



# Performance Evaluation of Fuzzy and Neuro Fuzzy Based Image Fusion

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**ABSTRACT:** Image fusion to decrease vagueness and severance despite the fact that mining all the advantageous evidence from the input images. Image fusion method is essential for various uses, remote sensing, medical imaging, image analysis, image classification, machine vision, robot navigation, biometrics and military applications. In this paper, neuro fuzzy logic methodology exploited to fuse images from dissimilar sensors, in order to improve conception and perception. The proposed algorithm additionally discovers assessment among Principal Component Analysis (PCA), wavelet transform and fuzzy, neuro fuzzy based image techniques along through quality assessment metrics for image fusion like image quality index (IQI), mutual information measure (MIM), fusion factor (FF), fusion symmetry (FS), fusion index (FI), root mean square error (RMSE), peak signal to noise ratio (PSNR), entropy, correlation coefficient (CC) and spatial frequency (SF). Experimental outcomes acquired from projected technique demonstrate that the utilization of neuro fuzzy fusion can powerfully reserve the spectral information and the spatial resolution as well.

**KEYWORDS:** Fuzzy logic, neuro fuzzy logic, fuzzy rules, membership functions, PCA and wavelet transform.

## I. INTRODUCTION

Image fusion [1] utilizing the convergence of wavelet transform and adaptive neuro fuzzy logic is employed. The outcomes are likened with the pixel based image fusion in spatial domain with fuzzy and neuro fuzzy logic methodology besides with the quality assessment indices for image fusion likes entropy, Root Mean Square Error, Peak Signal to Noise Ratio and Correlation Coefficient. Investigational outcomes demonstrate that the proposed procedure is superior to the further fusion approaches. Image fusion [2] is essential for proficient diseases diagnosis from multimodality, multidimensional and multi parameter category of images. Despite the fact of fusing multimodality images which derives information loss, incorrect edges, dark spots in tissue part and spatial distortion problem. To report these problems, a Neuro-Fuzzy logic grounded image fusion algorithm has been suggested. Later the output fused image is endorsed by utilizing the computable measures such as mean and standard deviation etc. Proposed [3] an approach for image fusion established on Wavelet Transform method and Fuzzy Logic approach to progress the geometric perseverance of the input images. In this proposed algorithm, input images will be processed, then disintegrated into sub-images and then the fusion technique is accomplished consuming these images underneath the convinced standards such as Wavelet Transform method and precise image fusion rules, and lastly these sub-images are administered under Fuzzy Logic approach and reassembled into the subsequent output fused image with bountiful information

## II. RELATED WORK

Images from [4] diverse modalities such as CT, MRI imaging of same organ are deliberated for the reason that of their key fright in diagnostic determination. While obtaining the input images from various imaging arrangements the images will be exaggerated by noise. Hereafter pre-processing procedure has been conceded out spending Wavelet



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transform method trailed by Curvelet transform approach. Beforehand fusing an image, the input images have to be associated appropriately of the same size such that the difficult of misregistration has been evaded. The output fused image is attained by means of Neuro fuzzy approach. The irregularities existing in output fused image are categorized with Support vector machine. Enactment of image fusion is quantitatively assessed using Peak signal to Noise Ratio, Mean Squared Error and Entropy. Fuzzy and Neuro-Fuzzy approaches [5] are utilized for image fusion process. Projected algorithm at this point auxiliary discovers the image fusion procedure in iterative approach expending Fuzzy and Neuro Fuzzy methodology. Projected method precisely valuable in remote sensing, medical imaging and additional domains, wherever quality of image is further significant than the real time application. The work is supplemented by algorithms, its simulation and qualitative analysis using Entropy. An image fusion technique [6] for fusing CT and MRI expending fuzzy logic approach is proposed. The bone tissue from CT image and the soft tissue from MRI image is segmented spending Otsu's segmentation approach. Later input images fused expending Fuzzy Logic and Discrete Wavelet Transform approaches. Experimentations are shown for both Mamdani type Fuzzy Logic System and Sugeno type FLS with varying number of membership functions. The outcomes are investigated consuming numerous performance metrics. Sugeno FLS has formed better results compared to Mamdani FLS. Reviewed different [7] applications, technologies, prototypes and performance when implemented sensor fusion by compelling into contemplation. The methods that is to say wavelet based fusion techniques, fuzzy logic approach, artificial neural network image fusion along with united methods to be exact multi-sensor data fusion from side to side efficient former assessment of collected works. An innovative [8] methodology to the multisensor, multimodal medical image fusion (MIF) problem, engaging multiscale formal investigation of non-subsampled contourlet transform approach and fuzzy-adaptive reduced pulse-coupled neural network (RPCNN) method. The connecting assets of the RPCNNs' neurons are adaptively set by demonstrating them as the fuzzy membership values, signifying their importance in the conforming input image. Usage of RPCNN with less complex configuration and obligating fewer number of factors, leads to computational proficiency, an significant necessity of point-of-care (POC) health maintenance equipment. The projected outline is unrestricted from the communal limitations of the up-to-date MIF procedures: contrast reduction, loss of image reasonable particulars and undesirable image deprivations etc. Particular and impartial assessments indicate improved enactment of this novel method equated to standing methods. Image fusion [9] is actual widespread subject currently for investigators so it is extensively castoff by many investigators. Image fusion is utilized in many submissions like remote sensing, medical imaging etc. As CT and MRI are additional precisely images which can give more suitable facts and this pattern is progressively used. More exhaustive evidence can be attained from a united image than institute in a single input image. Requirement of storage also lessening as it produce and keeps single fused image as a substitute of saving two dissimilar types of images. To deliver feature that is unseen to human discrimination. Upsurges robustness and increases exactness in biomedical examinations and clinical diagnosis.

### III. FUZZY BASED IMAGE FUSION

#### A. FUZZY LOGIC:

The reputation of fuzzy logic originates from the statement that most methods of human intelligent and exclusively collective wisdom perception are estimated in environment. Fuzzy logic based image fusion proposed and generated results outperform wavelet transform and Genetic Algorithm (GA) [12].

#### B. FUZZY SETS

Fuzzy set [10] is categorized by a association function which allocates to each entity a mark of membership oscillating between zero and one. It was familiarized as a mean to perfect the ambiguity and uncertainty in composite systems. The idea of fuzzy sets is humble and normal.

#### C. MEMBERSHIP FUNCTIONS

The membership or association function is a graphical illustration of the amount of contribution of each involvement in the input universe. Input space is regularly discussed as the universe of discourse or universal set, which comprise all the probable essentials of concern in each specific solicitation [11]. It acquaintances and allowance with to each of the

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participations that are held, define functional overlap between contributions, and eventually regulates a productivity response.

Membership functions and rules castoff in the projected technique

1. if (input1 is mf1) and (input2 is mf2) then (output1 is mf1)
2. if (input1 is mf2) and (input2 is mf2) then (output1 is mf2)
3. if (input1 is mf2) and (input2 is mf2) then (output1 is mf2)
4. if (input1 is mf3) or (input2 is mf2) then (output1 is mf3)
5. if (input1 is mf1) and (input2 is mf3) then (output1 is mf1)
6. if (input1 is mf3) or (input2 is mf3) then (output1 is mf2)

## D. FUZZY RULES

Human beings make conclusions grounded on fuzzy rules. Fuzzy machines, which always tend to mimic the performance of man, effort the similar way. Though, the conclusion and the means of indicating that conclusion are interchanged by fuzzy sets and the rules are replaced by fuzzy rules. Fuzzy rules also activate by means of a succession of if-then declarations. For occurrence, if X then A, if Y then B, where A and B are all sets of X and Y. Fuzzy rules refer to fuzzy patches, which is the main knowledge in fuzzy logic approach.

## E. FUZZY LOGIC BASED IMAGE FUSION

The source images in the gray level plane is imperiled to fuzzification and the alteration of membership functions is approved out in the membership plane. The outcome is the fused image attained next to the defuzzification.

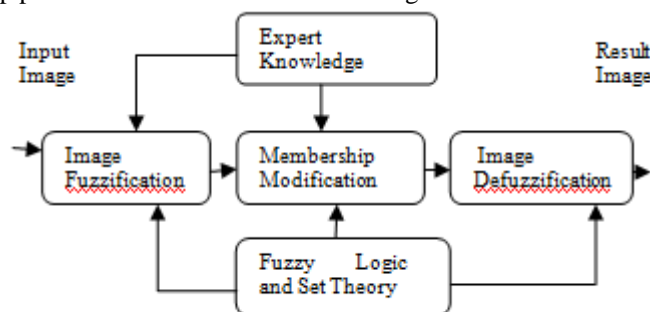


Fig. 1 The over-all organization of the fuzzy image processing

The procedure for image fusion using fuzzy logic

- a) Get first image in variable I1 and find its size (rows: r1, columns: c1).
- b) Get second image in variable I2 and find its size (rows: r2, columns: c2).
- c) Variables I1 and I2 are images in matrix form where each pixel gray level value is in the range from 0 to 255.
- d) Relate rows and columns of both input images. If these two images are not of the same size, choice the portion, which are of same size.
- e) Convert the images in column form which has  $C = r1 \times c1$  entries.
- f) Make a fuzzy inference system file, which has two input images.
- g) Resolve number and type of membership functions for mutually the input images by tuning the membership functions.
- h) Input images in antecedent are determined to a degree of membership ranging 0 to 255.
- i) Create fuzzy if-then rules for input images, which resolve those two antecedents to a single number from 0 to 255.
- j) For num = 1 to C in steps of 1, apply fuzzification using the rules developed above on the corresponding pixel gray level values of the input images, which gives fuzzy sets represented by membership functions and results in output image in column format.

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- k) Convert the column form to matrix form and display the fused image.

## IV. NEURO FUZZY BASED IMAGE FUSION

Neuro-Fuzzy hybridization results in a hybrid intelligent system that synergizes combining fuzzy systems with the learning and connectionist structure of neural networks. The fused images obtained from neuro-fuzzy logic reserves more texture features and also improves the information features of two original images.

The procedure for pixel-level image fusion expending neuro fuzzy logic is specified as trails.

- Get first image in variable I1 and find its size (rows:z1, columns: s1).
- Get second image in variable I2 and find its size (rows:z2, columns: s2).
- Variables I1 and I2 are images in matrix form where each pixel value is in the range from 0-255. Use Gray Colormap.
- Relate rows and columns of both input images. If the two images are not of the same size, choice the portion. Which are of same size.
- Translate the images in column form which has  $C = z1*s1$  entries.
- Form a training data, which is a matrix with three columns and entries in each column are form 0 to 255 insteps of 1.
- Practice a check data. Which is amatrix of Pixels of two input images in column format.
- Resolve number and type of membership functions for mutually the input images by fine-tuning the membership functions.
- For training FIS structure is used, which is produced by genfis1 command with training data, number of membership functions and type of membership functions as input.
- To start training, anfis command is used which inputs produced FIS structure and training data and returns trained data.
- For num=1 to C in steps of one, apply fuzzification using the generated FIS structure with Check data and trained data as inputs which returns output image in column format.
- Convert the column form to matrix form and display the fused image

## V. RESULTS AND DISCUSSIONS

In this paper, input images are fused using fuzzy and neuro fuzzy logic approaches and compared with PCA and wavelet transform techniques. In Fig 1, Ex. 1, Ex. 2 and Ex.3 Multispectral (MS) and Panchromatic (PAN) images are of the Hyderabad city, AP, INDIA are acquired from the IRS 1D LISS III sensor at 05:40:44.

The proposed fuzzy and neuro fuzzy logic based image fusion is implemented in Matlab 10.0. In order to assess the fusion outcomes gained from various approaches, the valuation parameters are engaged. The worth of each eminence valuation factors of all declared fusion methods are shown in Table 1. Our investigational outcomes displays that the fuzzy and neuro fuzzy logic based image fusion methods delivers improved eminence related to other techniques. So it is determined that outcomes gained from the execution of fuzzy logic based image fusion method accomplishes improved in few measures and neuro-fuzzy based image fusion accomplishes improved in other indices through distinctive valuation parameters.

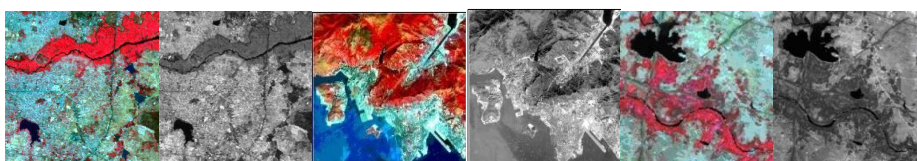


Fig.2 Ex. 1(a) MS (b) PAN Ex.2 (a) MS (b) PAN Ex.3 (c) MS (b) PAN images

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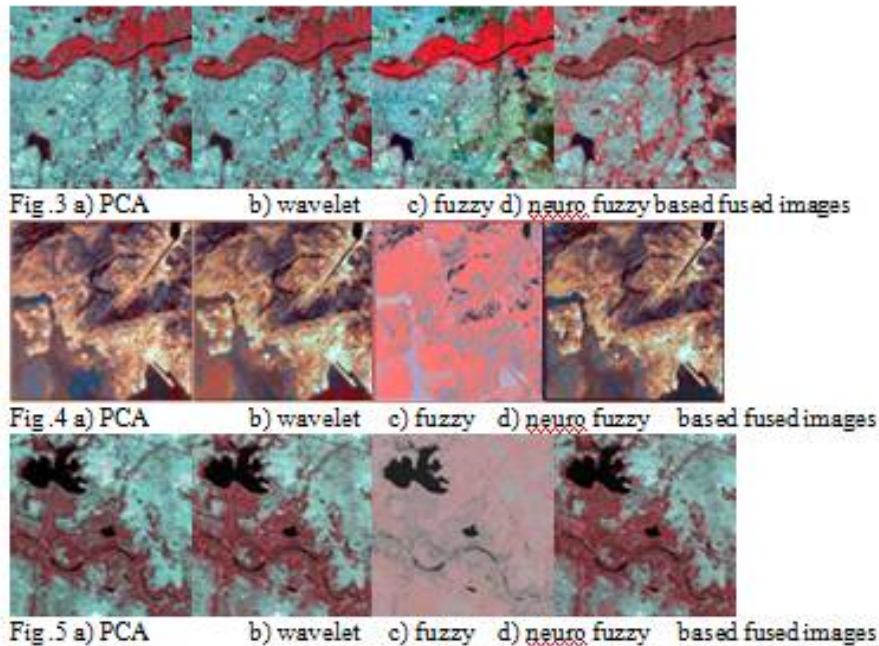


Table 1. Evaluation indices for image fusion based on fuzzy, neuro fuzzy, PCA and wavelet transform fusion techniques

Method	IQI	MIM	FF	FS	FI	RMSE	PSNR	Entropy	CC	SF
Fuzzy Fusion										
(Ex 1)	0.9890	0.5776	1.5994	0.1388	0.5653	35.5378	17.1355	7.9874	9.2449	0.9890
(Ex 2)	0.9809	1.0614	2.6137	0.0938	0.6838	48.0793	14.5423	7.3130	13.7456	0.9809
(Ex 3)	0.9691	0.7795	3.7628	0.2928	0.2614	35.6489	17.1764	7.2372	10.3946	0.9691
Neuro Fuzzy Fusion										
(Ex 1)	0.9995	2.0386	3.1154	0.1543	1.8932	13.0792	25.8975	7.3443	34.9068	0.9995
(Ex 2)	0.9979	1.7931	3.2734	0.0477	1.2113	11.9300	26.7453	7.3203	34.8754	0.9979
(Ex 3)	0.9994	1.4219	3.3985	0.0815	0.7194	38.7394	16.5467	7.2679	28.1024	0.9994
PCA based fusion										
(Ex 1)	0.9991	1.6641	2.8865	0.0764	1.3614	9.7893	28.5643	7.3522	0.8422	25.9834
(Ex 2)	0.9977	1.6147	3.3086	0.0119	0.9533	18.6332	22.9322	7.3130	0.8211	32.4424
(Ex 3)	0.9840	1.4459	3.1948	0.0151	1.0627	19.5621	22.5432	7.3405	0.7964	12.6804
Wavelet Transform based fusion										
(Ex 1)	0.9998	1.4476	2.6248	0.0514	1.2297	12.6311	26.2345	7.3817	0.9121	31.6701
(Ex 2)	0.9970	1.0723	2.1879	0.0098	0.9612	30.6754	18.5643	7.2949	0.8843	34.9315
(Ex 3)	0.9843	1.4123	2.7833	0.0073	1.0302	19.1644	22.6442	7.3381	0.8742	17.0502



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## VI. CONCLUSIONS AND FUTURE WORK

There are a great amount of solicitations, remote sensing, medical imaging and video surveillance etc. entails images with both spatial and spectral determination as thriving. In this paper, the capabilities of image fusion using fuzzy and neuro-fuzzy methods have been discovered along with eminence assessment indices. It is expected that the method can be additional protracted to image classification, imageanalysis video image processing and for fusion of multiple sensor images and to participate effective assessment procedures of image fusion.

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