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Multi-focus Digital Image Fusion Using Multi-Scale Wavelet Decomposition Scheme

Priti N. Makode[1], Avinash P. Wadhe[2]

[1]*ME Student, Department of Computer Science and Engineering, G.H. Raisoni College of Engineering & Management, Amravati, Maharashtra, India*

[2]*Assistant Professor, Department of Computer Science and Engineering, G.H. Raisoni College of Engineering & Management, Amravati, Maharashtra, India*

Abstract — ***The successful fusion of images acquired from different modalities or instruments is of great importance in many applications such as medical imaging microscopic imaging remote sensing computer vision and robotics. Optical imaging cameras suffer from the problem of limited depth-of-field of optical lenses, so it is difficult to get an image with all objects in focus. One way to overcome this problem is by using multi-focus image fusion technique, in which several images with different focus points are combined to form a single image with all objects fully focused. So, it is crucial to effectively extract the image information of the original images and reasonably combine them into the final fusion image. Image fusion is a process of combining relevant information from two or more images into a single informative image. The term image fusion refers to integration of information from different images of same object. The resulting fused output will be more clear and informative than the inputs. This paper proposes an efficient image fusion method based on different Multi-scale image wavelet decomposition techniques. Also quality assessment of fused images analyzes which overcome by our proposed method with better outcomes.***

Keywords- Image Fusion, Wavelet Decomposition Techniques, Quality Assessment, Multi Focus Images

I. INTRODUCTION

Nowadays, image fusion has become an important subarea of image processing. For one object or scene, multiple Images can be taken from one or multiple sensors. These images usually contain complete information. Image fusion is the process of detecting salient features in the source images and fusing these details to a synthetic image. Through image fusion, extended or enhanced information content can be obtained in the composite image, which has many application fields, such as digital imaging, medical imaging, remote sensing, and machine vision. As an example of fusion that is relevant to this paper, optica imaging cameras suffer from the problem of finite depth of field, which cannot make objects at various distances (from the sensor) all in focus. Therefore, if one object in the scene is in focus, then the other objects at different distances from the camera will be out of focus and, thus, blurred. Many satellite sensors provide both high-spatial-resolution panchromatic (Pan) images and low-spatial-resolution multispectral (MS) images. An image with high spatial and spectral resolution is necessary for many remote sensing. Many image fusion algorithms have been developed to merge a Pan image and an MS image into an MS image with high spatial and spectral resolution

In satellite imaging, two types of images are available.

1. Panchromatic images (PAN): An image collected in the broad visual wavelength range. in PAN mode, the image is acquired with high spatial resolution and depends on the type of the satellite. For example, lm pixel (IKONOS) [5].
2. Multispectral images (MS): An image optically acquired in more than one spectral or wavelength interval. In MS mode, the image is acquired with much lower spatial resolution and depends on the type of the satellite. For example, 4m pixel (IKONOS) [5].

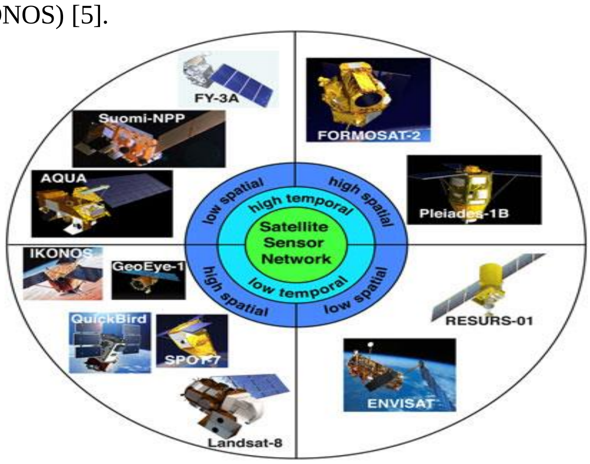

Figure1: Space borne sensors.

Proposed Multifocus image fusion based on wavelet transform. In the wavelet transform image fusion method the panchromatic and multispectral images are decomposed into coefficients specific levels using different wavelet transform. All coefficients are combined using fusion rule and finally taking inverse wavelet transform to obtain the original image. The resulting fused output will be more clear and informative than the inputs. The primary objective of multifocus image fusion is to integrate distinct features from different images to obtain more information than can be retrieved from each of the single images alone, the primary goal of this paper is to develop a new method for fusing the Daubechies SWT and Symlet SWT. More details will be provided to show how well the proposed layer-based approach overcomes the discrepancy problem and provides high-quality images with sharp edges [5]. The secondary goal is to show that the proposed layer-based approach can also be applied to another type of image pair.

Image quality assessment plays an important role in the performance of image fusion techniques. Data quality assessment is a key issue in order to broaden the applicability of image fusion image fusion to unconstrained imagining conditions, the quality factor of individual satellite image by assessing their prominent factors by their scores. There are many factors which may affect the quality of the satellite images. The fusion result is tested on Quick Bird multispectral and panchromatic images. The performance measurement parameters used are: Correlation Coefficient (CC), Root Mean Square Error (RMSE), and Signal to Noise Ratio (SNR), Execution Time, Entrophy, Peak Signal to Noise Ratio (PSNR), and Mean Square Error (MSE).

1.1 Project objective

The objective of the proposed system is to enhance the image fusion method based on different Multi-scale image wavelet decomposition techniques. Also quality assessment of fused images analyzes which overcome by our proposed method with better outcomes.

1. To study about image fusion and its different techniques.
2. To develop an algorithm which will fuse the relevant information of two images?
3. To simulate the designed model.
4. To verify the developed logic operation for various images.
5. To analysis the system performance parameter.

II. LITERATURE REVIEW

Chang-Hwan Son and Xiao-Ping Zhang, proposed new method for decomposing the image pairs into two layers, i.e., the base layer and the detail layer, is proposed for image pair fusion. a local contrast-preserving conversion method is first proposed to create a new base layer of the infrared image, which can have visual appearance similar to another base layer, such as the denoised noisy image. Then, a new way of designing three types of detail layers from the given noisy and infrared images is presented. To estimate the noise-free and unknown detail layer from the three designed detail layers [1].

Mamta Sharma, proposed image fusion for high resolution on panchromatic and multispectral images or real world images for better vision, Various methods of image fusion and some techniques of image fusion such as IHS, PCA, DWT, Laplacian pyramids, Gradient Pyramids, DCT, SF. Several digital image fusion algorithms have been developed in a number of applications [2].

Shashidhar Sonnad, furnish a survey on various image fusion algorithms of MS and PAN images such as, Brovey transform, Intensity- Hue-Saturation(IHS) transform, Principal Component Analysis (PCA), Highpass Filtering, Wavelet transform, Integration of different transform methods with IHS , fusion method based of PCA and feature product of Wavelet transform, Fourier transform, General Intensity- Hue-Saturation (GIHS) transform, Optimal Filter design, modified Wavelet Averaging Merging method and modified Bi-cubic Interpolation method in non Subsampled Contourlet transform, improved IHS and PCA merges based on Wavelet decomposition, etc. the different satellite images used to test the particular methods and different quantitative performance measurement techniques [3].

Suruchi Goyal, Rupinder Wahla, This paper presents a literature review on some of the basic image fusion techniques i.e. wavelet transform image fusion, PCA based image fusion and IHS based image fusion and introduces a hybrid approach which combines PCA, HIS and SWT (Stationary Wavelet Transformation) to get an enhanced fusion image with less possible changes in the pixels and resolution of the images [4].

T.Tirupal, B.Chandra Mohan and S.Srinivas Kumar, In this paper, an efficient method for fusion of multifocus images based on UDWT and contrast visibility is presented. First, the images to be fused are convolved with a predefined kernel then the edge features are extracted and contrast visibility is calculated for the edge features. Finally, the fused image is obtained by merging all edge planes and the residual plane [5].

III. PROPOSED WORK

The main objective in the development of this system is to provide efficient output within reasonable computation time. To achieve these objectives, instead of implementation of any traditional method of image processing, it is proposed to integrate different methodologies for image fusion. The block diagram of proposed system is as follows:

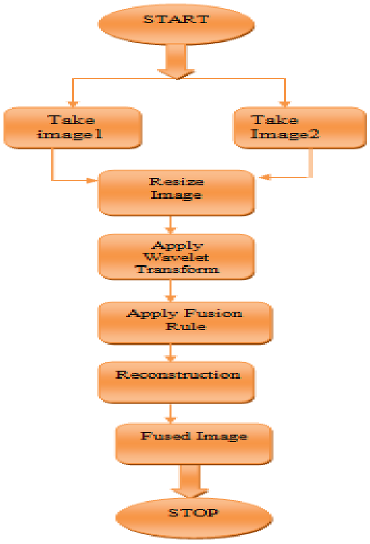

Figure 2 Generic System

The proposed system is divided into five major blocks namely, Input Block, Preprocessing Block, Different Wavelet Transform Block, Fusion Decision Rule Block and Different Inverse Wavelet Transform Block.
The input blocks load the images. It is then forwarded to preprocessing block where these process resizing input images. The Wavelet Transform Block is an integrated methodology implementing the four different Wavelet Transform Technique applying on the resizing images. Namely, Haar DWT, Daubechies SWT, Haar LWT, Hybrid WT. After Wavelet Transform Block next block is the fusion decision block in that block taking largest absolute values of the corresponding wavelet coefficient among input images. Next block is Inverse Wavelet Transform; in which block fused image is reconstructed by inverse wavelet transform from the modified coefficients. Final block is the fused image block, in which we got fused image.

3.1 Wavelet Transform

Wavelet transform is considered as an alternative to the short time Fourier transforms. It is advantageous over Fourier transform in that it provides desired resolution in time domain as well as in frequency domain whereas Fourier transform gives a good resolution in only frequency domain. In Fourier transform, the signal is decomposed into sine waves of different frequencies whereas the wavelet transform decomposes the signal into scaled and shifted forms of the mother wavelet or function. The wavelet transform gives a large number of small coefficients and a small number of large coefficients. Large coefficients mainly represent the signal values and the coefficients with smaller values represent the noise components. In the image fusion using wavelet transform, the input images are decomposed into approximate and informative coefficients using DWT at some specific level. A fusion rule is applied to combine these two coefficients and the resultant image is obtained by taking the inverse wavelet transform. Wavelet transform classified into four categories, namely discrete wavelet transform, Stationary wavelet transform, lifting wavelet transform.

3.2 Discrete Wavelet Transform:

Wavelet method is performed n level of decomposition getting low intensity image and extract the maximum number of feature from the input image. It is famous for its simplicity and speed of computation.
The discrete wavelet transform uses filter banks for the construction of the multi-resolution plane. The DWT uses multi-resolution filter banks and special wavelet filters for the analysis and reconstruction of image. In many image processing applications wavelets plays an important role. In 2-D discrete wavelet transform (DWT) is applying along the rows of image and after those results are decomposed along the columns. The results of this operation gives four decomposed sub band images that are low-low (LL), low-high (LH), high-low (HL), and high-high (HH).

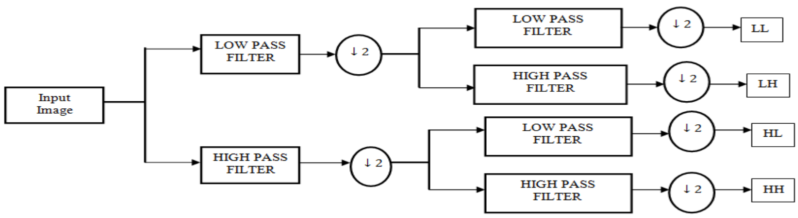

Figure 3: Discrete Wavelet Transform

3.3 Stationary Wavelet Transform:

SWT overcome the lack of translation invariance of the DWT, it is a translated version of DWT. Translation invariance achieved by removing the downsampling and upsampling, SWT is similar to DWT but it does not use downsampling hence the sub bands will have the same size as input image.

The stationary wavelet transform is an extension of the standard discrete wavelet transform. Stationary wavelet transform uses high and low pass filters. SWT apply high and low pass filters to the data at each level and at next stage produces two sequences. The two new sequences are having same length as that of the original sequence. In SWT, instead of decimation we modify the filters at each level by padding them with zeroes. Stationary wavelet transform is computationally more complex. In DWT information loss occurs due to the down sampling in each sub band. Hence to minimize this loss SWT is employed. SWT also decomposes the input image into four sub bands i.e., LL, LH, HL and HH. In which LL is the low frequency sub bands, LH, HL and HH are the high frequency sub bands.

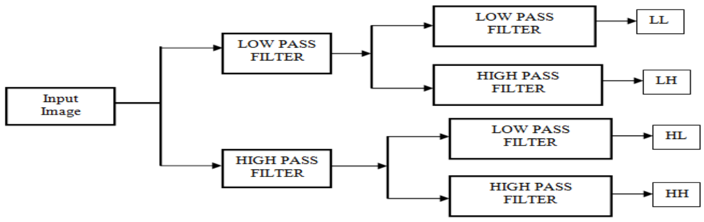

Figure 4: Stationary Wavelet Transform

3.4 Lifting Wavelet Transform:

The main feature of the lifting scheme is that all construction are derived in the spatial domain, it does not require complex mathematical calculation that are required in traditional method. Lifting scheme is simplest and efficient algorithm to calculate wavelet transforms. Lifting scheme is used to generate second generation wavelets, which are not necessarily translation of one particular function, great importance to have a transform algorithm that converts integer to integer. Constructing wavelet using lifting scheme consists of three steps.

- The first step is split phase: in which split data into odd and even sets
- The second step is predict phase: in which odd set is predicted from even sets, predict phase ensure polynomial cancellation in high pass.
- The third step is update phase: update phase that will update even set using wavelet coefficient to calculate scaling function, update stage ensure preservation of moments in low pass.

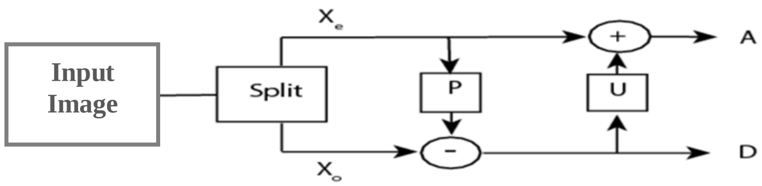

Figure 5 Lifting Wavelet Transform

3.5 Hybrid Wavelet Transform:

A single method of fusion may not be as efficient as it always lacks in one point or the other. Therefore their exists the need of developing a method which takes into consideration the advantages of various different fusion rules. Thus the hybrid image fusion is used. It performs processing of the image based upon the different fusion rules and then integrates these results together to obtain a single image. The results of various fusion techniques are extracted and then they are again fused by implementing a hybrid method presenting better quality results. In the hybrid method first the decomposition of the input images is done up to level N by passing the image through series of low and high pass filters. The low and high pass bands are then subjected to wavelet transform by decomposing it further into small tiles and then fused using wavelet transform and inverse wavelet transform to get full size images.

In the hybrid wavelet transform, we are applying two different wavelet families on our input images.

- Daubechies Stationary Wavelet Transform
- Symlet Stationary Wavelet Transform

Daubechies Stationary Wavelet Transform: The Daubechies wavelets, based on the work of Ingrid Daubechies, are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function which generates an orthogonal multiresolution analysis. In general the Daubechies wavelets are chosen to have the highest number *A* of vanishing moments, Daubechies wavelets are widely used in solving a broad range of problems, e.g. self similarity properties of a signal or fractal problems, signal discontinuities, etc. The Daubechies wavelets are not defined in terms of the resulting scaling and wavelet functions; In fact, they are not possible to write down in closed form. Daubechies orthogonal wavelets D2-D20 resp. db1-db10 is commonly used. The index number refers to the number *N* of coefficients. Each wavelet has a number of zero moments or vanishing moments equal to half the number of coefficients. The lack of the important property of shift invariance, has led to the development of several different versions of a shift invariant (discrete) wavelet transform. Both the scaling sequence (Low Pass Filter) and the wavelet sequence (High Pass Filter) will here be normalized to have summed equal 2 and sum of squares equal 2. In some applications, they are normalised to have sum, so that both sequences and all shifts of them by an even number of coefficients are orthonormal to each other.

Symlet Stationary Wavelet Transform: Symlet SWT are a family of wavelets, they are a modified version of Daubechies wavelet with increased symmetry. Daubechies wavelets are quite asymmetric. To improve symmetry Daubechies proposed Symlet as a modification to her original wavelets. Symlet (symN, where N is the order), also known as Daubechies least asymmetric mother wavelets, are compact supported, orthogonal, continuous, but only nearly symmetric mother wavelets. The purpose was to create wavelets with the same size and same number of vanishing moments as Daubechies, but with near linear phase filters. Symlet have the highest number of vanishing moments for a given support width. Their construction is very similar to the construction of Daubechies wavelets, but the symmetry of Symlet is stronger than the symmetry of Daubechies mother wavelets. Symlet have N=2 vanishing moments, support length N-1 and filter length N.

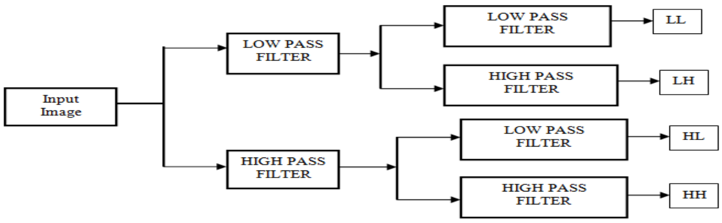

Figure 6: Stationary Wavelet Transform

3.6 Haar Transform:
Haar Transform is the one of the algorithms which is used for Wavelet Analysis. The one of the most advantage of Haar Transform is it's higher value of Peak Signal to Noise ratio(PSNR) can achieved by using Haar Transform. Using Haar lower frequency components are obtained by taking the average of the two pixel values and the lower frequency one is obtained by taking half of the difference of the two pixels. After the first level of decomposition we will get four bands LL, LH, HL and HH. Out of these four bands the LL band; the lower frequency band contains most of the information. The other three higher frequency bands are having only less information like edge details of the image. The four bands of first level decomposition is as shown in Fig 5.6.

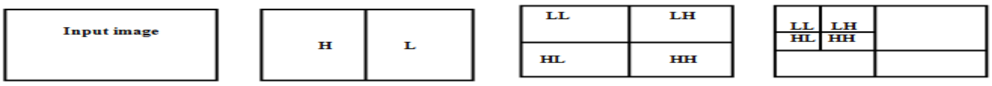

Figure 7: Wavelet Bands after second Level Decomposition.

3.7 Symlet Wavelet:
For this type of wavelets, bases are similar to Daubechies wavelet bases. The difference is Symlet wavelets are symmetric, whereas the Daubechies wavelets have maximal phase, the Symlet have minimal phase. Symlet wavelets are compactly supported wavelets with least symmetry and highest number of vanishing moments for a given support width.

3.8 Daubechies Transform
Daubechies wavelets are a family of orthogonal wavelets and asymmetric in nature. Daubechies defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support.

3.9 Inverse Wavelet Transform:
Final fused image is reconstructed by inverse wavelet transform from the modified coefficients, in the undecimated algorithm; the signal is up sampled after each level of transformation. In the case of a two-dimensional image, which downsamples the approximation coefficients and detail coefficients at each decomposition level, the undecimated wavelet transform (UWT) does not incorporate the downsampling operations. Thus, the approximation coefficients and detail coefficients at each level are the same length as the original signal. The UWT upsamples the coefficients of the lowpass and highpass filters at each level, the resolution of the UWT coefficients decreases with increasing levels of decomposition.

3.10 Fusion Decision Rule
Wavelet transform is first performed on each source images, and then fused decision map is generated based on a set of fusion rules. The fused wavelet coefficient map can be constructed from the wavelet coefficients of the source images according to the fusion decision rule. Finally the fused image is obtained by performing the inverse wavelet transform. We can see that the fusion rules are playing a very important role during the fusion process. When constructing each

wavelet coefficient for the fused image. We will have to determine which source image describes this coefficient better. This information will be kept in the fusion decision map. The fusion decision map has the same size as the original image

IV. RESULT

Table 1: Comparison of Execution Time

EXECUTION TIME				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	1.7834	1.0283	0.3936	0.6483
2.jpg	0.2106	0.7291	0.2573	0.6964
3.jpg	0.2067	0.7270	0.2654	0.6907
4.jpg	0.2453	0.7571	0.0598	0.7274

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 1 shows the HWT method gives less execution time.

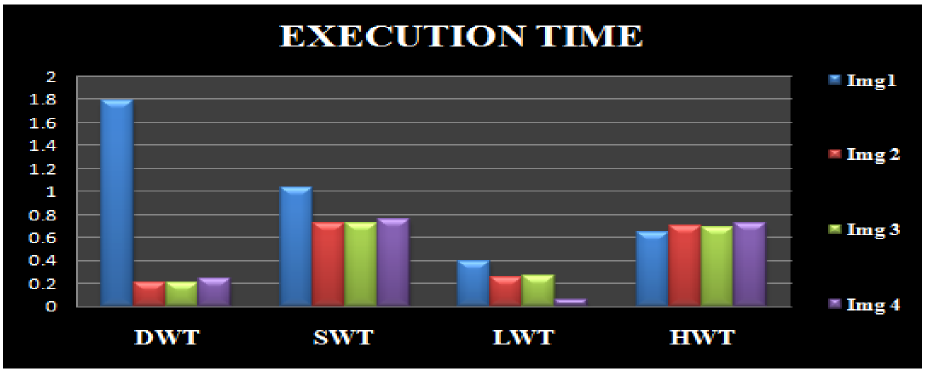

Figure 8: comparison of Execution Time

Table 2: comparison of MSE (Mean Squared Error)

MSE (Mean Squared Error)				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	43.3624	49.1871	42.7825	6.3937
2.jpg	89.4575	92.1593	89.1588	73.5516
3.jpg	136.4623	117.6772	136.0324	111.266
4.jpg	90.6108	83.2463	90.4783	69.2822

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 2 shows the HWT method gives less MSE (Mean Squared Error)

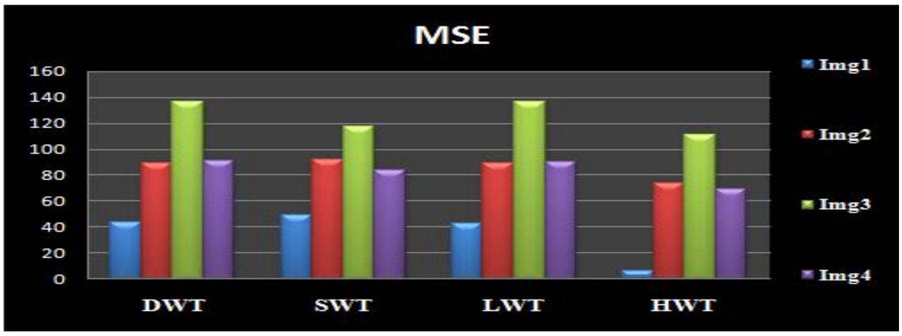

Figure 9: comparison of MSE (Mean Squared Error)

Table 3: Comparison of RMSE (Root Mean Squared Error)

RMSE (Root Mean Squared Error)				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	2.5661	2.6483	2.5575	1.5901
2.jpg	3.0754	3.0984	3.0728	2.9285
3.jpg	3.1479	3.2936	3.4152	3.2478
4.jpg	3.0853	3.0206	3.0842	2.8851

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 3 shows the HWT method gives less RMSE (Root Mean Squared Error).

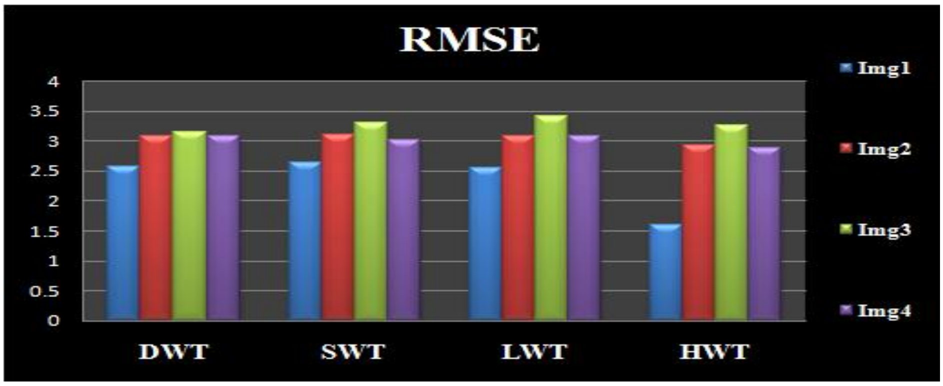

Figure 10: comparison of RMSE (Root Mean Squared Error)

Table 4: Comparison of PSNR (Peak Signal to Noise Ratio)

PSNR (Peak Signal to Noise Ratio)				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	31.7597	31.2123	31.8181	40.0733
2.jpg	28.6146	28.4854	28.6292	29.4649
3.jpg	26.7807	27.4239	26.7944	27.6673
4.jpg	28.5590	28.9272	28.5654	29.7246

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 4 shows the HWT method gives higher PSNR (Peak Signal to Noise Ratio).

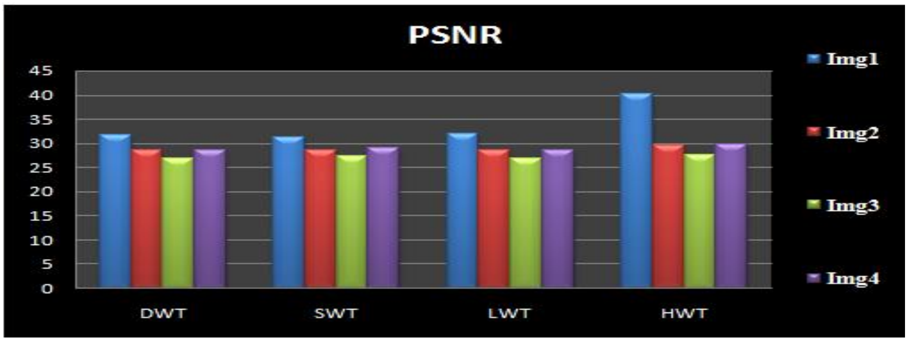

Figure 11: comparison of PSNR (Peak Signal to Noise Ratio)

Table 5: Comparison of Correlation

CORRELATION				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	0.9863	0.9168	0.9863	0.9967
2.jpg	0.8777	0.8437	0.8782	0.9260
3.jpg	0.8232	0.7863	0.8242	0.8913
4.jpg	0.6752	0.6598	0.6746	0.7524

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 5 shows the HWT method gives higher Correlation.

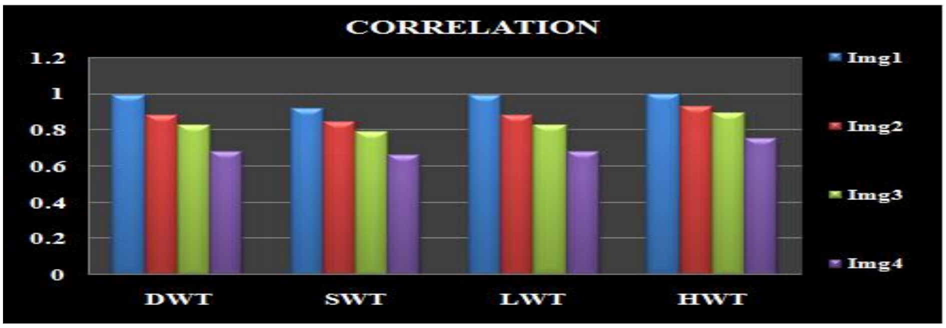

Figure 12: comparison of Correlation

Table 6: Comparison of SNR (Signal to Noise Ratio)

SNR (Signal to Noise Ratio)				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	7.1111	5.1193	7.0033	10.8008
2.jpg	4.2505	4.0224	4.2351	4.8313
3.jpg	6.4681	5.4538	6.4433	6.5636
4.jpg	2.3120	3.4177	2.3130	4.8138

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 6 shows the HWT method gives higher SNR (Signal to Noise Ratio)

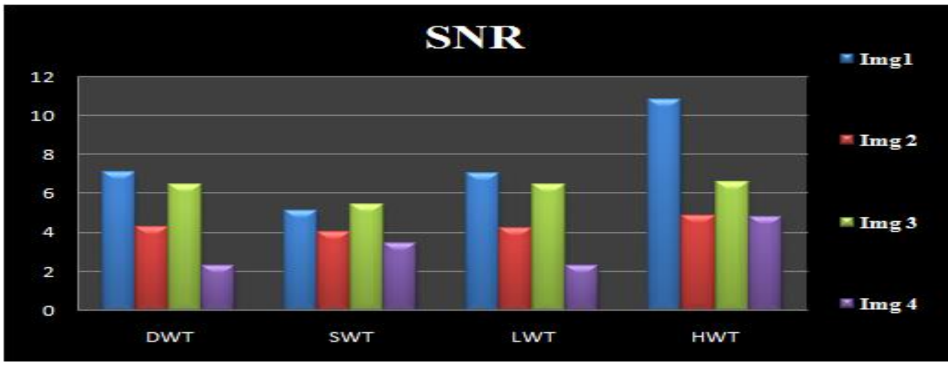

Figure 13: comparison of SNR (Signal to Noise Ratio)

Table 7: Comparison of Entrophy

ENTROPHY				
Name of images	**DWT**	**SWT**	**LWT**	**HWT**
1.jpg	6.5050	6.8476	6.5034	6.6928
2.jpg	7.0466	7.3593	7.0509	7.2056
3.jpg	6.7335	7.1482	6.7384	6.9724
4.jpg	7.0463	7.0269	7.0504	6.8971

In the proposed HWT fusion method is compared with DWT, SWT, LWT methods. Table 7 shows the HWT method gives higher Entrophy.

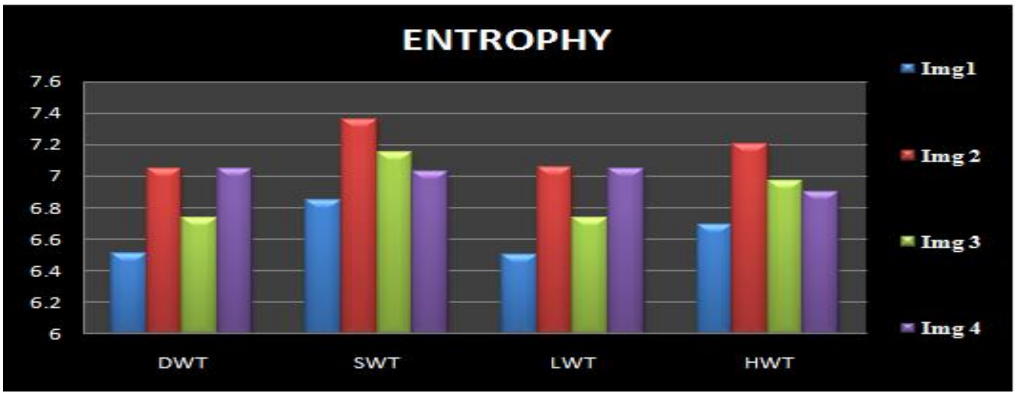

Figure 14 comparison of ENTROPHY

V. CONCLUSION

The system introduced in the proposed work implemented multifocus digital image pair fusion using multiscale image wavelet transforms. This project proposes an image fusion method based on Daubechies SWT and Symlet stationary SWT. Image fusion algorithms based on Daubechies SWT and Symlet SWT was demonstrated. It was observed that fusion using Hybrid with higher levels of decomposition provides better results. Similarly, Hybrid based image fusion produces better quality of fused images compared to Haar DWT, Daubechies SWT, Haar LWT based image fusion algorithm. A Hybrid image fusion algorithm had been developed by combining the features of Daubechies SWT and Symlet SWT. Using these fusion methods, one can enhance the image with high resolution. the Wavelet transforms is the very good technique for the image fusion provide a high quality spectral content. But a good fused image have both quality so the combination of Daubechies SWT and Symlet SWT method fusion algorithm improves the performance as compared to use of individual DWT, SWT, LWT algorithm. Finally this review concludes that a image fusion algorithm based on combination of Daubechies SWT and Symlet SWT will improve the image fusion quality. Finally, the fused compo- nents are combined to generate the all-in-focus image. The results indicate that the proposed fusion approach achieves better quality in comparison to the existing state-of-the-art methods.

REFERENCES

[1] Chang-Hwan Son and Xiao-Ping Zhang, "Layer-Based Approach for Image Pair Fusion," IEEE Transactions on Image Processing, Vol. 25, No. 6, June 2016.

[2] Mamta Sharma, "A Review: Image Fusion Techniques and Applications," (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 7(3), 2016, 1082-1085.

[3] Shashidhar Sonnad, "A Survey on Fusion of Multispectral and Panchromatic Images for High Spatial and Spectral Information," this full-text paper was peer-reviewed and accepted to be Presented at the IEEE WiSPNET 2016 conference.

[4] Suruchi Goyal, Rupinder Wahla, "A Survey on Image Fusion," IJIRCCS, Vol. 3, Issue 8, August 2015.

[5] T.Tirupal, B.Chandra Mohan and S.Srinivas Kumar, "Image Fusion of Natural, Satellite, and Medical Images using Undecimated Discrete Wavelet Transform and Contrast Visibility," National Conference on Recent Advances in Electronics & Computer Engineering, RAECE -2015, Feb.13-15, 2015, IIT Roorkee, India.

[6] Laxman Tawade, Abida Bapu Aboobacker2and Firdos Ghante, "Image Fusion Based on Wavelet Transforms," International Journal of Bio-Science and Bio-Technology Vol.6, No.3 (2014), pp.149-162.

[7] Swathy Nair1, Bindu Elias2 and VPS Naidu, "Pixel Level Image Fusion Using Fuzzylet Fusion Algorithm," IJAREEIE an ISO 3297: 2007 Certified Organization, Vol. 2, SpecialIssue1, December2013.

[8] Deepak Kumar Sahu, M.P. Parsai, "Different Image fusion Techniques-A critical review,"International Journal of Modern Engineering Research (IJMER) Vol. 2, Issue. 5, pp-4298-4301ISSN: 2249-6645, Sep.-Oct. 2012.

[9] Bin Yang and Shutao Li, "Multifocus Image Fusion and Restoration with Sparse Representation," IEEE Transactions on Instrumentation and Measurement, Vol. 59, No. 4, April 2010.

[10] Shuqin Ren, Jian Cheng, Min Li, "Multiresolution Fusion of Pan and Ms Images Based On The Curvelet Transform," 978-1-4244-9566-5/10/$26.00 ©2010 IEEE IGARSS 2010.

[11] Heng Chu and Weile Zhu, "Fusion of IKONOS Satellite Imagery Using IHS Transform and Local Variation," IEEE Geoscience and Remote Sensing Letters, Vol. 5, No. 4, October 2008.

[12] Sheng Zheng, Wen-zhong Shi, Jian Liu, and Jinwen Tian, "Remote Sensing Image Fusion Using Multiscale Mapped LS-SVM," IEEE Transactions On Geoscience And Remote Sensing, Vol. 46, No.5, May 2008.

[13] Zelang Miao, Wenzhong Shi, Alim Samat, Gianni Lisini, and Paolo Gamba, "Information Fusion for Urban Road Extraction from VHR Optical Satellite Images," IEEE Journal of Selected Topics In Applied Earth Observations and Remote Sensing.

[14] Ni-Bin Chang, Kaixu Bai, Sanaz Imen, Chi-Farn Chen, and Wei Gao, "Multisensor Satellite Image Fusion and Networking for All-Weather Environmental Monitoring," this article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of Pagination.

[15] Yashaswini V A, P. Bhuvaneswari, B.Aravind, "Multi Model Image Registration and Fusion using Fast Discrete Contourlet Transform," International Journal of Advanced Networking & Applications (IJANA) ISSN: 0975-0282.

[16] Y. Zhang and G. Hong, "An IHS and Wavelet Integrated Approach to Improve Pan-Sharpenin Visual Quality of Natural Color IKONOS and QuickBird images," Inf. Fus., vol. 6, no. 3, pp. 225–234, 2005.

[17] Gonzalo Pajares, Jesus Manuel De La Cruz, "A Wavelet-Based Image Fusion Tutorial," Pattern Recognition 37 (2004) 1855 – 1872 Accepted 22 March 2004.