A Novel Region based Image Fusion Method using Highboost Filtering and Fuzzy Logic

Tanish Zaveri, Mukesh Zaveri, and Ishit Makwana

***Abstract*—This paper proposes a novel region based image fusion scheme based on high boost filtering concept using discrete wavelet transform. In the recent literature, region based image fusion methods show better performance than pixel based image fusion method. Proposed method is a novel idea which uses high boost filtering concept to get an accurate segmentation using discrete wavelet transform. This concept is used to extract regions form input registered source images which is than compared with different fusion rules. The fusion rule based on spatial frequency and standard deviation is also proposed to fuse multimodality images. The different fusion rules are applied on various categories of input source images and resultant fused image is generated. Proposed method is applied on registered images of multifocus and multimodality images and results are compared using standard reference based and non-reference based image fusion parameters. It has been observed from simulation results that our proposed algorithm is consistent and preserves more information compared to earlier reported pixel based and region based methods.**

***Index Terms*—Normalized cut, discrete wavelet transform, high boost filter, fuzzy logic.**

I. INTRODUCTION

IMAGE fusion is a process of combining multiple input images of the same scene into a single fused image, which preserves full content information and also retaining the important features from each of the original images. There has been a growing interest in the use of multiple sensors to increase the capabilities of intelligent machines and systems. Actually computer systems have been developed that are capable of extracting meaningful information from the recorded data coming from the different sources. The integration of data, recorded from a multisensor system, together with knowledge, is known as data fusion [1, 2, 3, 4, 5, 6]. With the availability of the multisensor data in many fields, such as remote sensing, medical imaging or machine vision; image fusion has emerged as a promising and essential research area. The fused image should have more useful information content compared to the individual image. The different image fusion methods can be evaluated using different fusion parameters [7, 8, 9] and each parameter varies due to different fusion rule effect. In general, the parameter used to design fusion rules is based on experiments or it adaptively changes with the change in image contents so it is very difficult to get the optimal fusion effect which can preserve all important information from the source images. Image fusion system has several advantages over single image source and resultant fused image should have higher signal to noise ratio, increased robustness and reliability in the event of sensor failure, extended parameter coverage and rendering a more complete picture of the system [1]. The fusion of any registered source images can take place using two approaches pixel based or region based.

The simple pixel based image fusion method is to take the average of the source images pixel by pixels which leads to undesired side effects in the resultant image. There are various techniques for image fusion at pixel level available in the literature [2, 4, 5, 6]. The region based algorithm has many advantages over pixel base algorithm like it is less sensitive to noise, better contrast, less affected by misregistration but at the cost of complexity [2]. Recently researchers have recognized that it is more meaningful to combine objects or regions rather than pixels. Piella [3] has proposed a multiresolution region based fusion scheme using link pyramid approach. Recently, Li and young [10] have proposed multifocus image fusion using region segmentation and spatial frequency.

Zhang and Blum [4] proposed a categorization of multiscale decomposition based image fusion schemes for multifocus images. As per the literature [2, 4] large part of research on multiresolution (MR) image fusion has focused on choosing an appropriate representation which facilitates the selection and combination of salient features. The issues to be address are the specific type of MR decomposition like pyramid, wavelet, linear, morphological etc. and the number of decomposition levels. More decomposition levels do not necessarily produces better results [4] but by increasing the analysis depth neighboring features of lower band may overlap. This gives rise to discontinuities in the composite representation and thus introduces distortions, such as blocking effect or ringing artifacts into the fused image. The first level discrete wavelet transform (DWT) based decomposition is used in proposed algorithm to keep it free from disadvantages of Multiscale transform.

In this paper, a novel region based image fusion algorithm is proposed. The proposed method provides powerful framework for region based image fusion method which produces good quality fused image for different categories of images. The novelty of our algorithm lies in the way high boost filtering concept used to segment decomposed images using DWT. The novel fusion rule Mean Max Standard deviation (MMS) is also proposed to measure the activity level between two segmented regions of multimodality images. The normalized cut algorithm [11] is used to segment input images. The paper is organized as follows. Proposed algorithm is described in section II. The brief introduction of reference based and nonreference based image fusion evaluation parameters are

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described brief in section III. The simulation results are depicted in section IV. It is followed by conclusion.

II. PROPOSED ALGORITHM

In this section first framework of proposed region based image fusion method is introduced. The block diagram of proposed algorithm is shown in Fig. 1. Any region based fusion algorithm fusion results are affected by the performance of segmentation algorithm. The proposed algorithm is a novel idea to achieve accurate segmentation using high boost filtering concept. The various segmentation algorithms are available in literature [17] based on thresholding and clustering but the partition criteria used by these algorithms often generates undesired segmented regions. So in this paper, a graph based image segmentation algorithm normalized cut set [11, 16] is used for image segmentation. The idea of graph based image segmentation is that the set of points are represented as a weighted undirected graph [10, 11] where the nodes of the graph are the points in the image. Each pair of nodes is connected by edge and weight on each edge is a function of similarity between nodes. In our method, a strong similarity relation between nodes is established using high boost filtering.

It also desirable to emphasize high frequency components representing the image details without eliminating low frequency components to get an accurate segmentation. In this case, the high-boost filter can be used to enhance high frequency component while still keeping the low frequency components [13]. A high boost filters can be simply defined as a weighted combination of original image and the high pass filtered version of the original image. It improves the similarity and dissimilarity of nodes in the normalized cut set segmentation algorithm which leads to an accurate segmentation. To show the efficacy of using high boost filter in our proposed method, we apply the segmentation algorithm describe in [10] on source pepsi images as shown in Fig. 2 (a) & (b). In that algorithm [10] average of two input pepsi source image is taken as an input to apply normalized cut set segmentation algorithm and results is depicted in Fig. 1(c). For the same source images, the high boost filtered image is obtained after applying DWT [12] and segmentation applied on this image and the output is presented in Fig. 2 (d).

The fused image can be generated by following steps as describe below.

1) The DWT explained in [12] is applied on image IA which gives first level decomposed image of one approximate image ($LL^1{}_A$) and three detail images ($LH^1{}_A$, $HL^1{}_A$, $HH^1{}_A$).
2) The high boost image I_{A1} is generated by adding the scaled approximate image and detail images. The Normalized cut segmentation algorithm is applied on high boost image I_{A1}

$$I_{A1} = K*LL^1{}_A+LH^1{}_A+HL^1{}_A+HH^1{}_A \quad (1)$$

Where $LL^1{}_A$ is first level decomposed approximation image using DWT.$LH^1{}_A$,$HL^1{}_A$,$HH^1{}_A$ are first level decomposed detail images. Here K is weight that is used to scale $LL^1{}_A$ image.

3) The output of segmentation is used to extract regions from original image I_A and high boost image Ia1 generated from $LL^1{}_A$ size is not same. So I_{A1} is upscale to make it equal to the size of original input image which also called as I_{A1}.
4) Then n numbers of segmented regions are extracted from image I_A and I_B using segmented image I_{A1}.
5) These segments are superimposed on I_A and I_B and their corresponding regions are compared based on the parameters spatial frequency and standard deviation.

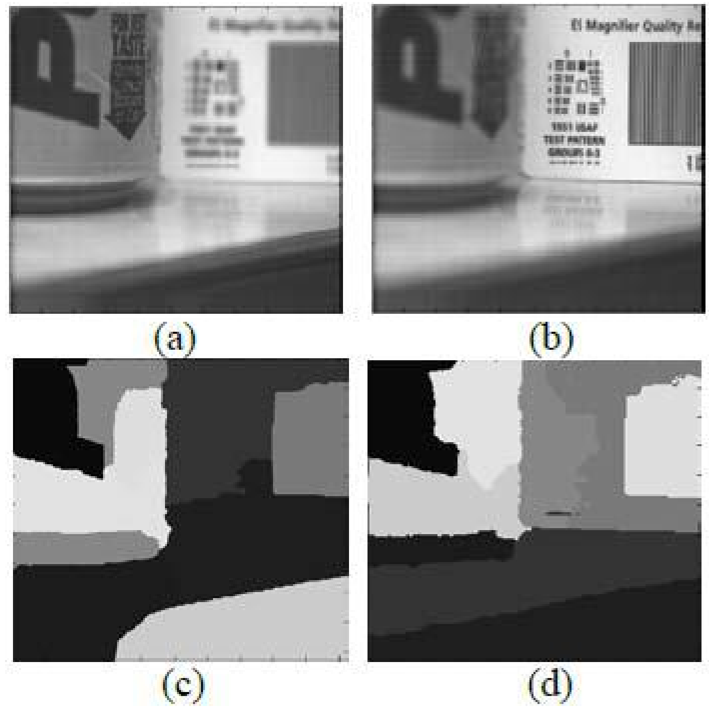

Fig. 2. Segmented Image (a), (b) Multifocus sources of pepsi (c) Using average of both source images as input (b) Using high boost approach

The fusion rule is based on spatial frequency (SF) which is used to identify good region extracted form multifocus source images. The SF is widely used in many literatures [10, 11] to measure the overall clarity of an image or region. The SF is computed according to the details given in [10] to compute the fusion rule. SF parameter presents the quality of details in an image. The higher the value of SF, then more image details will be available in that region extracted. It is used to compare regions of I_{A1} and I_{B1}. Intermediate fused image $I_{A,SF}$ is generated using following fusion rule 1 as described in (2).

$$I_{A,SF} = \begin{cases} R_{An} & SF_{An} \geq SF_{Bn} \\ R_{Bn} & SF_{An} < SF_{Bn} \end{cases} \quad (2)$$

SF of n^{th} region of Image I_A and I_B is defined as SF_{An} and SF_{Bn} respectively. Here n is a number of

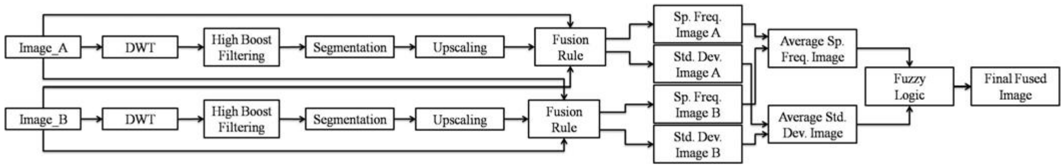

Fig. 1. Block diagram of proposed method

regions and it varies from 1 to i. where n = 1, 2, 3,...i. The value of i equals to 7 determined after analyzing many simulation results. Regions from image I_A and I_B are represented as R_{An} and R_{Bn} respectively. $I_{A,SF}$ is resultant fused image after applying fusion rule as described in (2).

Standard deviation (SD) is also an important parameter for identification of good region in the source images. Higher the value of SD, more is the information content in the region. The fusion rule 2 based on SD is described below

$$I_{A,SD} = \begin{cases} R_{An} & SD_{An} \geq SD_{Bn} \\ R_{Bn} & SD_{An} < SD_{Bn} \end{cases} \quad (3)$$

6) Repeat the steps 1 to 5 for image I_B and generate intermediate fused images $I_{B,SF}$,SF and $I_{B,SD}$.
7) Perform pixel-based average between $I_{A,SF}$ and $I_{B,SF}$ to obtain I_{SF}. Similarly, obtain I_{SD} by performing pixel-based average between $I_{A,SD}$ and $I_{B,SD}$.
8) Apply fuzzy logic based fusion on I_{SF} and I_{SD} to obtain final fused image.

For the fuzzy logic based fusion, the Mamdani fuzzy model is implemented in MATLAB based Fuzzy Inference System (FIS). The spatial frequency parameter is assigned higher priority than standard deviation. Three triangular functions representing low, medium and high values are used as input and output membership functions as shown in Fig. 3. The slope for all the triangular functions is kept constant. The implication method used is MIN (minimum), the aggregation method used is MAX (maximum) and the defuzzification method used is MOM (middle of maximum).

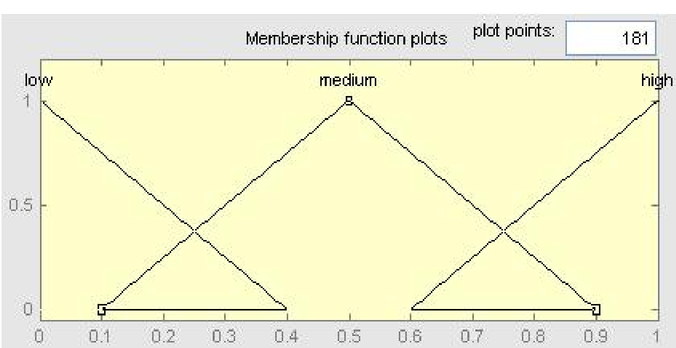

Fig. 3. Input and Output variables as triangular membership functions representing low, medium and high values.

The rules are as follows:

R1: IF Spatial Frequency is Low and Standard Deviation is Low THEN Spatial Frequency is Medium and Standard Deviation is Low.

R2: IF Spatial Frequency is Medium and Standard Deviation is Medium THEN Spatial Frequency is High and Standard Deviation is Low.

R3: IF Spatial Frequency is High and Standard Deviation is High THEN Spatial Frequency is High and Standard Deviation is Medium.

R4: IF Spatial Frequency is Low and Standard Deviation is High THEN Spatial Frequency is Medium and Standard Deviation is Medium.

R5: IF Spatial Frequency is Low and Standard Deviation is Medium THEN Spatial Frequency is Medium and Standard Deviation is Low.

R6: IF Spatial Frequency is Medium and Standard Deviation is Low THEN Spatial Frequency is High and Standard Deviation is Low.

R7: IF Spatial Frequency is Medium and Standard Deviation is High THEN Spatial Frequency is High and Standard Deviation is High.

R8: IF Spatial Frequency is High and Standard Deviation is Low THEN Spatial Frequency is High and Standard Deviation is Low.

R9: IF Spatial Frequency is High and Standard Deviation is Medium THEN Spatial Frequency is High and Standard Deviation is Medium.

Thus, two important activity level measurement feature parameters are considered to compare the details of the regions from both source images. After designing the rules, the impact of input variables on the output variables, is observed in case of each rule, in the rule viewer for MATLAB based fuzzy inference systems as shown in Fig. 4. Similarly the surfaces for different combinations of input variables and output variables are shown in Fig. 5.

This new framework of proposed algorithm avoids the shift variance problem because inverse wavelet transform is

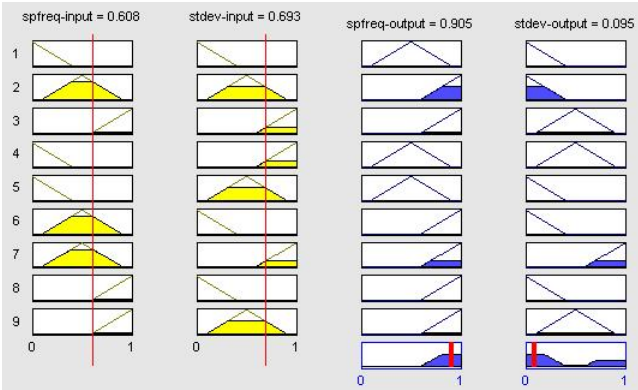

Fig. 4. The Rule Viewer

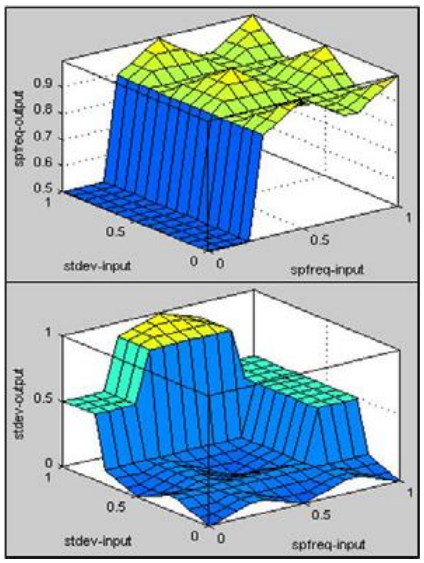

Fig. 5. Surfaces for the fuzzy rules for different input and output variables

not required in our algorithm. The high boost image concept is applied to generate accurate segmented image. The graph theory based normalized cut segmentation algorithm is used in proposed algorithm which can extract the regions from the decomposed image. The activity level measured in each region is decided by the spatial frequency and standard deviation parameter which is used to generate good quality fused image for all categories of multimodality and multifocus images. The next section describes image fusion evaluation criteria in brief.

III. Evaluation Criteria for Fused image

We evaluate our algorithm using two categories of performance evaluation parameters for the set of images which are subjective and objective which may further divided into reference and non reference fused image quality assessment parameters. Fusion performance can be measured correctly by estimating how much information is preserved in the fused image compared to source images.

1) Reference based Image Fusion Parameters Most widely used reference based image fusion performance parameters are Entropy, Structural similarity Matrix (SSIM), Quality Index (QI), Mutual Information (MI), Root mean square error (RMSE). The RMSE and entropy is well known parameter to evaluate the amount of information present in an image explained [14]. Mutual information (MI) indices also used to evaluate the correlative performances of the fused image and the reference image as explained in [9] which is used in this paper as MIr. A higher value of mutual information (MIr) represents more similar the fused image compared to reference image.

The structural similarity index measure (SSIM) proposed by Wang and Bovik [15] is based on the evidence that human visual system is highly adapted to structural information and a loss of structure in fused image is indicating amount of distortion present in fused image. It is designed by modeling any image distortion as a combination of three factors; loss of correlation, radiometric distortion, and contrast distortion as mention in [8, 9]. The dynamic range of SSIM is [-1, 1]. The higher the value of SSIM indicates more similar structures in fused and reference image. If two images are identical, the similarity is maximal and equals 1.

2) Non-Reference based Image Fusion Parameters The Mutual information (MI), the objective image fusion performance metric $Q^{AB/F}$, spatial frequency (SF) [10] and entropy [14] are important image fusion parameters to evaluate quality of fused image when reference image is not available. MI described [8] can also be used without the reference image by computing the MI between reference image I_A and fused image IFUSE called as I_{AF} and similarly find I_{FB} using image I_B as a reference image and calculate total MI as defined by

$$MI = I_{AF} + I_{BF} \quad (4)$$

The objective image fusion performance metric $Q^{AB/F}$ which is proposed by Xydeas and Petrovic [7] reflects the quality of visual information obtained from the fusion of input images and can be used to compare the performance of different image fusion algorithm. The range of $Q^{AB/F}$ is between 0 and 1. The 0 means all information is loss and 1 means all information is preserved.

IV. Experimental Results and Discussion

The novel region based image fusion algorithm described in previous section has been implemented using Matlab 7. The proposed algorithm are applied and evaluated using large number of dataset images which contain broad range of multifocus and multimodality images of various categories like multifocus with only object, object plus text, only text images and multi modality IR (Infrared) and MMW (Millimeter Wave) images to verify the robustness of an algorithm and simulation results are shown in Fig. 3 to 7.

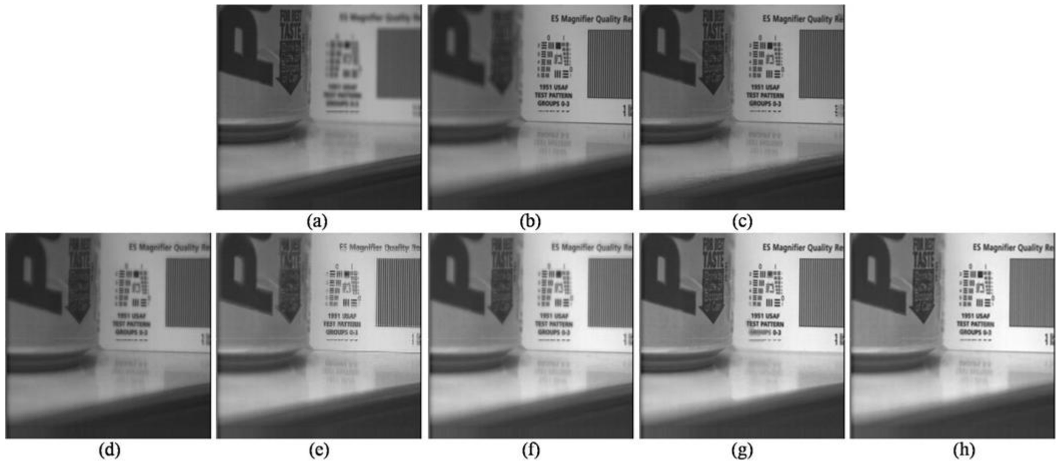

Fig. 6. Fusion results for multifocus image of pepsi (a), (b) are multifocus source images (c) Reference image (d) Fuzzy region feature based method (e)Contourlet transform based method (f) Wavelet transform based method (g) Region based method (h) Proposed method

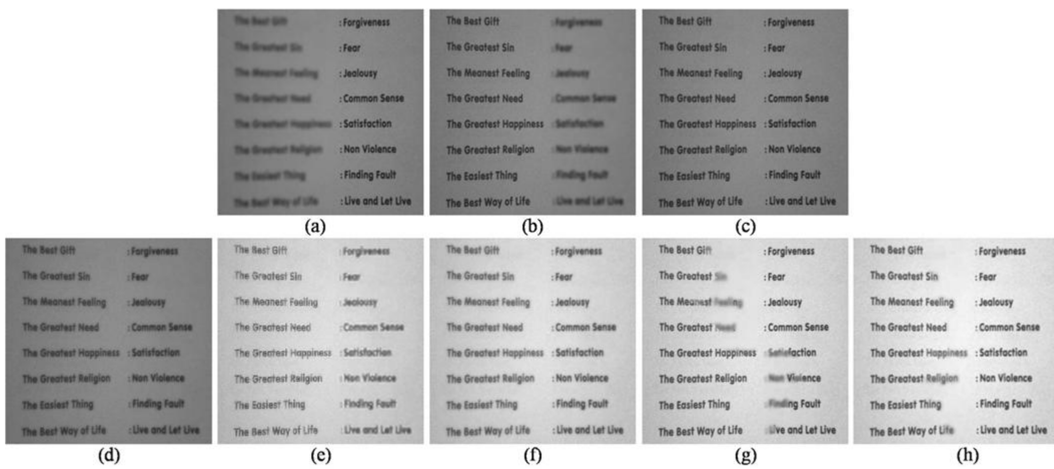

Fig. 7. Fusion results for multifocus image of text (a), (b) are multifocus source images (c) Reference image (d) Fuzzy region feature based method (e) Contourlet transform based method (f) Wavelet transform based method (g) Region based method (h) Proposed method

High boost filtering approach is used to increase the accuracy of segmentation and as described in (1) are used with the K equal to 5 for pair of multimodality images and K equal to 2 for pair of multifocus images. These values are determined after analyzing the simulation results of many experiments which improve the visual quality of final fused image. The performance of proposed algorithm evaluated using standard reference based and non-reference based image fusion evaluation parameters explained in previous section and proposed algorithm simulation results are compared with earlier reported region based [5] and pixel based image fusion algorithm [10] and simulation results are depicted in Table I, II and III.

The multifocus images presented are of two types (1) object plus text image, and (2) only text image, which are shown in Fig. 6 (a) & (b) pepsi image and Fig. 7 (a) & (b) text image, respectively. In Fig. 5 and 6, (a) and (b) are multifocus source images, (c) is the reference image, (d) shows the corresponding fused image obtained by applying fuzzy region feature based method proposed by Liu et al [18], (e) shows the fused image obtained by contourlet transform based method proposed by _, (f) is the fused image obtained by applying pixel based DWT method proposed by Wang [5], (g) region based fusion method proposed by Li and Yang [10] and (f) is the resultant fused image obtained by proposed method. The visual quality of the resultant fused image of proposed algorithm is better than the fused image obtained by other compared methods. The reference based and non reference based image fusion parameters comparisons are depicted in Table I and Table II. All reference based image fusion parameters SF, MIr, RMSE and SSIM are significantly good for proposed algorithm compared to other methods as depicted in Table I. Also non reference based image fusion parameters as depicted in Table II are better than compared methods. In Table II, SF and $Q^{AB/F}$ are remarkably better than other compared fusion methods which also evident from the visual quality of resultant fused image. The simulated results depicted in Table I, II and III shows that proposed method is performing well than other compared methods.

TABLE I
REFERENCE BASED IMAGE FUSION PARAMETERS FOR PEPSI IMAGE

Methods	SSIM	QI	MI	RMSE	PSNR	CC	Sp Freq
Fuzzy Region Feature based [18]	1.0000	0.9313	2.9641	0.0252	29.2128	0.9902	0.0409
Contourlet based [19]	0.9995	0.8733	2.9609	0.1111	19.0878	0.9898	0.0635
DWT based [5]	1.0000	0.9289	2.5808	0.0360	28.8810	0.9893	0.0629
Region based [10]	0.9991	0.8840	3.0049	0.1557	16.1517	0.9957	0.0725
Proposed Method	**1.0000**	**0.9812**	**5.7043**	**0.0183**	**34.7720**	**0.9982**	**0.0844**

TABLE II
NON-REFERENCE BASED IMAGE FUSION PARAMETERS FOR PEPSI IMAGE

Methods	Quabf	MI	Entropy	Sp Freq	TCE	Std Dev
Fuzzy Region Feature based [18]	0.6238	6.1219	**7.5375**	10.4560	1.0760	43.9421
Contourlet based [19]	0.6830	5.7395	7.3974	13.1503	1.2752	44.8867
DWT based [5]	0.6272	5.1146	7.5274	11.6721	1.1292	44.0611
Region based [10]	**0.7732**	5.9490	7.1123	9.8734	**0.0268**	7.4343
Proposed Method	0.7274	**9.9420**	7.5149	**21.5115**	0.0322	**63.1893**

TABLE III
REFERENCE BASED IMAGE FUSION PARAMETERS FOR TEXT IMAGE

Methods	SSIM	QI	MI	RMSE	PSNR	CC	Sp Freq
Fuzzy Region Feature based [18]	1.0000	0.8994	1.9203	0.0227	28.6653	0.9728	0.0254
Contourlet based [19]	0.9969	0.7530	1.5517	0.2874	10.8294	0.9391	0.0497
DWT based [5]	1.0000	0.8861	1.4850	0.0401	27.9391	0.9629	0.0515
Region based [10]	0.9966	0.7775	1.8193	0.3028	10.3778	0.9728	0.0666
Proposed Method	**1.0000**	**0.9792**	**4.5593**	**0.0148**	**36.5677**	**0.9946**	**0.1057**

TABLE IV
NON-REFERENCE BASED IMAGE FUSION PARAMETERS FOR TEXT IMAGE

Methods	Quabf	MI	Entropy	Sp Freq	TCE	Std Dev
Fuzzy Region Feature based [18]	0.5716	4.8970	6.7455	6.5154	1.5969	18.2532
Contourlet based [19]	0.4993	3.3369	6.4854	8.0804	1.5557	16.6404
DWT based [5]	0.5317	3.1937	**6.6600**	8.1956	1.4899	18.3966
Region based [10]	**0.7288**	3.1622	5.6188	17.0029	**0.0296**	33.8218
Proposed Method	0.5907	**8.1945**	6.6427	**26.9570**	0.0851	**35.5435**

V. Conclusion

In this paper, new region based image fusion method using high boost filtering concept is described. This novel idea is applied on large number of dataset of each category and simulation results are found with superior visual quality compared to other earlier reported pixel and region based image fusion method. Here two different fusion rules are applied on broad range of images. The novel MMS fusion rule is introduced to select desired regions from multimodality images. Proposed algorithm is compared with standard reference based and non-reference based image fusion parameters and from simulation and results, it is evident that our proposed algorithm preserves more details in fused image. There are number of other advantages of proposed algorithm (1) The segmentation algorithm is applied on decomposed image which is of less size compared to original image so less computation time required to segment source image (2) As inverse DWT is not required to generate final fused image, so algorithm is free from shift invariance problem (3) Because of high boost filtering approach accurate segmentation is expected so proposed method performance will not degraded as image content change so algorithm is not image content dependent (4) Region based algorithms are less sensitive to noise, misregistration, contrast change so proposed algorithm has this advantage. Algorithm can be further extended by applying it to other categories of images like medical images and satellite images.

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