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Image Fusion Technique Based on Hybrid Whale Optimization Algorithm Simulated Annealing (*h*WOA-SA)

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Abstract*: Curvelet transform is a multiscale directional transformer, which allows optimal non-adaptive sparse representation of object with edge. In this paper, a new image fusion technique has been developed by combination of whale optimization algorithm (WOA) and simulated annealing (SA) along with curvelet transform. The resulting combined algorithm is abbreviated as hybrid whale optimization algorithm with simulated annealing. Initially, hWOA-SA has been applied to enhancing the quality of image using de-noising scheme. Afterwards, the curvelet transform has been employed to carry out the fusion of images. In terms of PSNR, the curvelet transform exhibits the better performance. The effectiveness and validation of the proposed scheme has been carried-out using quality matrices. The performance analysis is carried out after checking the effectiveness of proposed approach by evaluating the various parameters such as: RSME, PFE, MAE, CORR, SNR, PSNR, MI, UQI and SSIM and compared with numerous techniques. Simulation results obtained from proposed hWOA-SA based image fusion are very competitive and better than other image fusion technique available in the literature.

***Index Terms*: Curvelet transform, Hybrid whale optimization algorithm simulated annealing (hWOA-SA). PSNR, RMSE, Saras type image.**

I. INTRODUCTION

In current scenario, image fusion is the practice of combining the most relevant information from multiple source images or multi-focus images to achieve an accurate and detailed fused image [1-5]. The fused image is designed to increase the image content, which makes further image processing simple and reduces computation. The fused image comprises richer and more accurate information content, which is advantageous in its analysis and processing. Image fusion is a vital element in the advancement of intelligent systems applications. The prosperous application of image fusion can lead to upgrade performance of military surveillance [20], medical imaging [5], face recognition [21] and remote sensing applications [22].Basic unit starts with pixel level fusion where fusion process does not transform image but use pixels for fusion process.

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These methods can be classified into two group viz. transform domain-based(TD) and spatial domain-based(SD) methods. The fused result are designed in SD based schemes directly by choosing the pixels, blocks or regions from the selected regions of the true images.Spatial bending can be extremely very much taken care of by recurrence space approaches on image fusion. In transform domain based the Fourier Transform of the picture is enlisted first and then all the combination operations are performed on the Fourier change of the picture and after that the Inverse Fourier change is performed to get the resultant picture. These operations are performed remembering the ultimate objective to adjust the picture shine, differentiate or the conveyance of the dull levels

II. LITERATURE REVIEW

The various emerging techniques of image fusion is presented by various researcher all over the world such as: DWT [6, 7], Dual Tree Complex WT (DTCWT) [8], Contourlet Transform (CT) [9], the Discrete Cosine Transform (DCT) [10,11] Laplacian Pyramid [11,12], Set Partitioning In Hierarchical Tree (SPIHT) discussed [13, 14], Optimal Curvelet Transform [15] and Modified Curvelet Transform in [16]. The literature shows that the optimal curvelet transform is better than other existing fusion techniques.

A wide range of wavelet-based tool and ideas have been proposed and studied. In this regard, initial efforts lead a very simple idea like thresholding of the orthogonal wavelet coefficient of the noisy data, followed by reconstruction. Later, the method called as translation of invariant which is based on threshold of an undecimate WT give the improvement in perceptual quality. The tree based wavelet de-noising methods invented recently have been developed in the context of image de-nosing, which exploited the tree structure of wavelet coefficient of image with edges. The various optimization techniques based on image fusion are elaborated in literature [3, 4, 6, 7, 14-17, 19, 23]. The PSO based thermal image fusion with DTCWT has been presented in [7]. This scheme provides better results as compared to existing schemes. The PSO algorithm is requires more initialization of parameters and it is a time consuming algorithm. The whale optimization algorithm (WOA)which is inspired by bubble flocking behaviour of whales has been discussed in [18].

This algorithm is better as comparing with existing optimization algorithm since it requires the less number of parameters at initial phase as well as less number of iterations. A noval hybrid technique may be developed by hybridizing WOA and simulated annealing (SA) due to their dominating properties which may exhibit better results as compared the exploitation phase of the WOA. In [24] WOA-BAT has been tested in which it has delivered fewer iteration as compared to individual BAT & WOA. In this paper, a new hWOA-SA has been applied in image fusion along with the curvelet transform and the validation of the presented scheme has been obtained in terms of quality matrices. The simulation results demonstrate that the proposed approach is far better than some other image fusion techniques available in the literature.The organization of this paper is as follow: Section III describes the basics of optimal curve-let transform and *h*WOA-SA and section IV present the proposed hWOA-SA image fusion technique. The simulation result have been discussed in section V. The conclusions are given in section VI followed by references and Authors Biography.

III. OVERVIEW OF OPTIMAL CURVELET TRANSFORM AND WHALE OPTIMIZATION ALGORITHM WITH SIMULATED ANNEALING

A. Optimal Curvelet Transform

The curvelet transform play an important role in applird mathematics and signal processing over the years. The image fusion method based on Curvelet transform gives more information in the spatial and spectral domains simultaneously. Curvelet transform is powerful at spotting image activity along with curves.

Discrete CT has been applied in this paper which uses Unequally Spaced Fast Fourier Transform" algorithm [USFFT] due to its easier, rapid and less redundant characteristics [14, 16]. Discrete CT employs a decimated rectangular grid. More information including mathematical expressions has been found in [14, 16]

B. Whale Optimization Algorithm and Simulated Annealing

By the inspiration of the hunting strategy of humpback whales, Mirjalili et al. has developed WOA. The overall operation of WOA is completed in three steps which are: encircling prey, bubble net attacking, and searching for prey. This section is presented mathematical formulation of modified whale optimization algorithm [23]. The detailed information about the WOA covering operation , mathematical modelling of WOA, validation with different examples, advantages and disadvantages can be found in [23].

C. Simulated Annealing (SA)

Simulated annealing is a metaheuristic approach based upon probabilistic method and it is used for approximating the global optimum of a given function by offering a large search space in optimization problem. In this paper, SA is combined with WOA resulting a new hybrid algorithm known as *h*WOA-SA for enhancing the exploitation phase and overcoming the in local optima stagnation.

IV. *h*WOA-SA BASED IMAGE FUSION TECHNIQUE

*h*WOA-SA based image fusion technique has been elaborated to remove the weakness of some algorithms available in the literature.

The Fig. 1 shows the hWOA-SA based Image Fusion Technique in which two fuzzy type images have been taken in to account for fusion. For the enhancement of these images, we have applied optimal curvelet transform on both the fuzzy type image using de-noising based on WOA-SA. The average fusion algorithm is used for fusion. After fusion, the fused image has been compared with true image to check effectiveness of hWOA-SA based image fusion scheme. The PSNR, RMSE and other parameters are computed to check effectiveness of system shown below.

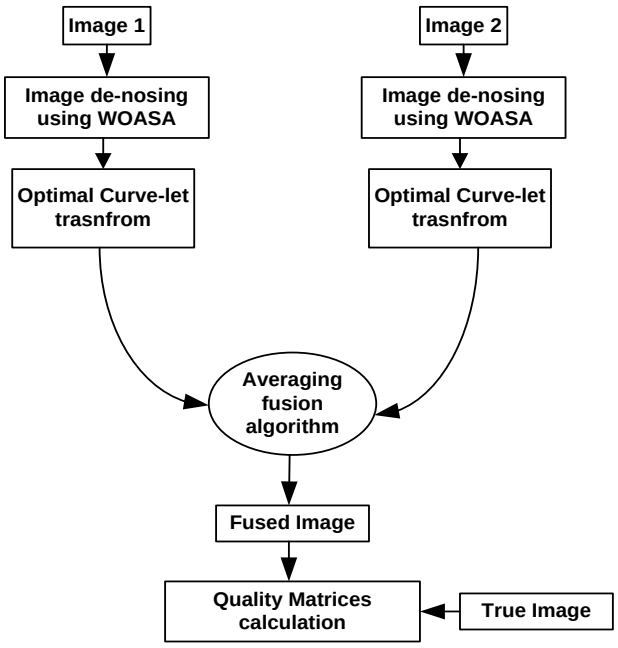

Fig.1. Proposed Image Fusion Technique using *h*WOA-SA

In *h*WOA-SA technique, the SA has been integrated with WOA for developing the hybridized model such as Low-Level team work Hybrid (LTH). In LTH, SA performs search for the best solution in the neighbor of both the randomly selected solution and the neighbor of the best known solution and replace the original one. The algorithm of complete fusion process is divided into two stages as follows:

Stage 1:

Image de-noising:
Initialization of WOASA parameters:
Search agents: 10
Maximum iteration: 10
Variable dimension: 6
Objective function:
MATLAB Code:

```
function p=vandana(x)
img=imresize(im2double((imread('saras9t.jpg'))),[256
256]);
imn = imnoise(img,'salt & pepper',0.05);
```

```
x(5)=round(x(5));
x(6)=round(x(6));
if x(5) == 1
string = 'sym4';
elseif x(5) == 2
    string = 'db4';
elseif x(5) == 3
   string = 'sym6';
elseif x(5) == 4
   string = 'db6';
elseif x(5) == 5
   string = 'coif4';
elseif x(5) == 6
   string = 'db8';
elseif x(5) == 7
   string = 'sym10';
elseif x(5) == 8
   string = 'coif2';
elseif x(5) == 9
   string = 'sym8';
end;
TH = [x(1) x(2) x(3) x(4)];
THR = repmat(TH(1:x(6)),3,1);
dn = wdencmp('lvd',imn,string,x(6),THR,'s');
p = psnr(img,dn)
end
```

Stage 2:

```
Image fusion algorithm:
Im1=curvelet (image1)
Im1'=Icurvelet (Im1)
Id1=Im1-Im1'
Im2=curvelet (image2)
Im2'=Icurvelet (Im2)
Id2=Im2-Im2'
Idf=abs(Id1)-abs(Id2)>=0;
Ima=(Im1+Im2)/2
Imf=Ima+Idf
Im=Icurvelet (Imf)
```

V.SIMULATION RESULTS AND PERFORMANCE ANALYSIS

The two images which are to be fused have been produced from the reference image as shown in Fig. 3 and Fig. 4. The fused image shown in Fig.5 is nearly identical to true/ reference image

Fig. 2 Reference saras type image [16]

Fig. 3 Saras type image 1

Fig.4 Saras image 2

Fig.5 Saras Image After Applying Fusion Process Algorithm

The *h*WOA-SA has been established and compared with the common image transform techniques. Performance analysis is carried out using MATLAB for various parameters such as. RMSE, PFE, MAE, CORR, SNR, PSNR, MI, UQI and SSIM for different techniques. Simulation results of *h*WOA-SA based image fusion are far better in terms aforesaid performance parameters while comparing with some other approaches available in literature. The results of comparison are given in Table-1 and described below .

A. Comparison for RSME

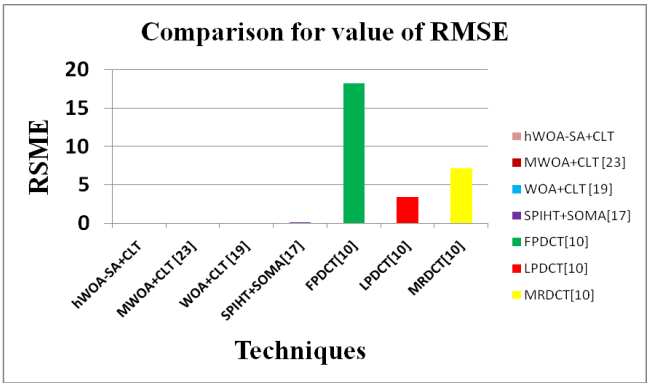

Fig. 6 Comparison the RMSE value for different techniques.

Root mean square error (RMSE) values for different image fusion techniques have been shown in fig.6. It is observed that *h*WOA-SA technique provides RMSE value as 0.0005986 which is very less as compared to other existing techniques.

B. Comparison for SNR

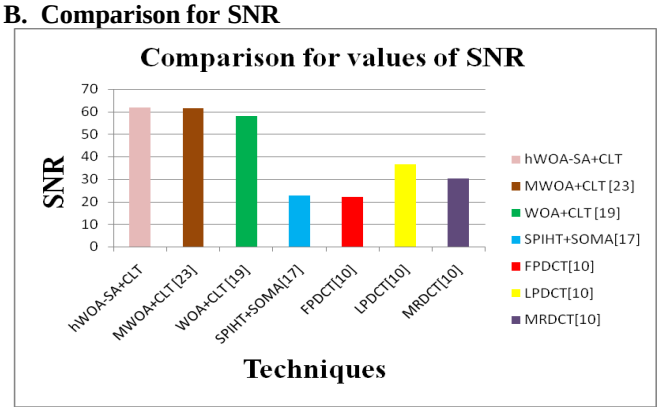

Fig.7 Comparison the SNR value for different techniques.

The Fig.7 shows comparison SNR values for different image fusion approaches available in the literature. It is observed that *h*WOA-SA is having improved value of SNR that is 61.9334 as compared to other technique.

C. Comparison for PSNR

The Fig. 8 shows the peak SNR (PSNR) value for different image fusion techniques. It is observed that PSNR is highest value of 80.4223 for *h*WOA-SA as compare to other techniques

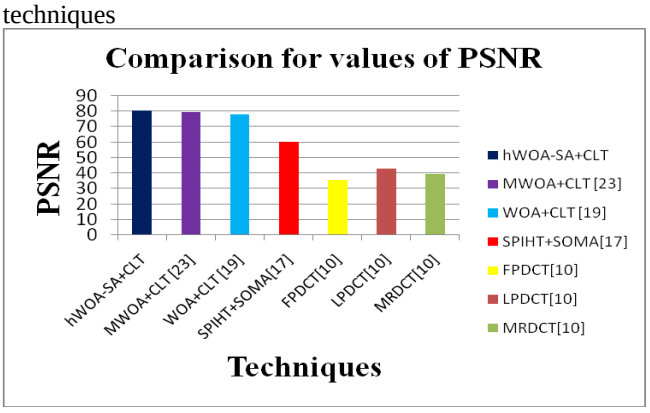

Fig. 8 Comparison the PSNR value of different techniques.

D. Comparison for PFE

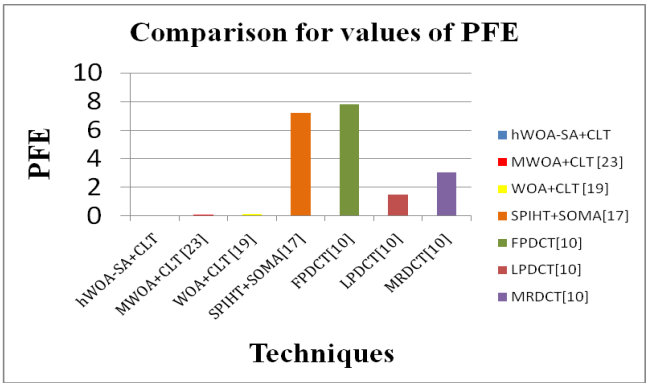

Fig. 9 Comparison the PFE value for different techniques

The Fig. 9 shows percentage fit error (PFE) values for different image fusion techniques. Here the PFE is value of 0.0529 for *h*WOA-SA which is less as compare to other techniques

E. Comparison for UQI

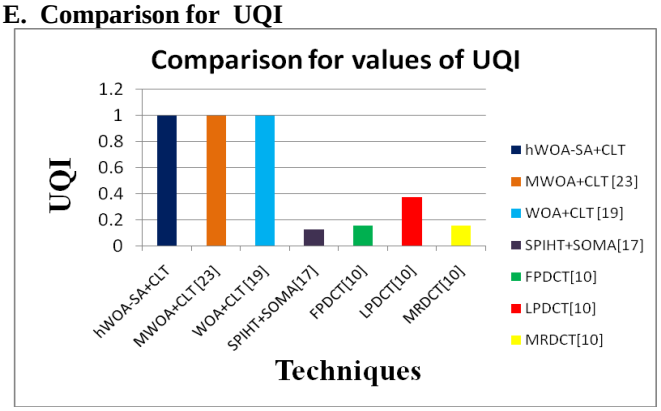

Fig. 10 Comparison the UQI value for different techniques.

The Fig.10 shows universal quality index (UQI) values for different image fusion techniques. It is observed that UQI is having value of 1.000 for *h*WOA-SA which is same as MWOA and WOA and higher than other techniques

F. Comparison for CORR

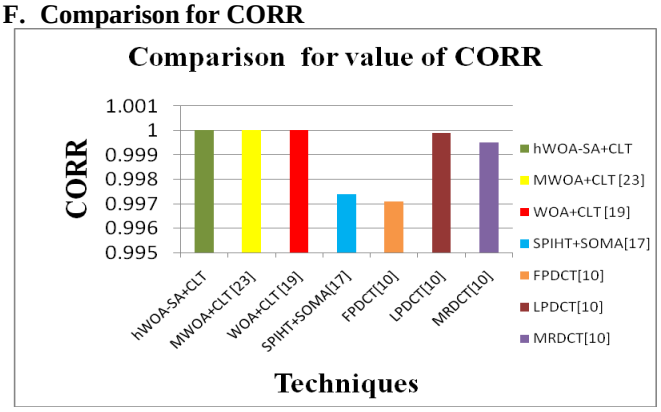

Fig.11 Comparison The CORR Value For Different Techniques.

The Fig.11 shows correlation (CORR) values for different image fusion techniques. It is observed that CORR is having value of 1.000 for *h*WOA-SA which is same as MWOA and WOA and high as compared to other technique

G. Comparison for MI

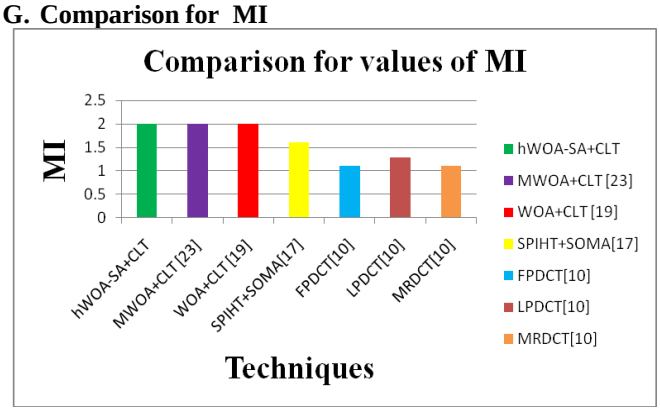

Fig.12 Comparison the MI value for different techniques

The Fig.12 shows mutual information (MI) values for different image fusion techniques. It is observed that MI having value of 1.9967 for *h*WOA-SA which is an improved value as compare to other technique

H. Comparison for MAE

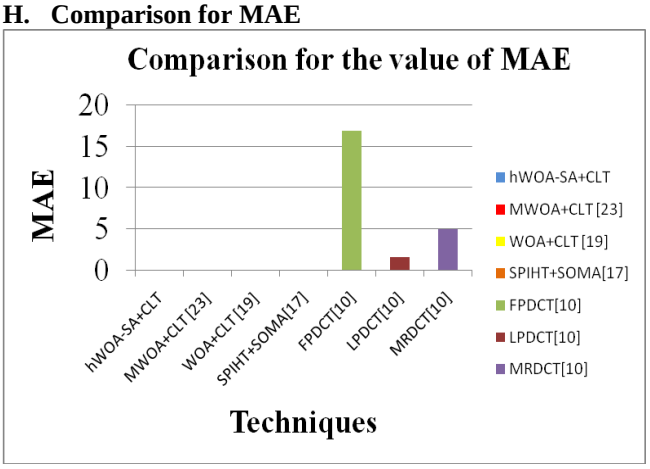

Fig. 13 Comparison the MAE value of different techniques.

The Fig.13 shows mean absolute error (MAE) values for different image fusion techniques. It is observed that MAE is having value of 0.00039288 which is very less for hWOA-SA as compared to other image fusion techniques.

I. Comparison for SSMI

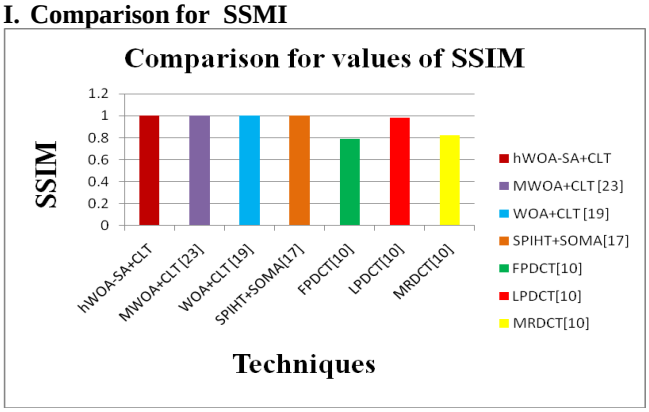

Fig.14 Comparison the SSIM value of different techniques.

The Fig.14 shows measure of structural similarity index (SSIM) values for different image fusion techniques. It is observed that SSIM is having value of 1.000 for hWOA-SA which is same as MWOA and WOA and high as compared to other techniques. present work also gives a comparison between presented approach and some other approaches available in the literature in which it has been found that the proposed scheme is far better in terms of various performance parameters as compared to other image fusion techniques such as: RSME, PFE, MAE, CORR, SNR, PSNR, MI, UQI and SSIM, etc some other techniques available in the literature. *h*WOA-SA based image fusion approach including multi spectral images is efficient and easier to implement. The

VI. CONCLUSIONS

A mixed/hybrid *h*WOA-SA technique along with curvelet transform has been applied for image fusion and its performance has been computed and compared with

Table 1 Performance parameter of different techniques.

	Performance Parameter								
Technique	**RMSE**	**PFE**	**MAE**	**CORR**	**SNR**	**PSNR**	**MI**	**UQI**	**SSIM**
***h*-WOASA+CLT**	**0.0005986**	**0.0529**	**0.0003929**	**1**	**61.9334**	**80.4223**	**1.9967**	**1**	**1**
MWOA+CLT [23]	0.0007486	0.0829	0.00059288	1	61.6334	79.4223	1.9947	1	1
WOA+CLT [19]	0.0011	0.1238	0.00090881	1	58.1438	77.728	1.9937	1	1
SPIHT+SOMA[17]	0.0643	7.218	0.0405	0.9974	22.8317	60.0814	1.5988	0.1255	0.9997

FPDCT[10]	18.2385	7.8243	16.8633	0.9971	22.1311	35.5549	1.1064	0.1521	0.7888
LPDCT[10]	3.4201	1.4672	1.6386	0.9999	36.67	42.8244	1.2884	0.3728	0.9827
MRDCT[10]	7.1313	3.0593	4.9386	0.9995	30.2875	39.6331	1.1106	0.1568	0.8236
MRDCT[10]	7.1313	3.0593	4.9386	0.9995	30.2875	39.6331	1.1106	0.1568	0.8236

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