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Image Fusion using Hybrid Genetic Algorithm

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ABSTRACT: Image fusion combines the input images having spatial or spectral information and produces a high quality fused image. This will improve the performance of image analysis algorithms used in different applications. Image fusion can be performed at the pixel level, feature level, and decision level. The process is performed either in the spatial domain or in the transform domain. In the spatial domain, the spectral quality of the fused image is degraded. Afterward, research was done in the transform domain which is giving better spectral quality in the fused image. With this, several techniques are available for the image fusion process and it becomes difficult to find an optimal solution for image fusion. Thus Genetic Algorithm (GA) is used for image fusion. The result obtained after applying transform methods and GA were compared. After objective analysis, it was concluded that GA is giving better results than transform methods but through subjective analysis, fused images after transform methods such as Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Kekre Transform (KT) are also good. To get further improvement, a genetic algorithm is used in conjunction with these transform techniques to obtain an improved results. This paper gives the quality index of image fusion obtained using the combinations of different transform techniques and genetic algorithms. This technique will produce a better-fused image using discrete wavelet transform, discrete cosine transform, Kekre transform for feature extraction and Genetic Algorithms to get the near-optimal fused image. The performance of the proposed image fusion scheme is evaluated with mutual information (MI), Root Means Square Error (RMSE), Average Gradient (AG), Image Quality Index (IQI), Peak Signal to Noise Ratio (PSNR) and Spatial Frequency (SF).

Keywords: Evolutionary algorithm, Image fusion, Genetic algorithm, Hybrid genetic algorithm.

I. INTRODUCTION

In most of the remote sensing applications, it is necessary to have a high spatial resolution as well as the spectral resolution to extract the desired information. The remote sensing satellites give either a panchromatic image or multispectral. The process of improving the spatial characteristics of a multispectral image is known as pansharpening. This is the image fusion process in which two registered images from different sources are combined to obtain an improved image which is more useful for object detection and segmentation [9].

The remote sensing images are also used to observe change detection in land use, forest, urban growth and vegetation dynamics as well as monitoring disaster or flood [8, 11]. These techniques assume that all source images are properly aligned. The error introduced during registration will usually affect the quality of the resultant image [10].

Several techniques are available for image fusion that includes spatial domain and transform domain fusion. In transform domain based image fusion, input images are first transformed to another form using a suitable transform such as DCT, DWT, KT etc. followed by some processing and image fusion. The transform domain techniques usually give better results compared to spatial domain methods.

To improve the quality of image fusion and to acquire more information, optimization techniques using evolutionary algorithms such as Genetic Algorithm (GA) are useful. In this paper, initially, GA is employed to perform image fusion for improvement in one of the performance parameters giving better performance compared to the transform techniques. However, the quality of the fused image obtained using transform techniques was observed to be better in visual inspection. In the objective analysis, an information deviation parameter such as RMSE was used. And GA was giving a smaller value of this parameter [15]. As a result, this paper introduces the use of a hybrid genetic algorithm that combines the GA and one of the transform techniques to obtain better image fusion. The hybrid GA was implemented using three transform technique namely DCT, DWT, and KT. The simulation results of these techniques are presented and compared with the GA method. It shows that hybrid GA is a good approach for image fusion.

The remainder of the paper is organized as follows: Section II gives the information of image fusion using GA, DCT, DWT, and KT; Section III discussed the implementation details of the hybrid GA. Section IV gives evaluation criteria used to evaluate the proposed technique; Then Section V presents the simulation results and discussion and finally, Section VI and VII draw the conclusion and future scope respectively.

II. IMAGE FUSION USING GENETIC ALGORITHM AND TRANSFORM TECHNIQUES

The evolutionary algorithms give near-optimal solutions for complex search and optimization problems. They are based upon Charles Darwin's proposed theory of evolution which states that the fittest individuals will survive generations of population and will produce the individuals in the next generation. They include genetic algorithms, genetic programming, evolutionary programming, and evolution strategies amongst other

techniques. These algorithms work on a set of solutions (called population) and find near-optimal solutions with the help of predefined fitness function. These algorithms comprise several generations of populations in which solutions of one generation act as parents for the next generation. The mutation and crossover are the primary operators to determine the offspring for the next generations. The mutation operator works at an individual level and modifies a small part of it whereas crossover exchanges the information from two or more individuals [1]. The fitness of an individual is calculated by a fitness function which takes into account the desired properties for the problem under consideration [3]. A genetic algorithm is a well-known technique for search and optimization.
A genetic search comprises initialization, evaluation, selection, reproduction, and termination. In the initialization step, initial populations are generated randomly and then each individual is evaluated using the fitness function. Then the GA repeatedly performs the selection, reproduction and evaluation steps to produce a new generation of the population until the termination condition is satisfied. In the selection step, the individual with the highest fitness is selected to take part in the reproduction process. Crossover and mutation are the genetic operators used to produce a new generation from the selected individuals. Then the individuals in the newly generated population are evaluated. The termination condition may be based on the number of generations, fitness value or specific time [4].
The genetic algorithm is also used here for data assimilation. Data assimilation involves changing the objects such that one object becomes similar to the other object. The assimilation of two images is done either by changing one image and keeping the other unchanged or changing both the images towards each other [7].
DCT works with real numbers having strong energy compaction. The information in the low-frequency component of the DCT is useful in some applications. The 1D DCT is represented by using the following equation.

$$F(u) = \alpha(u) \sum_{x=0}^{n-1} f(x) \cos\left[\frac{\pi(2x+1)u}{2N}\right] 0 \leq N-1 \quad (1)$$

where,

$$\alpha(0) = \sqrt{\frac{1}{N}} \text{ and } \alpha(u) = \sqrt{\frac{2}{N}} \text{ for } 1 \leq u \leq N-1$$

The coefficients are calculated at the variables *u* and *x*. The corresponding coefficients of input images are compared and by using maximum fusion rule, largest coefficient is used to form fused image. The inverse DCT is then applied to the fused image. The fused image contains more information than any of the input images.
In DWT, an image is converted into a series of wavelets which are stored more efficiently than pixel blocks. It decomposes an image into the components that include approximation coefficients and details coefficients in horizontal, vertical, and diagonal direction. Approximation component is decomposed to find next level components. As it is working on each level, minor information also reflected in the output image [3]. The discrete wavelet packet transform decomposes the detail components also into next level components. In a discrete wavelet transform, the mother wavelet is shifted and scaled by the power of two given by the following equation.

$$\varphi_{j,k}(t) = \frac{1}{\sqrt{j}} \varphi\left(\frac{t-k}{j}\right) \quad (2)$$

where *j* and k are the scale and shift parameters respectively
In Kekre transform, the matrices need not be of size powers of 2. Kekre transform is generated by using the following equation:

$$K(x,y) = \begin{cases} 1, & x \leq y \\ -N + (x+1), & x = y+1 \\ 0, & x > y+1 \end{cases} \quad (3)$$

Normalized local or global transform is applied to two input images separately. After this transformation, three coefficients are available which will be useful for further processing.

III. IMAGE FUSION USING HYBRID GENETIC ALGORITHM

A single metric is not sufficient to find the quality of the fused image. It should contain the qualities of multiple methods [5]. A hybrid genetic algorithm is the combination of transform technique and genetic algorithm. It gives the advantages of both techniques. Here three transform techniques used which are discrete cosine transform, discrete wavelet transform and Kekre transform.

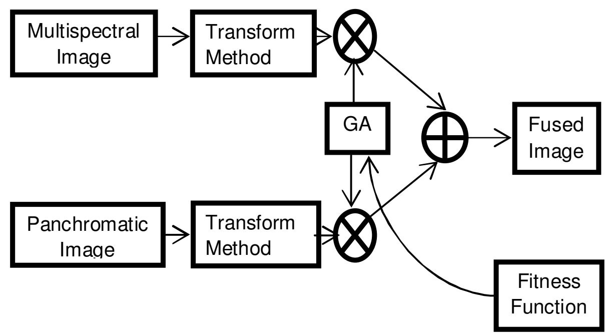


Fig. 1. Image Fusion using Hybrid Genetic Algorithm.

The steps for hybrid genetic algorithm based image fusion are as follows:
– Select two input images i.e. panchromatic image and multispectral image from the dataset for image fusion.
– Apply transform technique on each band of input images separately. Now two transformed images are available.
– Initial population is generated randomly with pop size and number of bits in chromosome. Separate populations are generated for two input images.
– The chromosome from the population is considered as the weight for the corresponding input image.
– Multiply this weight with transformed image. Now two new images are available for fusion. The fusion is performed at the pixel level.
– Calculate the fitness of the fused image using fitness function. Here RMSE equation is considered.
– Repeat steps 4 to 6 on each individual.
– Sort the GA population fitness values in the ascending order.
– The selection probability is calculated for the selection of parents.
– The parent selection is done by using the roulette wheel method with the probability of selection calculated in step 9.
– These parents are taking part in the formation of the new population using the crossover operator. Here two-point crossover is used.
– With the mutation probability, two off springs are mutated and place the resulting chromosomes in the new population.

– Replace the current population by the new population.
– Repeat step 2 to 13 till termination condition is satisfied.

IV. EVALUATION CRITERIA

The quality of the fused image can be calculated regarding the reference image.

1. Root mean square error (RMSE): It is the measure of accuracy. RMSE can be calculated in two ways- with a reference image and without a reference image. During the GA run, it is assumed that the standard or reference image is not available. As a result, RMSE is calculated for the input images as

$$R1 = \sqrt{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}(F(i,j) - I1(i,j))^2}$$

$$R2 = \sqrt{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}(F(i,j) - I2(i,j))^2}$$

$$RMSE = \frac{R1 + R2}{2} \quad (4)$$

where I1 and I2 are input images and F is the fused image.

2. Peak Signal to noise ratio: It is the measure of signal strength for noise in an image.

$$PSNR = 10 * \log\left[\frac{max}{MSE}\right] \quad (5)$$

Where max the maximum number of pixels in the image and MSE is the mean square error calculated by the above formula. Larger the value of peak signal to noise ratio, better is fused image. This indicates that the algorithm is working better than other techniques.

3. Mutual Information: This parameter reflects the mutual information between two images. As the fused image contents the information from both input images, mutual information value is larger for the fused image. Mutual information between input images and the standard image is calculated. As well as Mutual information between the fused image and the standard image is calculated.

$$I_{AB} = \sum_{a,b} P_{AB}(a,b)\log_2\frac{P_{AB}(a,b)}{P_A(a).P_B(b)} \quad (6)$$

Where P_{AB} (a,b), P_A(a) and P_B(b) are the normalized of the joint and marginal histograms.

4. Spatial frequency: This gives the information corresponding to features of an image depending on the high frequency and low -frequency spatial domain.

$$SF = \sqrt{CF^2 + RF^2} \quad (7)$$

Where CF is column frequency and RF is the row frequency of an image.

5. Average Gradient: This is the change in intensity or in color which is useful in change detection. It is calculated by taking the vector of first derivatives. It is applied separately to each band of the image.

$$AG = \frac{1}{N}\sum \sqrt{\frac{\Delta I_x^2 + \Delta I_y^2}{2}} \quad (8)$$

Where, ΔI_x and ΔI_y are the differences in x and y direction

6. Image Quality Index: This gives the information or measures the similarity between two images. The value ranges from -1 to 1. If both the images are identical, it is 1 and if they are independent then it is -1.

$$IQI = \frac{\sigma_{ij}}{\sigma_i\sigma_j}\frac{2\,\mu_i\mu_j}{(\mu_i^{\,2}+\mu_j^{\,2})}\frac{2\sigma_i\sigma_j}{(\sigma_i^{\,2}+\sigma_j^{\,2})} \quad (9)$$

Where σ_{ij} is sample covariance. μ_i and μ_j are sample mean

V. RESULTS AND DISCUSSIONS

To observe the effectiveness of the hybrid genetic algorithm, it is tested on test sets. In our experiments, five data sets are used. Each data set includes a high-resolution panchromatic image and a low-resolution multispectral image. Matlab image processing toolbox and Celeron processor are used to carry out the simulation.

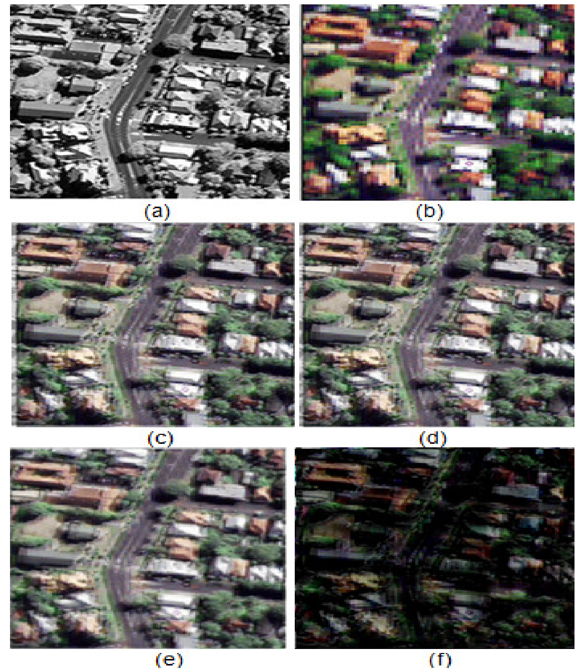


Fig. 2. Test set 1 (a) and (b) are input images, (c) is fused image due to Genetic Algorithm and (d) to (f) are fused images due to Hybrid Genetic Algorithm using DCT, DWT, KT respectively.

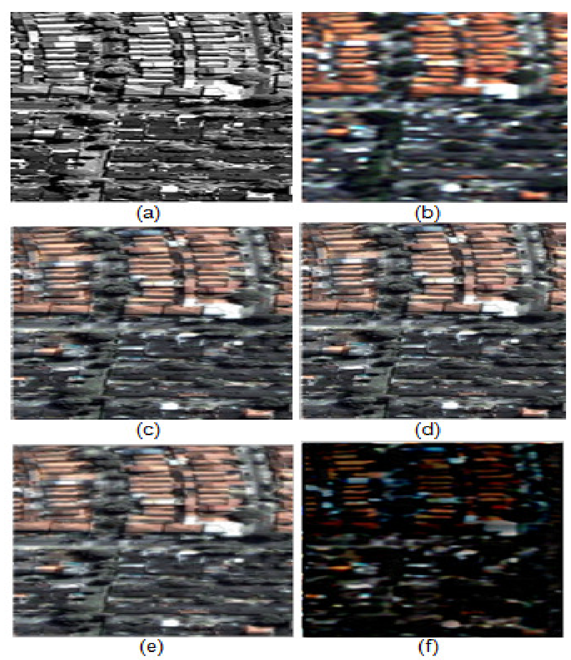


Fig. 3. Test set 2 (a) and (b) are input images, (c) is fused image due to Genetic Algorithm and (d) to (f) are fused images due to Hybrid Genetic Algorithm using DCT, DWT, KT respectively.

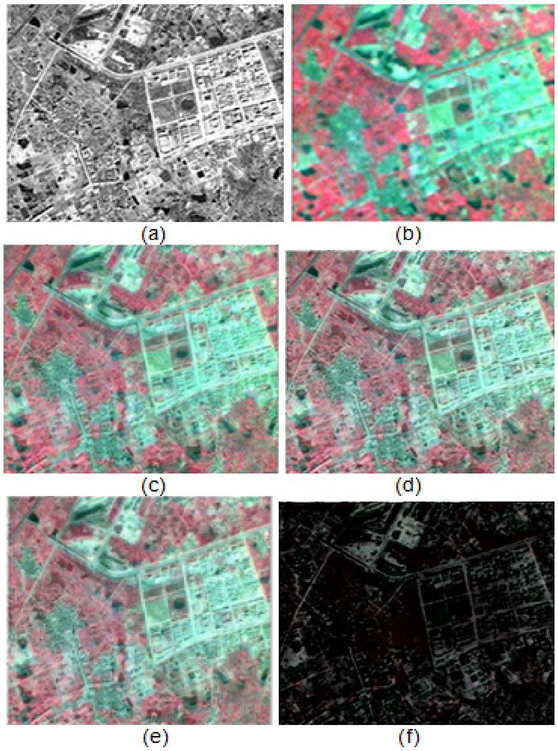


Fig. 4. Test set 3 (a) and (b) are input images, (c) is fused image due to Genetic Algorithm and (d) to (f) are fused images due to Hybrid Genetic Algorithm using DCT, DWT, KT respectively.

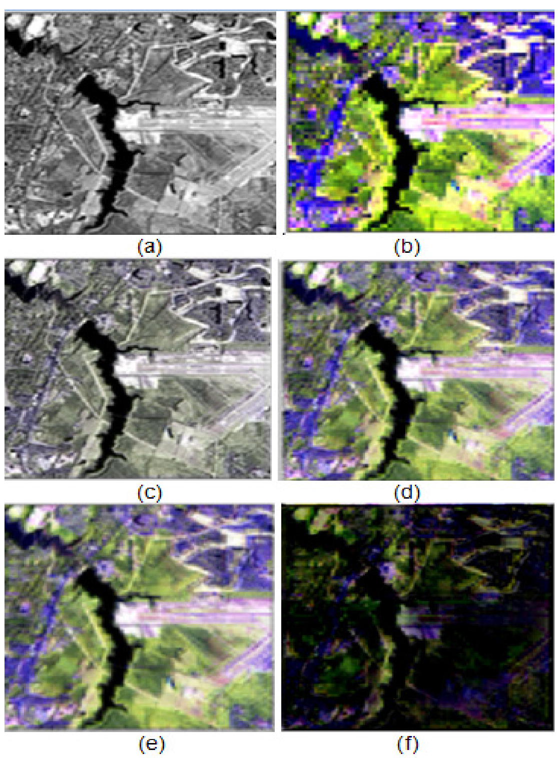


Fig. 5. Test set 4 (a) and (b) are input images, (c) is fused image due to Genetic Algorithm and (d) to (f) are fused images due to Hybrid Genetic Algorithm using DCT, DWT, KT respectively.

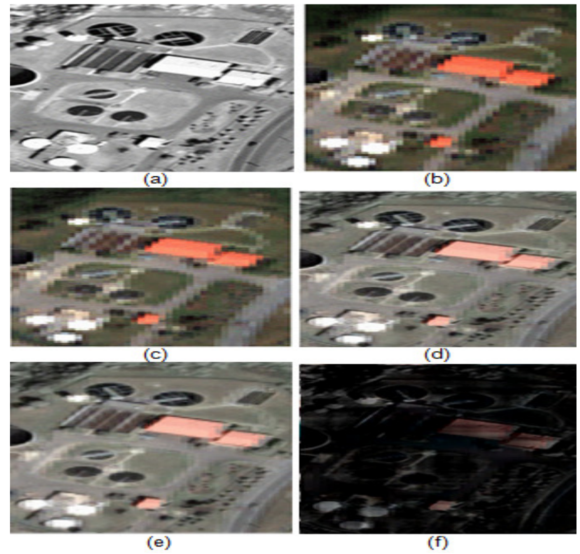


Fig. 6. Test set 5 (a) and (b) are input images, (c) is fused image due to Genetic Algorithm and (d) to (f) are fused images due to Hybrid Genetic Algorithm using DCT, DWT, KT respectively.

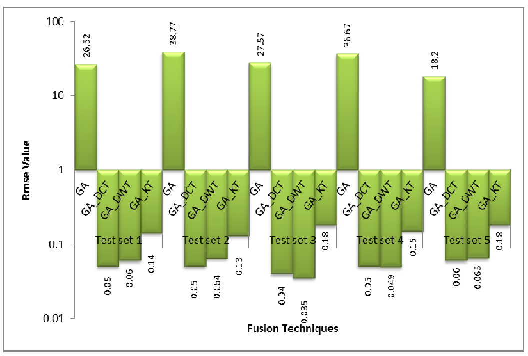
Table 1: RMSE, PSNR, SF assessment for proposed method.

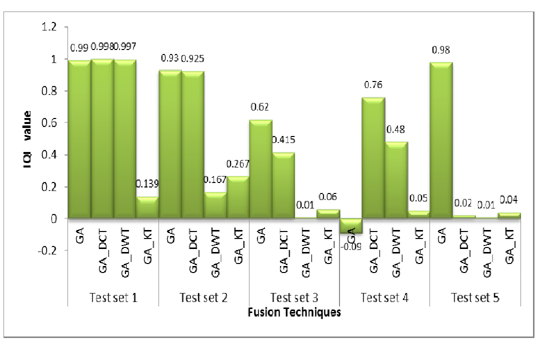
Test set	Fusion Tech.	RMSE	PSNR	SF
1.	GA	26.52	89.11	28.66
	GA_DCT	0.05	151.79	28.84
	GA_DWT	0.06	150.6	29.45
	GA_KT	0.14	141.26	19.73
2.	GA	38.77	85.31	38.19
	GA_DCT	0.05	151.97	39.8
	GA_DWT	0.064	149.31	31.67
	GA_KT	0.13	141.99	24.33
3.	GA	27.57	88.72	19.70
	GA_DCT	0.04	155.09	23.2
	GA_DWT	0.035	155.42	22.77
	GA_KT	0.18	138.87	17.73
4.	GA	36.67	85.86	22.36
	GA_DCT	0.05	152.21	19.01
	GA_DWT	0.049	152.02	22.22
	GA_KT	0.15	140.3	19.57
5.	GA	18.20	92.87	21.52
	GA_DCT	0.06	149.38	18.63
	GA_DWT	0.065	149.2	18.02
	GA_KT	0.18	138.65	15.02

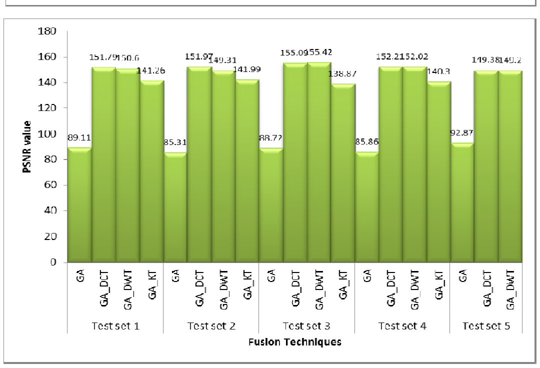
Table 2: AG, IQI, MI assessment for the proposed method.

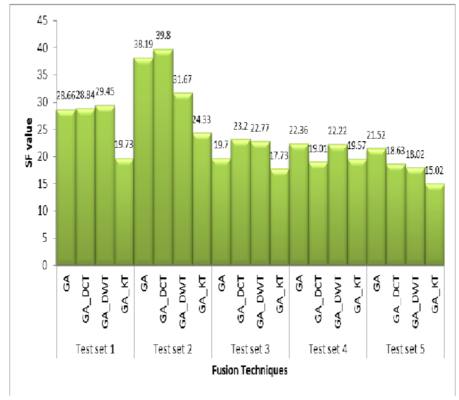
Test set	Fusion Tech.	AG	IQI	MI
1.	GA	435.63	0.99	0.87
	GA_DCT	113.68	0.998	1.33
	GA_DWT	40.85	0.997	1.06
	GA_KT	227.13	0.139	0.31
2.	GA	483.08	0.93	0.40
	GA_DCT	170.91	0.925	1.37
	GA_DWT	51.3	0.167	0.89
	GA_KT	257.44	0.267	0.2
3.	GA	298.99	0.62	0.35
	GA_DCT	131.95	0.415	0.75
	GA_DWT	32.16	0.01	0.73
	GA_KT	188.15	0.06	0.15
4.	GA	357.74	-0.09	0.73
	GA_DCT	84.33	0.76	1.33
	GA_DWT	44.07	0.48	1.53
	GA_KT	183	0.05	0.26
5.	GA	222.44	0.98	1.20
	GA_DCT	86.89	0.02	1.08
	GA_DWT	25.87	0.01	0.94
	GA_KT	132.11	0.04	0.26

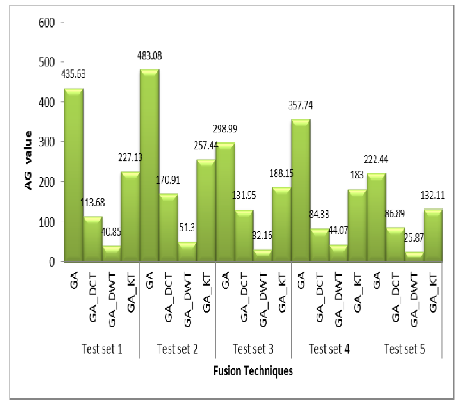
Image fusion is done by taking two input images i.e. panchromatic and multispectral images from test sets. Here five test sets are used and observed the output of fusion techniques i.e. genetic algorithm and hybrid genetic algorithm. The quality of output image is measured for given evaluation parameters as RMSE, PSNR, SF, AG, IQI, and MI. In the fitness function of a genetic algorithm, only the RMSE parameter is considered. From Table 1 and 2, by observing the values of each parameter for applied methods, it found that we are getting a better value of RMSE for GA-DCT and GA-DWT. As RMSE and PSNR are correlated, PSNR is also good for these two methods. For the remaining parameters, performance is varying. For example, IQI is good using GA but worst using GA-DCT whereas MI is good for GA-DCT but worst using GA for test set 1. And similar is reflected for other test sets also. As other parameters are not considered in the fitness function, variation in performances is observed. So it may be considered in fitness function to improve the quality of remaining performance parameters. Fig. 2 to 6 shows the input and output images for the different test set. Here (a) and (b) are input images, (c) is fused image due to GA and (d) to (f) are fused images due to Hybrid Genetic Algorithm (HGA) using DCT, DWT, KT respectively. Through visual inspection, fused images due to HGA using DCT and DWT are better than KT and GA. Fig. 7 shows the graphical representation of performance parameters using different methods.











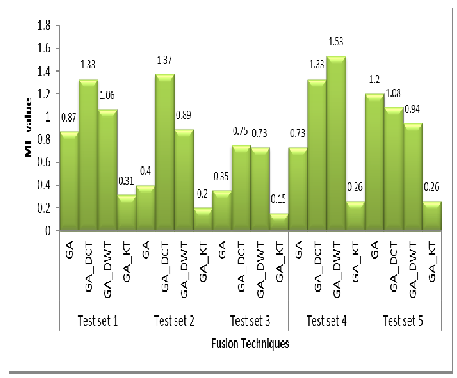


Fig. 7. Performance parameters of fused image using Hybrid Genetic Algorithm.

VI. CONCLUSIONS

From spatial image fusion methods and transform based fusion methods, it was concluded previously in reference number 14, that transform methods are good but need some optimization. Thus evolutionary algorithm method i.e. Genetic Algorithm is added for optimization. Combining transform technique and GA forms a hybrid genetic algorithm. The input images given to GA are from the output of DCT, DWT or KT mentioned in the paper. And it proved from the result that, this hybrid method is giving better performance than the transform method and the GA method individually. In the hybrid genetic algorithm, the fitness function is considered for the RMSE parameter only. And thus, in the result table, the value of RMSE for GA-DCT and GA-DWT is far better compared with the rest of parameters. And again by comparing GA-DCT and GA-DWT, GA-DCT is good.

VII. FUTURE SCOPE

In the future, to achieve a better result for the rest of parameters, the hybrid multiobjective genetic algorithm may be useful where in the fitness function, some parameters can be added and then selecting an optimal value.

Conflict of Interest. No conflict of interest.

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