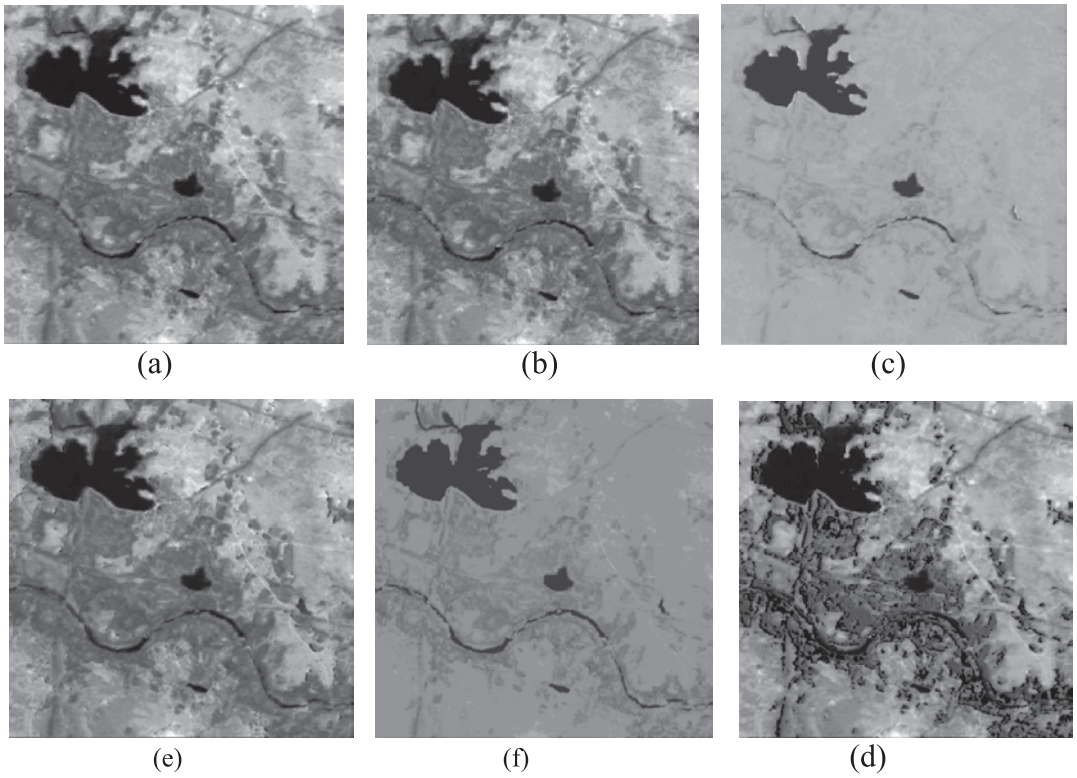

Figure 6: Fused images (a) PCA (b) wavelet (c) fuzzy based(d) neuro fuzzy bsed (e) iterative fusion based on fuzzy logic and (f) iterative fusion based on neuro fuzzy logic respectively

8. Conclusions

Image fusion is a method used to combine two or more images obtained from one or more sensors so as to generate the one fused image and improves image content than any of the input images. In this work, we propose a novel approach for iterative image fusion using fuzzy logic and neuro fuzzy logic techniques. We analyze the experimental results obtained from proposed approach with both the PCA and wavelet based image fusion approaches. In Fuzzy based image fusion technique, choosing absolute membership functions and suitable fuzzy rules plays major role to fuse the input images and hence obtain the fused image through fuzzy inference system. Image fusion using neuro fuzzy logic technique converges both artificial neural networks and fuzzy logic approaches to obtain fused image from the source images. In iterative image fusion approach, we repeat the fused approach, intended to improving the fused image content and to interpret easily, in which the fused image obtained from the previous fusion process is used as one of the two input images for second iteration onwards. We use the typical evaluation metrics for assessing the fused images obtained from different approaches. The output fused images obtained are then primarily used to view, observe and interpret by humans. These images are then processed by use of suitable image processing techniques. Fused images generated from the fusion techniques are used in diverse application areas such as image classification, image analysis, medical imaging, video surveillance, biometrics to name a few. All these domains are in need of images having improved content with spatial and spectral information as well. Fused images computed from iterative image fusion using fuzzy logic and neuro fuzzy logic techniques displayed improved results contrast to one time fusion process, wavelet based fusion and PCA based image fusion techniques in all assessment parameters.

Convergence of fuzzy and neural networks (neuro fuzzy) approaches gives better results compared to other methods (fuzzy, PCA and wavelet) in all cases considered here. This paper has showed that carefully determined fuzzy membership functions and fuzzy rules for fuzzy logic and neuro fuzzy logic based image fusion methods outperforms wavelet and PCA based fusion methods in all evaluation indices through preserving both spectral and spatial information as well. The potentiality of the fuzzy logic and neuro fuzzy logic based fusion method shows that fused results computed from the proposed method are evidently shows that the

iterative image fusion using fuzzy logic and neuro fuzzy logic offers further improvement on the quality of the fused image besides preserving more spatial and spectral information. Proposed method improves the image information. Full extension of the class of fuzzy and neuro fusion process did converted into identical adaptive networks. Neuro-fuzzy based system could recognize variables by using supervised learning methods. ANFIS would be used for edifice the intelligent fusion process that is, process that could think logically with simple fuzzy inference and that are able to learn from experience in the fuzzy logic and ANN based approaches. It is anticipated that the proposed iterative image fusion using fuzzy and neuro fuzzy logic can be applied further for image classification, image analysis, video image processing and fusion of color images taken from multiple sensors and to incorporate accurate assessment indices for image fusion.

References

Anjali, A. P, Neelesh. G. and Meha, S., 2013, New Image Fusion Method based on Integration of Wavelet and Fast Discrete Curvelet Transform, *International Journal of Computer Applications*, Vol. 69, No. 18, 31-34.

Balasubramaniam, P. and Ananthi, V. P., 2014, Image Fusion using Intuitionistic Fuzzy Sets, *Journal on Information Fusion*, Vol. 20, 21-30.

Christinal, J. J. and Jebaseeli, J. T., 2013, A Novel Color Image Fusion for Multi Sensor Night Vision Images, *International Journal of Computer Applications Technology and Research*, Vol. 2, 155-159.

Dammavalam, S. R., Maddala, S., KrishnaPrasad, M. H. M., 2012, Quality Assessment of Pixel-Level Image Fusion using Fuzzy Logic, *International Journal on Soft Computing*, Vol. 3, No.1, 13-25.

Godse, D. L. A. and Bormane, D. S., 2011, Wavelet Based Image Fusion using Pixel Based Maximum Selection Rule, *International Journal of Engineering Science and Technology*, Vol. 3, No. 7, 5572-5577.

Mary, P. S., 2009, Multiresolution Optimization of Image Fusion, *National Conference on Recent Trends in Communication and Signal Processing*, 111-118.

Maruthi, R. and Sankarasubramanian, K., 2008, Pixel Level Multifocus Image Fusion Based on Fuzzy Logic Approach. *Journal Information Technology*, Vol. 7, No. 4, 168-171.

Min, X., Hao, C. and Pramod, K. V., 2011, An Image Fusion Approach Based on Markov Random Fields, Vol. 49 , No. 12, 5116-5127

Mitra, R. A., 2014, A Comparative Analysis of Wavelet Transform and PCA Image Fusion Techniques, International Journal of Engineering Development and Research, Vol. 2, 2437-2442.

Mohammad, B., Akbari, H., Ali, A. and Hadi, S., 2011, Multi-Focus Image Fusion for Visual Sensor Networks in DCT Domain, *Journal on Computers and Electrical Engineering*, Vol. 37, 789-797.

Mumtaz, A. and Masjid, A., 2008, Genetic Algorithms and its Applications to Image Fusion, *IEEE International Conference on Emerging Technologies*, 6–10.

Naidu, V. P. S. and Rao, J. R., 2008, Pixel-level Image Fusion using Wavelets and Principal Component Analysis, *Defense Science Journal*, Vol. 58, No. 3, 338-352.

Peiguang, W., Hua, T. and Wei, Z., 2013, A Novel Image Fusion Method Based on FRFT-NSCT, *Journal on Mathematical Problems in Engineering*, 1-9.

Qiwei, X., Qian, L., Seiichi, M, Chunzhao, G. and An, J., 2014, Image Fusion Based on Multi-Objective Optimization, International Journal of Wavelets, Multiresolution and Information Processing, Vol. 12, No.2.

Quadric, S. A. and Othman, S., 2013, Pixel-Level Image Fusion using Kaman Algorithm, *International Journal of Signal Processing, Image Processing and Pattern Recognition*, Vol. 6, No. 2, 75 – 86.

Ramesh, R., Adrian, I. and Jingyi, Y., 2004, Image Fusion for Context Enhancement and Video Surrealism, *Proceedings of the 3rd International Symposium on Non-Photorealistic Animation and Rendering, Mitsubishi Electric Research Laboratories*, 85-152.

Rajiv, S. and Ashish, K., 2013, Multiscale Medical Image Fusion in Wavelet Domain, *The Scientific World Journal*, 1-10.

Raghavendra, R. and Christoph, B., 2014, Novel Image Fusion Scheme Based on Dependency Measure for Robust Multispectral Palmprint Recognition, *Journal onPattern Recognition*, Vol. 47, 2205-2221.

Sharma, J. B., Sharma, K. K. and Vineet, S., 2014, Hybrid Image Fusion Scheme using Self-Fractional Fourier Functions and Multivariate Empirical Mode Decomposition, *Journal on Signal Processing*, Vol. 100, 146-159.

Shutao, Li. and Bin, Y., 2008, Multifocus Image Fusion by Combining Curvelet and Wavelet Transform, Pattern Recognition Letters, Vol. 29, No. 9, 1295-1301.

Srinivasa Rao. D, Seetha, M. and Krishna Prasad, M. H. M., 2012, Comparison of Fuzzy and Neuro Fuzzy Image Fusion Techniques and its Applications, *International Journal of Computer Applications*, Vol. 43, No. 20, 31-37.

Xie, Q., Long, Q., Mita, S., Guo, C. and Jiang, A., 2014, Image Fusion Based On Multi-Objective Optimization, *International Journal of Wavelets, Multiresolution and Information Processing*, Vol.12.

Xin, Z., Wei, W. and Rui-an, L., 2014, Compressive Sensing Image Fusion Algorithm Based on direction lets, *EURASIP Journal on Wireless Communications and Networking*, 1-6.

Yang, Y., Zheng, W. and Huang, S., 2014, Effective Multifocus Image Fusion Based on HVS and BP Neural Network, *The Scientific World Journal.*

Seetha, M., MuraliKrishna, I. V. and Deekshatulu, B. L., 2005, Data Fusion Performance Analysis Based on Conventional and Wavelet Transform Techniques, *IEEE Proceedings on Geoscience and Remote Sensing Symposium*, Vol. 4, 2842-2845.

The Online Resource for Research in Image Fusion, http://www.metapix.de/examples_r.ht

Yong, Y., Shuying, H., Junfeng, G. and Qian, Z., 2014, Multi-focus Image Fusion using an Effective Discrete Wavelet Transform Based Algorithm, Measurement Science Review, Volume. 14, No. 2.

Zhou, X., Wang, W. and Liu, R., 2014, Compressive Sensing Image Fusion Algorithm Based on Direction Lets, *EURASIP Journal on Wireless Communications and Networkin*g, Vol. 19.