Asian Journal of Information Technology 15 (3): 384-392, 2016
ISSN: 1682-3915

Fuzzy Based Weight Estimation and Sub Band Architecture in Image Fusion

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Abstract: This research reports on the fuzzy based approach to improve visualization of the image by combing multiple exposure image in to a single high quality image. A fuzzy based luminance correction for weight adoption along with sub band architecture for image decomposition is carried out. The multiple exposure images of low dynamic range of natural scenes are considered as input images. Fuzzy based Weighted Sub banding (FWS) algorithm is proposed for enhancing the fusion method. From multiple exposures input image, the Y, CbCr color model is obtained and the illumination based weight is calculated with fuzzy member function. The proposed method is compared with the existing approaches in terms of saturation, color. Accuracy of the proposed technique is shown with reference to the other methods. The resultant output produced is visually pleasing.

Key words: High dynamic range images, illumination, sub banding, fuzzy membership, exposure fusion

INTRODUCTION

The extraction of information's from several domain is called as image fusion. Images used for the fusion may be multisensory, multi temporal, multi focus or multimodal and multi exposure images from which a single image is obtained with high quality. The quality of the image vary from one to another depending upon the application of the image. Fusion can be effectively used in different areas like in remote sensing with the satellite images with high spectral and spatial resolutions can be combined as single image. Multimodal images like Magnetic Resonance Images (MRI) and Computer Tomography (CT) can be combined to get both bone and flush materials combined together for better identification of doctors. The multi sensory images like visible and infrared images are fused to get the detailed information's from the surveillances and military and security purposes. There are many restrictions like camera response curve in case of the ordinary digital cameras this can be eradicated in case of computational photography. The limited dynamic range of the image depends on the sensor of the camera, the sensor can be of different dynamic range. The higher, the dynamic range the expensive the sensors. The primary goal of digital imaging system is to capture the natural scene with high contrast and dynamic range. The captured scene generally contains both highly and poorly illuminated region. To get the real world scene with high dynamic range, the general approach is to take differently exposed images and the exposure setting of the camera is set to different values. The imaging methodology used for combining this various exposure images in to a single image is called High Dynamic Range (HDR) imaging. The dynamic range of real scene is approximately 10^8: 1. As the development in technology is faster the luminance of HDR image can be presented in low cast devices (Reinhard *et al*., 2005).

Even though, the new specialized devices has been developed, they are not very popular because of their cost and hard ware setup (Seetzen *et al*., 2004). So, the easy method is to capture the series of LDR with normal camera and with the help of changing the response curve of the camera and radiance map the image scan be displayed in LDR device with some of the famous tone mapping operators (Durand and Dorsey, 2002). The tone mapping algorithm produces a HDRI, the computational complexity and the and memory requirement needed is more for the display devices. So, the exposure fusion method is introduced in recent years in which images are fused directly into high quality composite image on low dynamic range devices. When the dynamic range of the fused image is not considered then approaches gives an excellent results but in case of high dynamic range the fusion methods are to be refined with contrast, camera exposure parameter or the weight. In such HDR imaging, the procedure used is to fuse the multiple exposure images in to single image by converting them to radiance map and tone reproduction algorithms helps to enhance the image to high dynamic range images. The reproduction algorithm may be classified as global and

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local tone reproduction algorithms (Punithavathani and Sujatha, 2015). These algorithms uses a non linear curve to map, the pixel values in global, its mapped, it is mapped with less computational intensive but the resultant output is lesser in quality compared with local tone mapping since the apply, the mapping to each and every pixel according to the neighborhood (Schlick, 1995). There are many tone reproduction operators with variation in choosing the neighborhood pixels for reproduction. But in case of exposure fusion, we omit the step of tone reproduction, we directly fuse them into High dynamic range image. There are many researches being carried out in this exposure fusion. Image is divided in to blocks and the fusing takes place with minimal averaging to smoothly combine the best exposed image block as proposed by Goshtasby (2005) fusing takes place with minimal averaging to smoothy combine the best exposed image block as proposed by Goshtasby (2005). A pixel level fusion is proposed by Merten, etc. in which he used the common parameters like contrast of the image, the point of saturation and the camera exposure to generate the weight map. Zhang and Cham (2010) proposed a method where other quality measure like visibility and consistency. A bottom up segmentation algorithm was proposed with super pixels which enables us to detect the changes in every pixels and it can be combined to get a HDR image proposed by Raman, etc. in 2009. Most of the fusion approaches goes with the step of determining the particular value gauge for each pixel of the input and to find the contribution of each pixel in contributing the final image. Some of the basic measures like magnitude of laplacian (Piella, 2009). Learning the procedure in the literatures, a new fuzzy based weight modification by illumination based method named Fuzzy based Weighted Sub banding (FWS) method is proposed. The method the image is converted to YCbCr color model and the weight is modified.

MATERIALS AND METHODS

The fuzzy based weighted sub banding method is used for fusion in the proposed method.

Input images: The multiple exposure images are taken as the input. The sample multiple exposure image is as shown in Fig. 1. The input image can be natural scene or medical image or underwater image. The fusion can be carried out with multi exposure images which are with different exposure time and variable luminance change or images which are taken at different focal length and positions, multi model images like in medical MRI and CT images. The input that has been taken for this proposed method is multi exposure image of natural scenes.

Fig. 1: Multi exposure image of Chinese garden

Problem statement: Combination of multiple exposure LDR image into single HDRI is the fusion procedure. We fuse differently exposure images with the parameters like exposedness, saturation and contrast. The parameters are used to determine the weight of the pixels. The objective of this research is to identify the parametric value which minimizes the false colours there by the fused image looks very naturally-looking with original colours. The colour information ids preserved by unfaltering the colour component of the colour space image.

Illumination preservation: The input image is converted YCbCr color space to modify only on the illumination. The changes in the illumination cannot be done without any assumptions. So, the assumptions are made in order to avoid the smoothness of the filter applied as in that, the surface can reflect the light only which it can shed on it and the estimated illumination is discontinuous in some of the places where the input has discontinuities. This assumption helps to reduce the computational time as proposed with recursive filter in the reference paper. Normally, the computational time increases since the computations are made one dimensional at a time and in four different spatial directions of processing.

Membership function and pixel weight calculations: In order to modify the weight of the image the illumination for each image sequence is computed and the fuzzy membership function is applied to each illumination image. The final image is contains the well suitable weighted pixels. A member ship function is chosen in a such a way it classifies the pixels with reference to the weight whether it is well exposed or under exposed. The fuzzification carried out either based on the threshold (Kimmel *et al*., 2003) or other parameter. The threshold can be fixed as upper and lower threshold and the fuzzification can be performed on every section individually. A threshold fuzzification is obtained with Gaussian membership function threshold. After estimating the illumination £ from every exposure image sequence, the membership function is applied to get the weight. The weight can be as Eq. 1:

$$Wt_{\alpha} = Mr_{\alpha}(£\alpha) \text{for } \alpha\, 1, 2, 3, ..., N \text{Exposures} \quad (1)$$

Where:

(£ α) = Illumination value and

Mr_{α} = The membership function for calculating the illumination

Wt_{α} = The pixel weight matrixes

The objective of this step is to assign the greater weight to those pixels which represents the well exposed image region. After assigning weight to the images they have to be classified as under exposed and over exposed by their weights. The greater weight is considered as over exposed and lesser weight is considered as under exposed. The degree if exposure can be identified by the distance between the middle of the Y channel to the pixel. The input image is converted to RGB to YCbCr transform the general range is from (Shen *et al*., 2011). Under exposed pixel value will be 16 whereas the overexposed will be of 235 and the well exposed may be of 128. A trapezoidal member ship function with can be used. The member function of the image with longest exposure from shortest exposure. So, the pixel interval can be fixed. The pixel with higher weight contributes to the final value, the black color generally accounts to zero and the white color accounts to white the procedure of fuzzy membership threshold results are shown in Fig. 2 and the experiment different dataset with different number of input is used to ensure the clarity of the proposed method. Figure 1 and 2 is the Chinese garden with 3 different exposure one with low contrast and other with high contrast.

Proposed Fuzzy Weighted Sub banding (FWS) approach: As shown in Fig. 3, the exposure fusion has few stages. As first stage, the N input exposure LDR image is taken with RGB colour.

This RGB color id transformed to YCbCr color space so as to separate the illumination. There are so many methods followed to improve the weight of the pixel by processing the various component of the pixel. Intensity enhancement is achieved in HIS color model. The YCbCr color space is a simple linear model from which Y component is used to calculate the weight is computed with fuzzy member function (Fig. 4). The detailed part of the image is separated with sub banding the image with DTDWT.

Fig. 2: Fused Image with proposed method

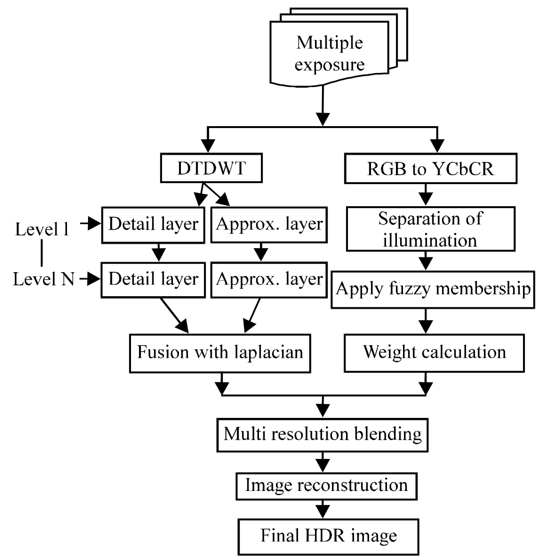

Fig. 3: Proposed approach for fusion frame work

Fig. 4: The fusion results of proposed method with other methods: a) Mertens; b) Shen and c) Proposed

The detailed layer and the approximation layer is obtained and laplacian pyramid is applied to reconstruct the spatial domains. The final image is constructed with blending weight with every level of input of DTDWT using multi resolution spline based scheme (Burt and Adelson, 1983). In the study, the problem statement is precisely discussed and the steps involved in color correction and the illumination enhancement to find the pixel weight with Gaussian membership function.

Sub band architecture: This part of the study describes the over view of the proposed exposure fusion method is presented and the feature of sub band architecture is investigated.

Blending with fusion method: There are many approaches presented for constructing the sub band architecture. In sub banding the filter tree and synthesis tree designing must be carefully handled. These symmetric filters are highly effective in controlling non distortions. Dual tree filter is used to sub band the input. For simplicity, two inputs ($I_1(x_i, y_i)$, $I_2(x_i, y_i)$ are shown in Fig. 4 including over and under exposure images. The input image is split into a set of sub band image ($B_{s1}(x_i, y_i)$ ... $B_{s6}(x_i, y_i)$, $C_{s1}(x_i, y_i)$...$C_{s6}(x_i, y_i)$). The weight map (Wt_α is computed as referred in this study with to guide the blending process of the subband co-efficient so as to get a set of updated sub bands (B_1' (x_i, y_i), ..., B_6' (x_i, y_i), C_1' (x_i, y_i), ... C_6' (x_i, y_i). The gain control maps are (G_1^{ag} (x_i, y_i), ... (G_8^{ag} (x_i, y_i) are calculated according to the fused sub band signals (Fu_i (x_i, y_i), ..., Fu_6 (x_i, y_i) are modified according to those gain control maps so as to get another set of improved sub bands. The final reconstruction result F_R (x_i, y_i) is generated using the synthesis filters of dual tree sub band system.

Laplacian, Gaussian pyramid in fusion: In exposure fusion, the sub band pyramids architecture used for decomposition and reconstruction to get the fuse the final image. The projected algorithm the detail layer at different resolutions are manipulated based on weight map that helps in reconstructing the fused base and approximation layer of the sub band architecture. The summing up of all the spatially banded high pass and low pass bands of each image can be represented in the pyramid expression at each level (Fig. 5). The pyramid representation expresses an image as a sum of spatially band-passed images while retaining the local information's of each band and each level. A pyramid is created by low pass filtering an image G_0 with a compact two-dimensional filter. Sub sampling of the filtered image removes the other pixels to reduce the image to G1 this process is repeated to number of levels that is the same process is continued till the G_d is obtained:

$$G_L(i,j) = \sum_m \sum_m G_{L-1(2i+m,2j+n)}, L = 1,...d \quad (2)$$

where, L (0<L<d) lies between 0 and levels of decomposition. A Laplacian pyramid can be built by decreasing the size and spatial frequency:

$$Lp = G_L - G_{L+1}, L = 1,...d-1 \quad (3)$$

The expanded image G_{L+1} is given by:

$$G_{L+1} = 4\sum_m \sum_n w(m,n)\left[G_L\left(2i+\frac{m}{2}, 2j+\frac{n}{2}\right)\right] \quad (4)$$

The Gaussian pyramid contains the low passed version of the original G_0.

Detail preservation in exposure fusion: We have taken N exposure image in our application, the dual tree sub band decompose the exposure in to (6n+2) N sub band image. In order to simplify the calculations the input images here is considered as two. The blended final image can be obtained F_R (x, y) with the following blending of sub band images:

$$F_i(x_i,y_i) = B'_k(x_i,y_i) + C'_k(x_i,y_i) \quad (5)$$

$$B'_k(x_i,y_i) = Wt_{\alpha i}(x_i,y_i)B_{si}(x_i,y_i) \quad i = 1,2,...,6n+2 \quad (6)$$

$$C'_1(x_i,y_i) = Wt_{\alpha i}(x_i,y_i)C_{si}(x_i,y_i) \quad i = 1,2,...,6n+2 \quad (7)$$

After the gain control map G_1^{ag} (x, y) are the blended sub bands are reconstructed as:

$$F_{ui}(x_i,y_i) = G_1^{ag}(x_i,y_i) \, x \, F_i(x_i,y_i) \quad (8)$$

And, final F_R(x, y) is reconstructed with (Fu_i (x, y), ..., Fu_6 (x, y)) as described in the above section 3. 2. Fusions the sub band pyramid for decomposition and reconstruction applied to get the fuse the final image. Each image sequence is computed and the fuzzy. membership function is applied to each illumination image. The final image is contains the well suitable weighted pixels. A member ship function is chosen in a such a way it classifies the pixels with reference to the weight whether its well exposed or under exposed. The fuzzification carried out sometimes based on the threshold (Kimmel *et al.*, 2003). The threshold can be fixed as upper and lower threshold and the fuzzification can be performed on each region separately.

RESULTS AND DISCUSSION

The technique used for implantation is carried out using MATLAB 7.5.0 in windows 7 platform with 2GB ram of PC. To evaluate the effectiveness the proposed method is compared with the existing methods where the results

Table 1: Performance compared with proposed method And different approaches in terms of NIQE

	Methods						
LDR sequence	Mertens	1	2	3	4	GFF	Proposed
Aloe	2.99	2.55	2.88	2.77	2.83	2.85	2.85
Tree	1.93	3.09	1.87	1.79	1.75	1.98	2.90
Sofa	3.29	2.55	3.11	3.18	3.05	3.19	3.12
Grand	2.33	3.09	2.27	2.16	2.08	3.12	3.08
Lamp	2.61	2.55	2.53	2.27	2.25	2.24	2.22
Landscape	3.06	3.09	3.00	2.79	2.63	2.98	3.08
Lighthouse	3.40	2.55	3.44	3.09	3.34	3.45	3.46
Wall	2.55	3.09	2.15	2.55	2.29	2.39	3.08
Church	2.79	2.55	1.77	1.98	1.86	1.94	2.70
House	2.52	3.09	2.53	2.33	2.41	3.07	3.05
Average	2.74	2.82	2.55	2.50	2.50	2.70	3.10

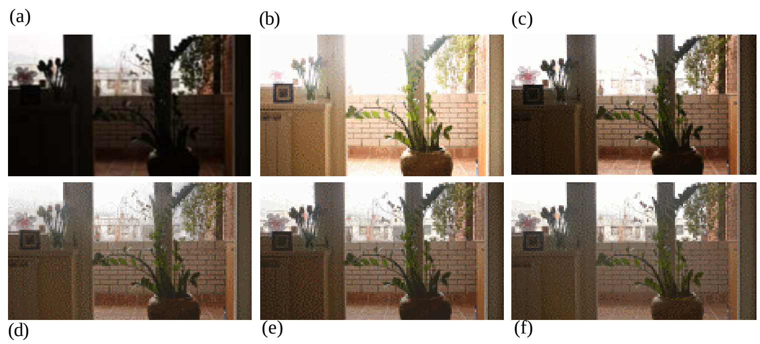

Fig. 5: Comparision with packages; a-c) Multiple exposure image sequence of LDR (images); d) Proposed method; e) Photoshop and f) Photomax

is directly applied as the code is available. The other methods like HMF (Li *et al*., 2012), GFF (Li *et al*., 2013) are implemented and tests results are tabulated. IQA refers to the algorithm which the quality measure of the image with reference as well as no reference (Moorthy and Bovik, 2010). A probability weighted summation is used to compute the final BIQI score. SSIM Index (Wang *et al*., 2004), the saturation and the naturalness image quality evaluator (Mittal *et al*., 2013) are employed for the assessment of experimental results. The comparison of 7 methods are shown in Table 1 (Zhang and Cham, 2010, 2012; Shen *et al*., 2011; Li *et al*., 2012,2013).

The performance of the proposed method is validated and the average of performance is calculated. The results depicts that the overall performance compared with the state of art. In this study, depicts the results of various methods used in the study and the proposed method. The scene includes 10 multiple exposure images few of the images are illuminated with strong light and few with dull illumination. So, far the best results were obtained for the GFF method and weighted filter methods but the sub banding architecture helps to preserve the edges along with saturation levels.

Figure 5 exhibits the results of the readymade packages like photoshop and phomatix with our proposed method. Though the results seems to be similar they have better contrast compared with the two existing method. In Fig. 5, the overall enhancement of the quality of fused image is comparatively enhanced with our proposed method.

Comparison with other fusion method: Figure 6 is the example of multi exposure fusion method and the result obtained from fusion them. Proposed approach reduces the color details and the texture details and also preserves the edge details and reduces the halos in the dark regions. The final output image is the perfect combination of the input image. In the multiple exposure none of the texture details are visible whereas in the fused image the texture of the leafs and the red colour bells with the human are visible. Figure 7, the proposed method is compared with the software packages like Photoshop and Photomatix the results were equally good. As shown in Fig. 8, the sub banding architecture helps in preserving the details of the edge in the fusion which gives the natural colours compared with other methods.

The sub banding architecture with the fuzzy gives an excellent output compared with other methods. The results has to be justified with quantitative and qualitative metrics whichever is feasible. Table 1 represents the performance SSIM index of various methods 10 dataset is chosen and the results are displayed as shown for 6 different methods. It is proved that the average of SSIM is comparatively good. From Table 1, we infer that the

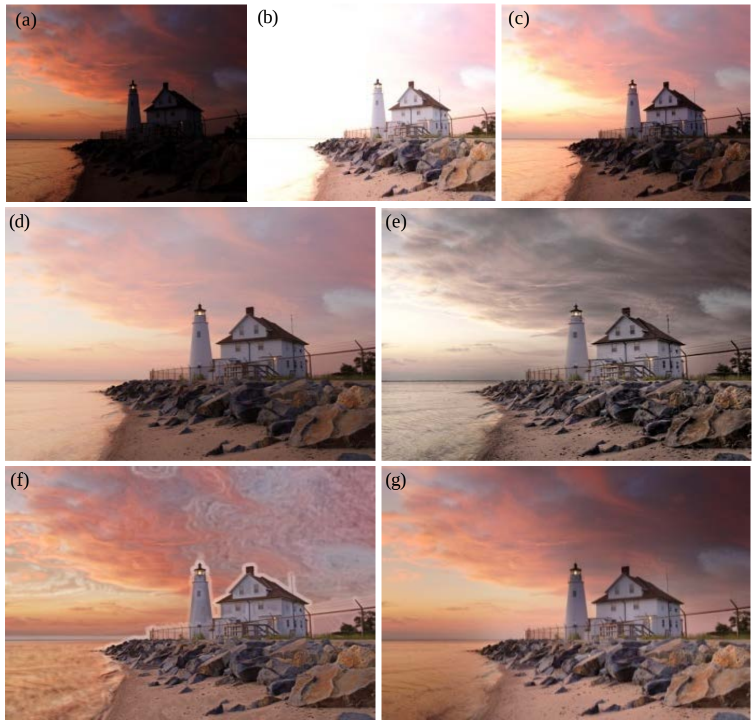

Fig. 6: Fusion with 3 exposure images; a-c) Multi exposure inputs; d) Without fuzzy; e) Without subbanding; f) With fuzzy and g) Proposed method

Table 2: Performance compared with proposed method and different approaches in terms of saturation

	Methods						
LDR sequence	Mertens	1	2	3	4	GFF	Proposed
Aloe	0.33	0.31	0.38	0.33	0.45	0.43	0.45
Tree	0.15	0.13	0.15	0.15	0.18	0.19	0.19
Sofa	0.82	0.78	0.85	0.81	0.87	0.86	0.90
Grand	0.22	0.14	0.22	0.22	0.25	0.26	0.23
Lamp	0.39	0.38	0.39	0.39	0.44	0.47	0.48
Landscape	0.18	0.17	0.16	0.18	0.22	0.21	0.19
Lighthouse	0.39	0.34	0.41	0.39	0.37	0.39	0.36
Wall	0.20	0.11	0.19	0.20	0.17	0.17	0.17
Church	0.64	0.6	0.65	0.64	0.69	0.71	0.76
House	0.33	0.25	0.35	0.33	0.36	0.34	0.35
Average	0.36	0.31	0.37	0.36	0.40	0.40	0.40

the contrast of the image, this can be calculated from the red green blue colour of RGB Model to the input and the obtained fused output to 0-100. The saturation value is taken for ten different dataset and the value is tabulated values of NIQE is a blind image quality metrics for the proposed method is better compared with other methods. Table 2 infers the value of saturation that is equivalent to for six methods and the resultant value obtained for the proposed method is high. In the visible light source, the energy can be expressed as the intensity of light as energy.

The colour depends on the saturation as it increase the appearance is more pure and as it decreases the colour is washed out. Figure 8 gives the fusion of 2 input image with over and under exposed. So, the saturation also plays an important role in the fusion. The parameter chosen for evaluation differs according to the applications.

The fused image quality can be measured with qualitative and quantitative measures. There are few measures made to prove the results to be efficient (Fig. 9).

Illumination estimation with fuzzy membership: Figure 1 and 2 depicts the results of proposed method with other 2 fusion methods. The fusion method identifies the pixel whether it is over exposed or under exposed by using the member functions. The main highlight of this method is that it uses the illumination estimation with gives whether the pixel falls under any one of the region like under over

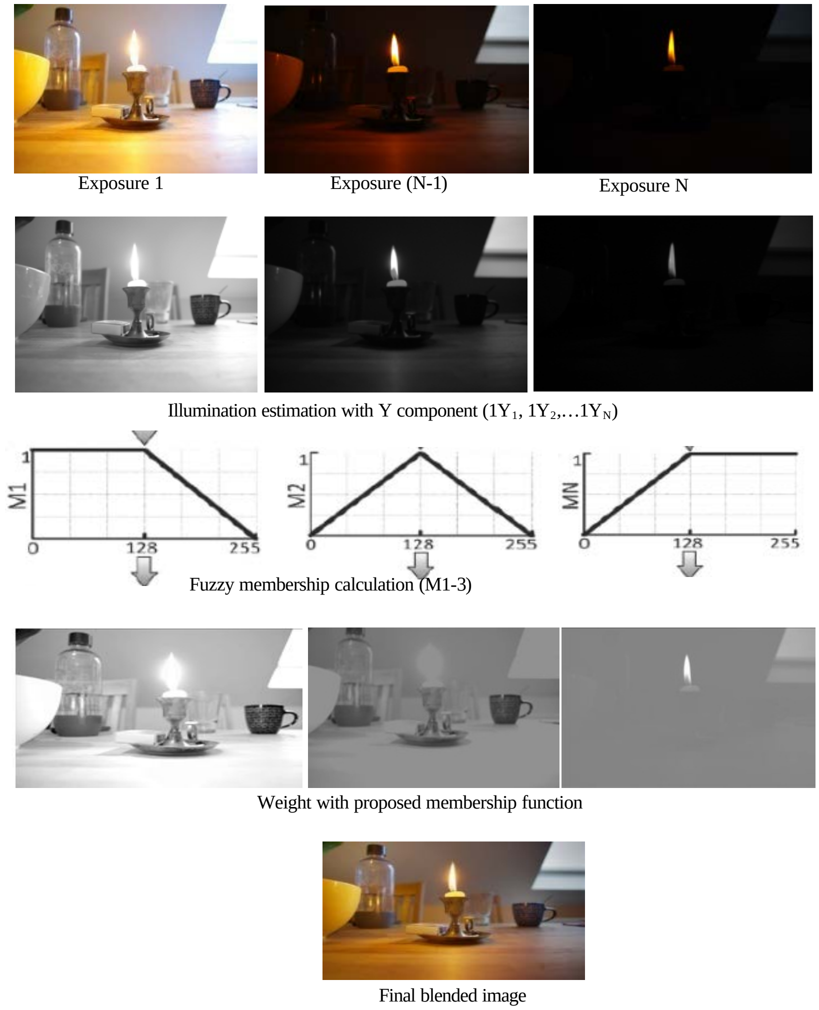

Fig. 7: The steps involved using the fuzzy to optimize the weight value

Fig. 8: Comparison of various method specified in the literature

Table 3: Performance compared with proposed method and different approaches in terms of SSIM (Wang et al., 2004)

	Methods						
LDR sequence	Mertens	1	2	3	4	GFF	Proposed
Aloe	68.20	70.0	71.0	61.2	89.7	76.9	86.40
Tree	70.10	70.3	70.4	67.0	65.0	72.1	72.30
Sofa	61.20	61.4	62.1	57.5	64.1	63.7	66.20
Grand	62.20	62.2	61.5	57.3	73.6	74.3	75.20
Lamp	80.80	81.6	80.5	76.4	79.6	82.1	82.06
Landscape	75.80	72.8	70.9	68.0	80.5	82.6	83.03
Lighthouse	71.10	72.8	70.8	68.0	80.5	69.3	72.30
Wall	59.90	61.1	59.3	59.4	67.4	65.4	64.80
Church	70.30	70.7	70.9	63.6	67.7	71.3	72.30
House	42.10	43.2	41.9	40.4	51.5	50.6	53.40
Average	66.17	70.0	71.0	61.2	89.7	76.9	90.40

(a)

(b)

(c)

Fig. 9: a, b) Input images without and flash and c) fused image

and well exposed. According to the degree illumination, the weight of pixels of well exposed part contribute to the final image. Figure 5 compares the proposed method with the visual similarity between the commercial packages like photomap and photoshop. The color contrast and the saturation are very clearly enhanced and it provides a clear pleasing enhanced of the images. Here, only 3 input images are taken for fusion. Though, it is difficult to conclude only with the images seen as the output. They have to be justified with the subjective and objective quality measures. The metrics are accurate and the results are tabulated in Table 2-3. The luminance is preserved in the fuzzy based method. When, the histogram of the original image of ground truth is comparatively similar with the proposed method. So, the pixel based measurement like MI which helps to find the features of boundaries and edges in the high frequency bands, since the proposed method uses the dual tree for sub banding the high frequency bands when the input images are sub banded and applied fuzzy rules the results have clarity in the output. Figure 6, the 3 inputs are taken for experiment and the results are as shown. Figure 6a-d is the three input images, the fusion is carried out without the fuzzy application the image in the darker pixels near the sky does not have clearity. Figure 6e, f gives the false color only when the fuzzy is applied without subbanding. Figure 6g gives the best results with proposed method.

CONCLUSION

Image fusion has been an active research topic in the past decade and a significant number of image fusion methods have been proposed. The illumination plays a vital role in estimating the weight with fuzzy member function. The dark pixel with longer exposure and the light pixel with shorter exposure also contribute to the final image. The classification of well exposed pixel is weighted and they contribute in the reconstruction of the final fused image. Fuzzy based weighted sub banding architecture results make obvious that the algorithm can effectively dig out the salient information from the source images and well combine them. Based on Table 3 results, the objective performance measures of the proposed method are better than those of the compared approaches. In future, the research will be extended to form a fuzzy rule to fix the thresholds.

ACKNOWLEDGEMENTS

Researcher thank my reach centre Government College of Engineering Tirunelveli and the Dc members P. Latha and A. Sivanantharaja for their constant support during my research period.

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