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Optimization in Image Fusion Using Genetic Algorithm

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***Abstract*—**Day by day, the advancement in sensor technology is increasing which is used for image acquisition. Different sensors can acquire the information of different wavelength. These sensors are not able to capture the complete information from the scene. Thus it is necessary to combine the images from different sensors to produce more informative image. Image fusion is the process of combing the information from input images. According to the application or need, image fusion technique can be used. Number of techniques with varieties of solutions is available for image fusion process. And thus it becomes difficult task to find an optimal solution for image fusion. Genetic algorithm is an optimization technique used for searching solution for large number of complex problems [15]. This paper gives the quality index of image fusion obtained using the combinations of different selection methods and crossover techniques in genetic algorithm. These techniques have been compared using root mean square error to obtain information about relative performance. The experimental result on some standard test images shows that performance parameters i.e. root mean square error (RMSE) and peak signal to noise ratio (PSNR) are good for multifocus and multisensor image fusion.

***Index Terms*—**Image Fusion, Evolutionary Algorithm, Genetic Algorithm

I. INTRODUCTION

Different sensor acquires the information through different wavelength. The images captured from these sensors are used for image fusion. The image fusion techniques can be in spatial domain or in transform domain. The level of processing decides the image fusion technique. Multisensors, multitemporal, multifocus and multiview are image acquisition techniques. The levels of processing techniques are pixel level, block level, feature level and decision level [3,15]. These techniques are divided into subtypes according to data processing method. Fusion can be applied in various fields such as medical imaging, geographical analysis, change detection and wireless sensor network for computer vision, image classification, and automatic object detection [15]. Remote sensing, robotics and military and law enforcement require the image with both spatial and spectral information. This data can be obtained from multisensor, multitemporal, multi frequency or multi resolution input sources [16]. The optimization in multisensor image fusion needed during bandwidth management or resource management [18] whereas in multiresolution image fusion to minimize the deviation and noise in input images [19]. Different image fusion methods are Average, Select Maximum, Select Minimum, Multiplicative Method, Brovey Transform, Intensity Hue Saturation, Principal Component Analysis, Gram Schmidt method, Pyramid based Method, Wavelet Transform based Methods, Curvelet Transform and Contourlet Transform [20]. As variety of solution is available with application of different fusion algorithms, it is necessary to find an optimal solution for image fusion. Optimization is achieved by using evolutionary algorithm. This is the process of obtaining the best solution of any complex problem. The basic idea behind optimization is to generate iteratively and progressively improved solution to a given problem. For any optimization problem, a performance criterion known as an objective function needs to be formulated in terms of parameters. Optimization is necessary in image analysis to find noise, objects and variation in image perception and understanding. Different optimization methods are being used widely in image restoration, image compression, image segmentation, image registration, object recognition, perceptual grouping, and stereo and motion estimation.

An optimal solution for global optimization problems is very difficult to solve using traditional methods. Thus stochastic optimization methods are used to find the solution for global optimization problems. The stochastic optimization methods are Hill-Climbing, Tabu Search, Simulated Annealing, Evolutionary Algorithms etc. Initial solution is randomly chosen from the solution space in Hill

Climbing method. Then algorithm searches a better solution in the neighborhood to be used as the new solution. This process is iterated until a better solution cannot be found. Simulated annealing is similar to the metallurgical process of annealing. The new solution is selected as per probability of a global parameter. Tabu search is a heuristic search technique where the initial solution is chosen at random. If it is not on Tabu list then a new solution is chosen. Evolutionary computation methods evaluate multiple solutions to a single candidate solution. Therefore, they are less used in a local optimum and are good for global optimization techniques. The Genetic Algorithm is one of the evolutionary computation methods. Evolutionary algorithms are working with some set of solutions to find efficient result. These may deal with single objective or multi objective optimization. In this paper we have concentrated our research on genetic algorithm for single objective. The rest of paper is organized as follows: Section II gives the Literature review. Section III gives the information about the genetic algorithm. Section IV explains the image fusion using genetic algorithm. Section V contains the results and discussions and Section VI gives conclusion.

II. Literature Review

Different evolutionary approaches such as genetic algorithm, genetic programming, and evolutionary programming were explained by Igor *et al* [18]. Chaunte *et al* [1] proposed image fusion using genetic algorithm and discrete wavelet transform. The performance of this method measured using mutual information and RMSE. The input images were visual and thermal image. Liu et *al* [2] explained multi-focus image fusion in DCT domain. In this, an image block with high spatial frequency was used in fused image. Image fusion based on spatial and spectral similarities was proposed by Arash *et al* [4]. Richa *et al* [5] explained the wavelet packet image fusion using genetic algorithm. Different parameters were used to check the performance of proposed system. Another application of genetic algorithm is image segmentation also. This was proposed by Mantas *et al* [6] and Mohamad *et al* [9]. The quality of fused image assessed by using different quality assessment parameters such as image quality index, mutual information, fusion factor, fusion symmetry, fusion index, root mean square error, peak signal to noise ratio and entropy. All these parameters were explained by Srinivasa *et al* [8]. Data assimilation can be used with genetic algorithm for image fusion. It is the process of changing either image towards the other or changing both the images to achieve the required parameter. This was explained by Liang *et al* [11]. Jyoti *et al* [13, 14, 15] explained image fusion using different transform techniques. Multiple parameter approach in genetic algorithm for image fusion can be achieved by multiobjective genetic algorithm [19].

III. Genetic Algorithm

Genetic Algorithm is an evolutionary algorithm from the guided random search techniques. The genetic algorithm is used to simulate processes for evolution by following the survival of the fittest principle. The genetic algorithm is based on the principle of natural selection where a string of bits is taken as genetic material [1,5,6]. Each individual cost evaluated by fitness function. Among this, high fitness individual will take part in next generation and low fitness individual are usually ignored [11]. This algorithm uses the chromosome to represent a single candidate solution to a given problem and its smaller block represented by genes. Optimized solution achieved through the objective function to find the fitness. Then parental chromosome selected according to their fitness. The fitter chromosome selected as parent for next generation [18]. Several selection methods are roulette wheel selection, rank based selection, tournament selection, truncation selection, steady state selection, elitism and stochastic universal selection [7]. Crossover takes a cross point randomly to exchange the substrings to form two offspring. Mutation works by changing some of the bits in the offspring [18]. Thus genetic algorithm has the elements as populations of chromosomes, selection according to fitness, crossover to produce new offspring and random mutation of new offspring.

A simple genetic algorithm works as follows:

1. Start with a randomly generated population i. e. chromosomes.
2. Calculate the fitness of each chromosome from objective function.
3. Select a pair of parent chromosomes from the current population. The selection of chromosome decided as per value of fitness function. Crossover rate cross over the pair to form two offspring. Mutation rate flips the bit to form the chromosome in the new population. This is repeated until all offspring have been created.
4. Step 3 repeated up to the condition of termination or maximum generation.

IV. Image Fusion Using Genetic Algorithm

The image fusion method used to fuse the images with high spatial and high spectral resolution should not distort the spectral characteristics [16]. In Cao et al. [2], the multifocus image fusion using quality assessment of spatial domain and genetic algorithm is explained. The images are divided into blocks. The block size is generated by genetic algorithm. The quality assessments can be spatial domain assessment or frequency domain assessment. The image fusion using genetic algorithm is an iterative process. The genetic algorithm run until the fused image of desired quality is obtained or maximum numbers of iterations are completed. Sometimes genetic algorithm is used for longer time to get optimized solution [9]. In medical applications, magnetic resonance image is considered for the feature elements. The optimized feature vector is selected by using genetic algorithm [10]. In Das et al. [12], input images are decomposed into two subbands as low frequency sub band and high frequency sub band by using wavelet transform. The averaging information from low frequency subbands and high frequency subbands for maximum information are selected by applying genetic algorithm. And then inverse wavelet transform is applied to find fused image. The genetic algorithm is used to fuse images by combing the pixel level and discrete wavelet transform information. The evaluation of fused image is done by using the performance parameters such as Peak signal to noise ratio (PSNR), Root mean square error (RMSE) and Spatial frequency [14,15]. Image fusion using genetic algorithm adopted through following procedure.

For image fusion, select multispectral image and panchromatic image of one scene from available data set. The initializations of the parameters are done with a randomly generated population i.e. chromosomes. According to requirement of input images, population is generated. The fitness function is used to find optimal value. The fitness of each chromosome in the population is calculated using fitness function. The optimal value for each generation is the minimum value among the value calculated for each chromosome. The fitness function used is

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

For next iteration, the cross over and mutation is used to get the optimized solution. This procedure is repeated till required iteration or required optimal value is reached. Thus genetic algorithm provide the populations of chromosomes, selection according to fitness, crossover to produce new offspring and random mutation of new offspring. Here image fusion using genetic algorithm works as follows:

1. Select two input images from dataset for image fusion. Here panchromatic image and multispectral image are the input images.
2. Create an initial population. Population is generated randomly having parameters as popsize and *nbits*. Popsize is nothing but number of chromosomes and *nbits* means the size of chromosome. Initially popsize is taken as 50 and *nbits* as 16 bits. Separate populations are generated for two input images. The chromosome from separate population is considered as the weight for input image.
3. Multiply the weight with input image. Two new images are available for fusion. Pixel level fusion is used for image fusion.
4. Apply the fitness function on fused image. This will give fitness value of each population.
5. Repeat step 3 & 4 for each population. At the end, number of fitness values is equal to the number of population.
6. Find the average fitness of these populations.
7. Sort the fitness values in ascending order. As smaller RMSE value is best, the best cost from fitness function is the first value whereas worst cost is the last value.
8. Calculate the selection probability for selection of parents using Roulette wheel selection.
9. With the probability *pc*, cross over the pair to form two offspring using single point or double point crossover. If no crossover takes place, form the two offsprings that are exact copies of their respective parents.
10. With the probability *pm*, mutate the two offspring and place the resulting chromosomes in the new population.
11. Replace the current population with the new population.
12. Repeat step 2 to 11 for all generations.

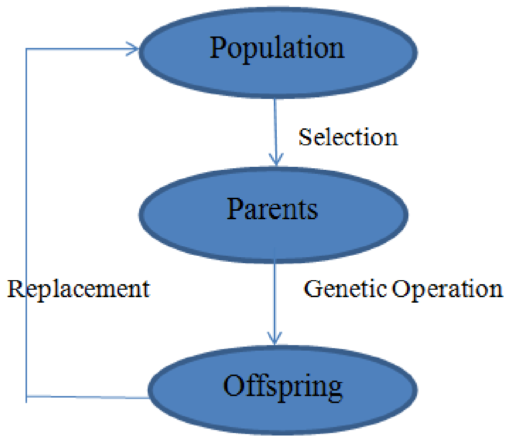

Fig.1. GA cycle [13]

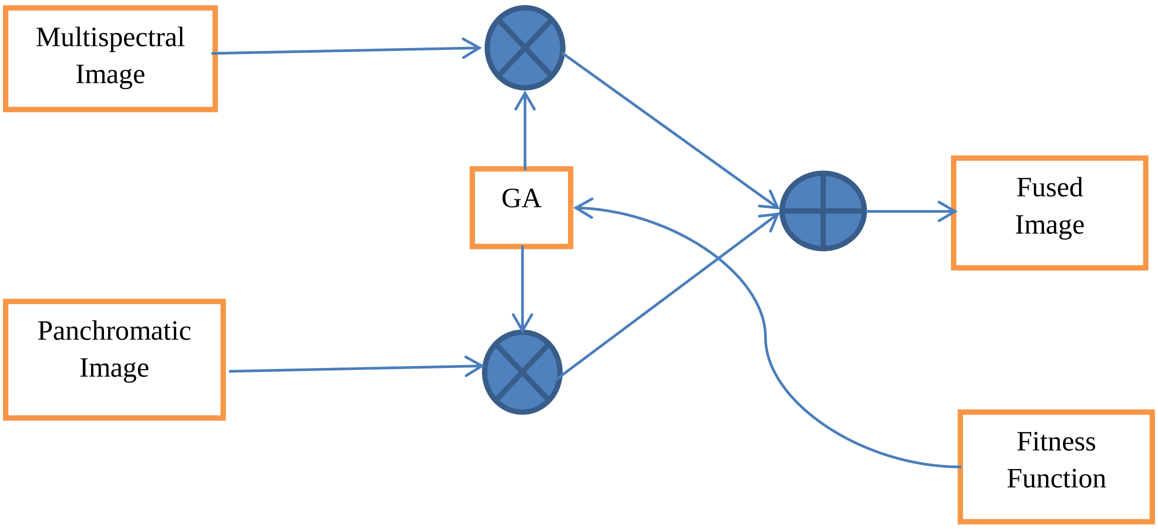

Fig.2. Image Fusion using Genetic Algorithm

Table 1. Genetic parameter setting

Sr. No.	Genetic Operator	Value
1	Number of generation	100
2	Popsize	50
3	Mutrate	0.05
4	Nbits	16
5	Crossover	Double point
6	Selection method	Roulette wheel

V. Results And Discussions

The performances of image fusion techniques can be evaluated by using two strategies: one by using the correlation and the other by using the information deviation. In correlation method, correlation degree of source images and fused image is checked. The greater correlation method is better than rest of the methods. The other one is using the information deviation as comparison parameter between fused image and source images. The smaller deviation method is better than rest of the methods [17]. RMSE value R1 is calculated between source image im1 and fused image imf. Similarly R2 is calculated between source image im2 and fused image imf. Then overall RMSE is computed by taking average of R1 and R2. Peak signal to noise ratio gives the quality of fused image. Mutual information reflects the independent information available in two input images. Spatial frequency is the change in pixel value. According to Table. 1, the genetic operators are set and the performance of each image fusion method is observed. Simulation is carried out using the Image processing toolbox in Matlab. The set of images are taken from http://datatang.com. The input images are applied for experimentation using different image fusion techniques and observed the output.

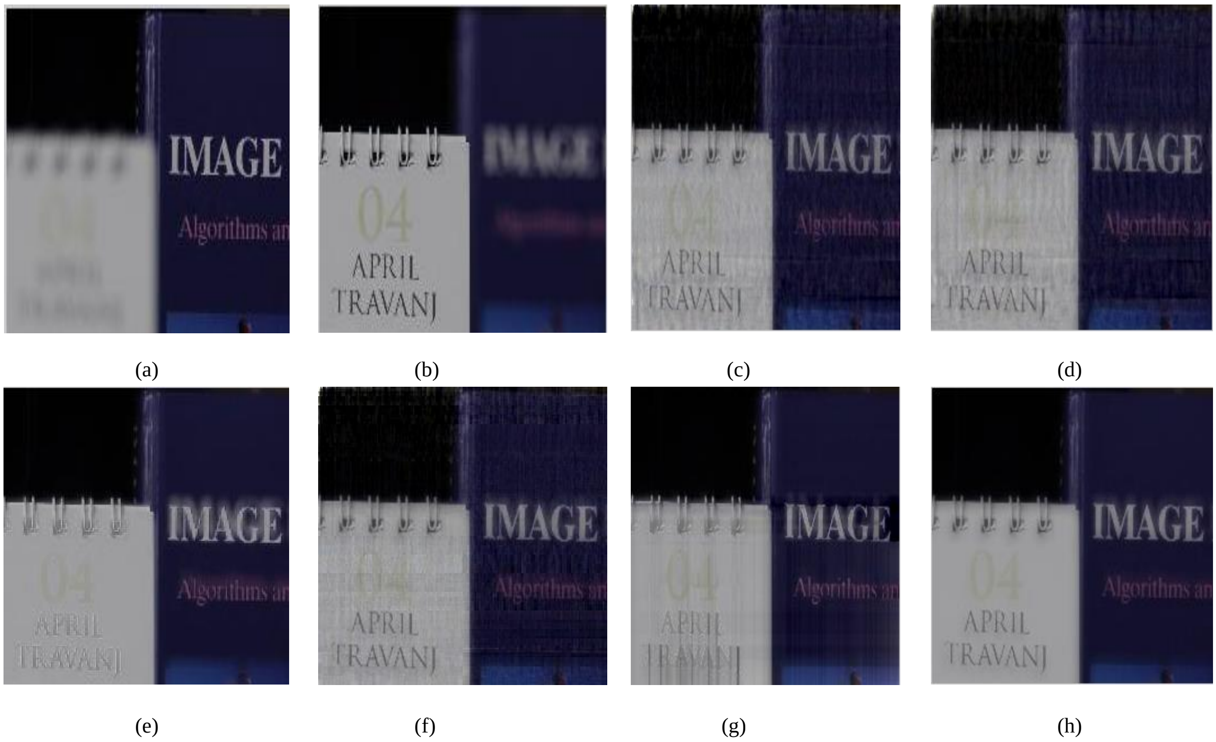

Fig.3. Test set 1 of multifocus images. (a) and (b) are input images at different focus, (c) to (h) are fused images due to different transform methods as DCT, DST, DWT, WT, KWT and GA respectively.

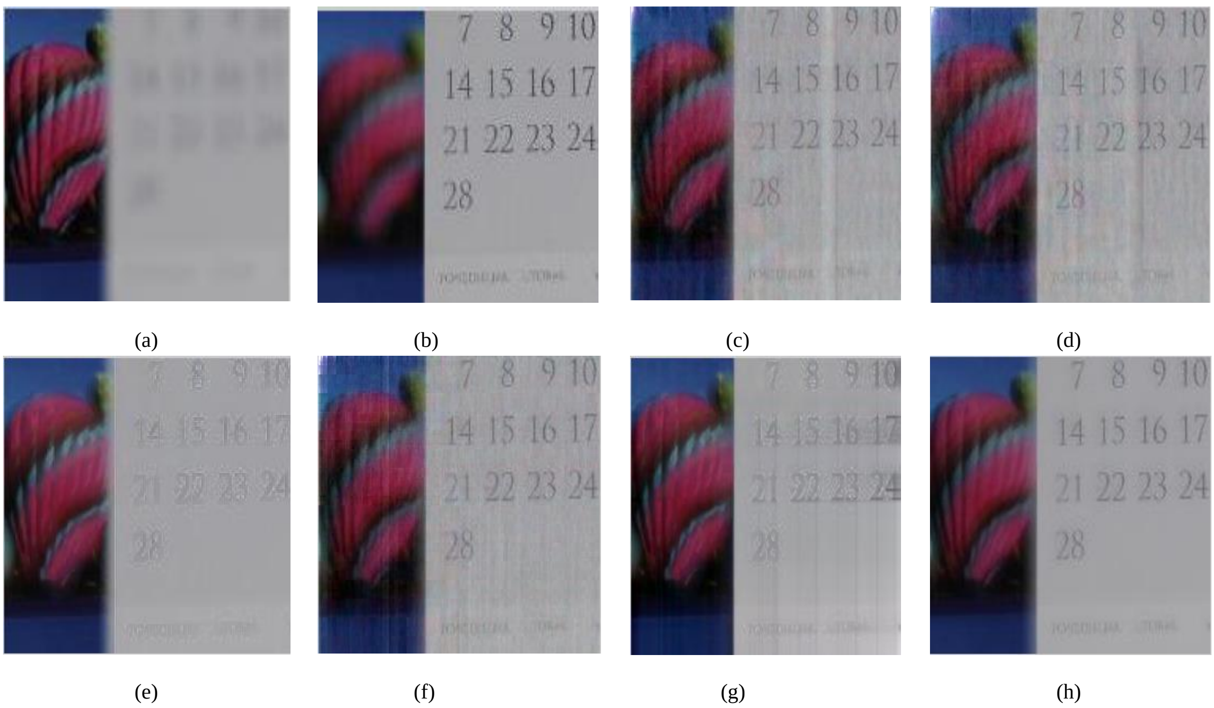

Fig.4. Test set 2 of multifocus images. (a) and (b) are input images at different focus, (c) to (h) are fused images due to different transform methods as DCT, DST, DWT, WT, KWT and GA respectively.

Multisensor Images (Satellite Images)

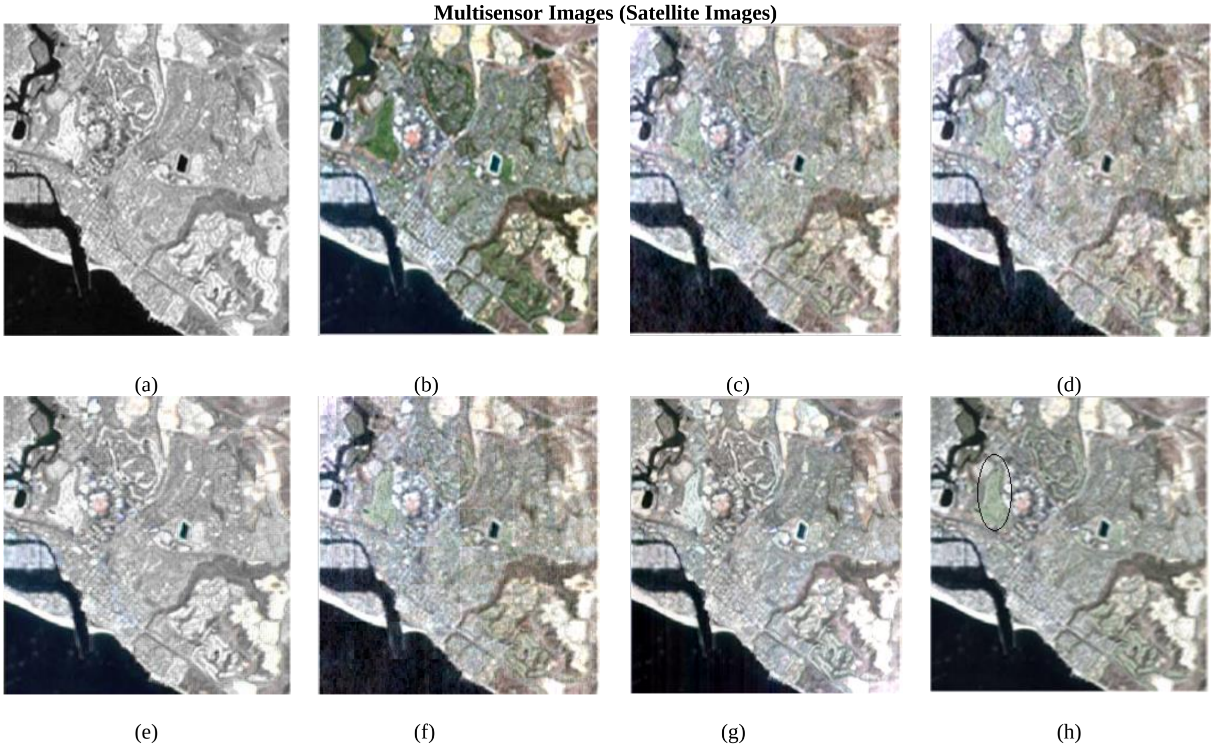

Fig.5. Test set 3 of multisensor images. (a) and (b) are input images from different sensors, (c) to (h) are fused images due to different transform methods as DCT, DST, DWT, WT, KWT and GA respectively.

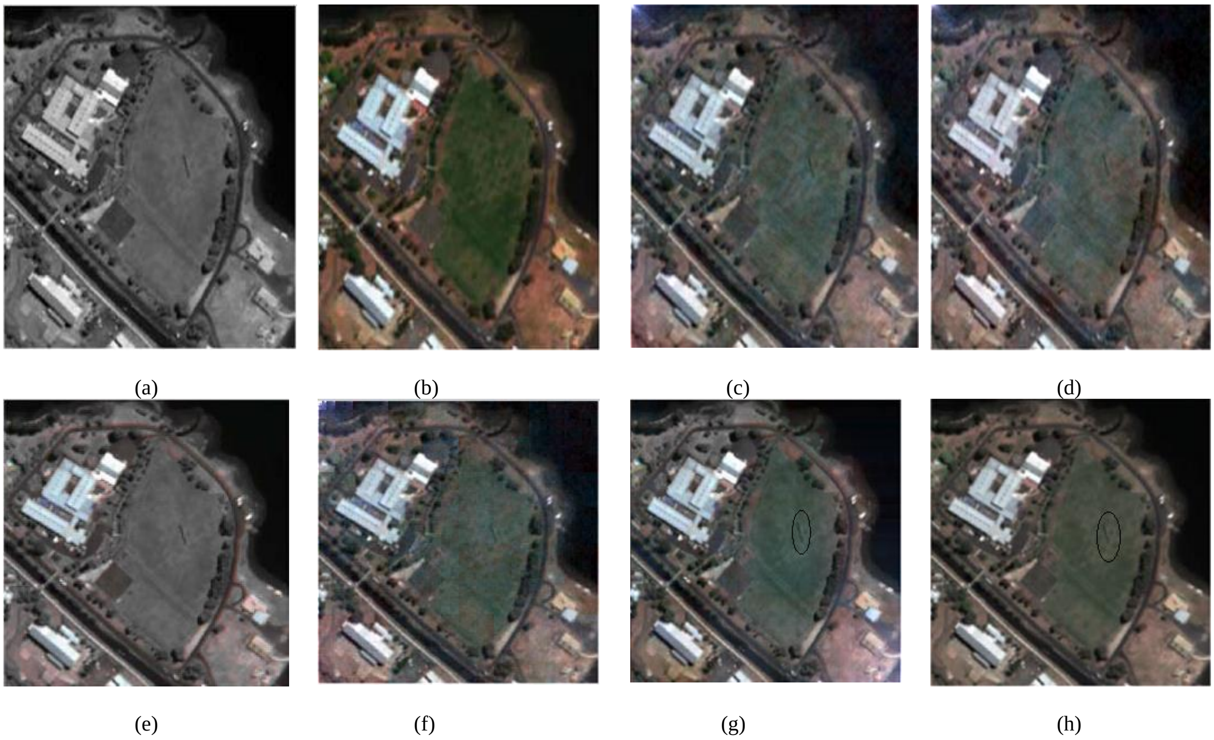

Fig.6. Test set 4 of multisensor images. (a) and (b) are input images from different sensors, (c) to (h) are fused images due to different transform methods as DCT, DST, DWT, WT, KWT and GA respectively.

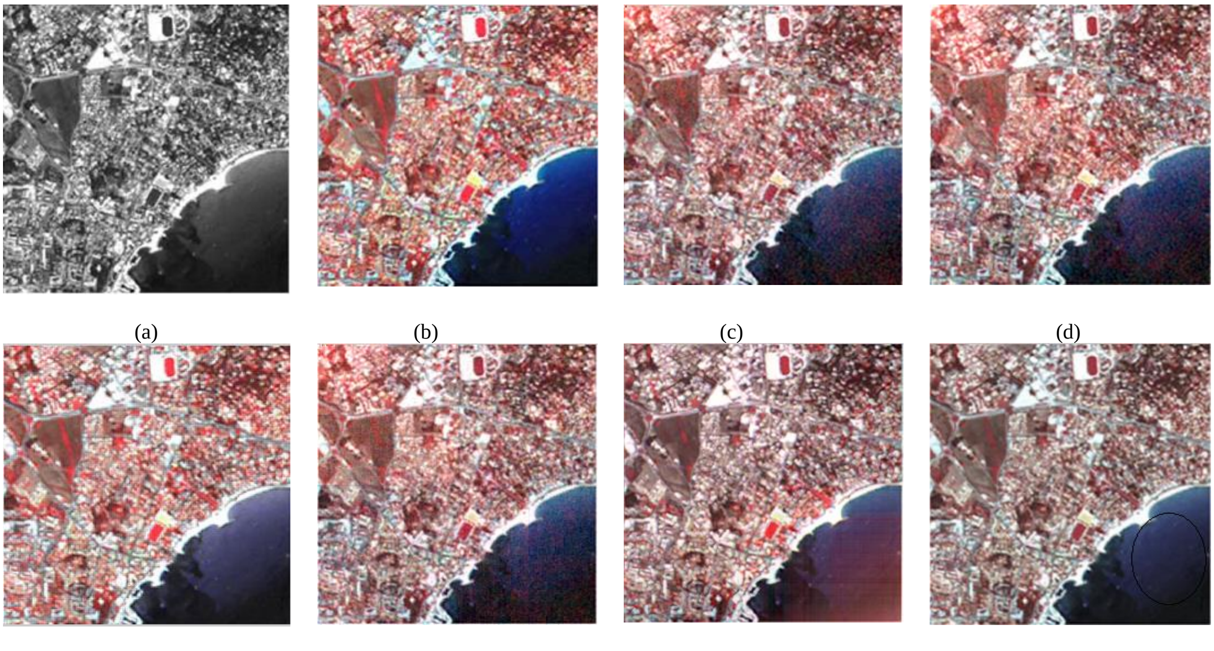

Fig.7. Test set 5 of multisensor images. (a) and (b) are input images from different sensors, (c) to (h) are fused images due to different transform methods as DCT, DST, DWT, WT, KWT and GA respectively.

The image fusion is studied through fusion of input images from test set. These images are multifocus and multisensor images such as panchromatic and multispectral images from satellite imaging. The panchromatic image reflects spatial information whereas multispectral image reflects spectral information. Fig.3 shows test set 1 and Fig.4 shows test set 2 of multifocus images where two input images as focused on different side. Image (a) is right side focus image whereas image (b) is left side focus image. Images (c) to (h) are fused images due to different fusion methods such as DCT, DST, DWT, WT, KWT and GA respectively. Here image due to genetic algorithm is clearer than rest of images obtained from different transform techniques.

Fig.5 and Fig.7 shows the input and output images of test set 3 and test set 5 respectively. Input images are from different sensors and output images are fused image due to different fusion methods such as DCT, DST, DWT, WT, KWT and GA respectively. In both cases, genetic algorithm is giving better performance than rest of the techniques. In Fig.6, i.e test set 4, the genetic algorithm as well as KWT is giving better performance compared with other techniques. Table.2 shows the quality indices of fused image. The performance parameters used are root mean square error (RMSE), peak signal to noise ratio (PSNR), spatial frequency (SI), average gradient (AG), image quality index (IQI) and mutual information (MI). The performance of specific spectral band can be evaluated using relative average spectral error [4] and the quality of methods used for image fusion calculated using fusion index [8]. From Table.2, RMSE using GA is very small compared to the rest of methods. For test set 1 and 3, SF is good using DWT whereas AG value is larger using WT. Kekre's wavelet transform produces good result for MI. Table.3 shows the quality indices of fused image for different generations. As GA has the ability to find the optimum value described in fitness function, it producing the same at 10^{th} generation. By increasing the generations, the parameter's values are changing slightly.

Table 2. Quality indices of fused image for different test set

Test set	Fusion Technique	RMSE	PSNR	SF	AG	IQI	M1
1	GA	4.8547	106.0903	10.4513	15.2485	-0.8571	2.9018
	WT	11.8508	86.1796	11.6763	124.6621	-0.7345	2.0171
	DWT	13.008	85.2534	12.3054	80.6532	0.7461	2.1002
	DST	12.9876	85.2636	10.5361	123.6876	-0.9610	1.9578
	KWT	11.4583	86.5164	10.3760	88.2680	0.1953	2.3594
	DCT	11.6855	86.3201	10.6271	120.9503	-0.7341	2.0455
2	GA	0.1510	105.7059	8.0826	8.1392	0.9997	2.5647
	WT	12.7198	85.4719	7.9006	96.2591	0.9923	1.8693
	DWT	8.5689	89.4222	6.8645	63.8906	0.9926	1.7867
	DST	13.0267	85.2335	6.5858	89.0019	0.9977	1.7503
	KWT	15.0433	83.7942	6.8677	74.9879	0.8199	2.1331
	DCT	12.5273	85.6244	6.8816	91.5084	0.9985	1.8509
3	GA	15.7923	94.1902	21.5435	84.4772	0.9903	1.7023
	WT	41.2091	73.7170	24.4499	348.5720	1.0000	1.2935
	DWT	51.0125	71.5828	25.6664	331.5745	-0.1323	1.1284
	DST	44.6204	72.9216	22.8596	342.2952	0.9999	1.2914
	KWT	45.5282	72.7202	24.4122	343.6937	0.9999	1.7391
	DCT	40.9121	73.7893	22.8193	343.6136	1.0000	1.3101
4	GA	17.2302	93.4230	19.8643	52.6585	0.9946	2.3461
	WT	28.1967	77.5115	20.6408	251.0978	1.0000	1.8443
	DWT	30.2625	76.8045	17.6568	219.5716	0.9997	1.8223
	DST	30.1234	76.8505	20.4721	248.2364	0.9996	1.8545
	KWT	26.7090	78.0536	18.9688	231.6089	1.0000	2.0500
	DCT	28.0707	77.5563	20.0903	246.8050	1.0000	1.8949
5	GA	12.8194	93.2959	31.2452	104.8876	0.9965	1.9436
	WT	30.3386	76.7793	31.5874	480.5268	0.9828	1.4574
	DWT	30.6462	76.6785	30.8699	448.5477	-0.1554	1.5485
	DST	30.7278	76.6519	30.0808	481.2902	0.9639	1.4328
	KWT	41.5449	73.6358	31.6754	473.5715	0.9873	1.5886
	DCT	30.0740	76.8669	30.0055	481.3952	0.9663	1.4567

Table 3. Quality indices of fused image for different generations.

Generation	RMSE	PSNR	SF	AG	IQI	M1
10	5.1765	105.0805	8.1715	9.6154	0.9997	2.8557
50	5.2931	105.1690	8.1235	14.4545	0.9997	2.5688
100	5.2846	105.2420	8.1392	14.3323	0.9997	2.5693
500	5.3340	105.1486	8.1192	14.6925	0.9997	2.5682
1000	5.3687	105.1405	8.1053	14.5219	0.9997	2.5675

VI. CONCLUSIONS

Image fusion increases the information contents in fused image. The analysis of fused image is done using visual inspection and by finding performance parameters. Visual inspection describes that fused image is better than either input images. It gives more information. Performance parameters i.e. RMSE and PSNR are better using genetic algorithm than other fusion techniques. As fitness function is considering only RMSE, the value of this parameter is far better. From visual inspection, transform techniques are also giving better performance for remaining parameters. In subjective analysis, KWT is giving good fused image. Thus in future, hybrid method can be used which combines the performance of transform technique and genetic algorithm. And by including multiple parameters in fitness function, other parameters can also improve.

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REFERENCES

[1] Chaunte W. Lacewell, et.al. 2010. Optimization of image fusion using genetic algorithm and discrete wavelet transform. National Aerospace and Electronics Conference.

[2] Liu Cao, et. al. 2015. Multifocus image fusion based on spatial frequency in discrete cosine transform domain. IEEE Signal Processing Letters, vol. 22, no.2.

[3] H. B. Kekre, et. al. 2013. Review on image fusion technique and performance evaluation parameters. International Journal of Engineering Science and Technology, vol. 5, no. 4, pp. 880-889.

[4] Arash Golibagh Mahyari and Mehran Yazdi, 2011. Panchromatic and multispectral image fusion based on maximization of both spectral and spatial similarities. IEEE Transactions on Geoscience and Remote Sensing, vol. 49, no. 6.

[5] Richa Gupta and Deepak Awasthi, 2014. Wave-packet image fusion technique based on Genetic Algorithm. IEEE International Conference on Confluence the Next Generation Information Technology Summit, pp. 280-285.

[6] Mantas Paulinas and Andrius Usinskas, 2007. A survey of genetic algorithms applications for image enhancement and segmentation. Information Technology and Control, vol. 36, no. 3, pp. 278-284.

[7] Aqeel Mumtaz, et. al. 2008. Genetic algorithms and its application to image Fusion. IEEE International Conference on Emerging Technologies.

[8] Srinivasa Rao Dammavalam, et. al. 2012. Quality assessment of pixel level image fusion using fuzzy logic. International Journal on Soft Computing. vol.3, no.1.

[9] Mohamad Awal, et. al. 2008. Enhancement of the segmentation process of multicomponent images using fusion with genetic algorithm. IEEE International Multi-Conference on Systems, Signals and Devices.

[10] Anil Kumbhar, et. al. 2013. Fusion of multiple features in magnetic resonant image segmentation using genetic algorithm. 3rd IEEE International Advance Computing Conference, pp. 811-816.

[11] Liang Hong,et. al. 2009. Fusion of infrared and visible image based on genetic algorithm and data assimilation. IEEE International Workshop on Intelligent Systems and Applications.

[12] Arpita Das and Mahua Bhattacharya. 2009. Evolutionary algorithm based automated medical image fusion technique: comparative study with fuzzy fusion approach. 2009 World Congress on Nature & Biologically Inspired Computing.

[13] Jyoti Kulkarni, Dr. Rajankumar S. Bichkar. 2015. A Survey of Image Fusion using Genetic Algorithm. International Journal of Computer Applications, Proceedings NCAC 2015 *(6)*, pp.33-35.

[14] Jyoti Kulkarni, Dr. Rajankumar S. Bichkar. 2017. Image fusion using genetic algorithm and different transform techniques. International conference on Signal processing, Computing and Networking,

[15] Jyoti Kulkarni, Dr. Rajankumar S. Bichkar. Comparative analysis of image fusion using DCT, DST, DWT, Walsh transform and Kekre's wavelet transform. Advances in Intelligent Systems and Computing (Springer), Vol. 632, Ch.22, 978-981-10-5520-1_22, pp: 227-232.

[16] Nupoor Prasad, et. al. 2001. Evaluation of various image fusion techniques and imaging scales for forest features interpretation. Current Science, vol. 81, no. 9.

[17] Qiang Wang, et. al. 2004. Fast Quantitative Correlation Analysis and Information Deviation Analysis for Evaluating the Performances of Image Fusion Techniques. IEEE Transactions on instrumentation and measurement, vol. 53, no. 5.

[18] Igor V. Maslov and Izidor Gertner. 2006. Multi-sensor fusion: an Evolutionary algorithm approach. Elsevier journal on Information Fusion, 7(2006), pp. 304-330.

[19] Veysel Aslants and Rifat Kurban. 2009. Extending Depth-of-field by Image Fusion using Multi-objective Genetic Algorithm. 7th IEEE International Conference on Industrial Informatics.

[20] Vaibhav R. Pandit, and R. J. Bhiwani. 2015. Image Fusion in Remote Sensing Applications: A Review. International Journal of Computer Applications, vol.120, no.10, pp:22-32

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