Quality Assessment for Multi-Exposure Multi-Focus Image Fusion

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Abstract- *Image fusion is a procedure of joining various images, into a solitary image that contains a bigger number of subtle elements than the info images for human visual observation or PC preparing errands. The techniques to objectively assess the nature of fused images have not been legitimately comprehended. Target evaluation is a troublesome assignment due to the wide range of necessities and the absence of plainly characterized certainties. Here we play out a strategy for objective quality assessment for multi-exposure multi-focus image combination based around the assessment of three key components of fused image quality – contrast preservation, sharpness, and structure preservation*

Keywords- Contrast preservation, Fusion Quality Index, Image fusion, Objective Assessment, Sharpness preservation, Structure Preservation.

I. INTRODUCTION

The goal of image combination is to coordinate data from numerous information images to make an intertwined image which contains more data for human or image discernment when contrasted with some other information images.[1],[2],[3]. The far reaching utilization of image combination strategies, in military applications, in observation, in restorative diagnostics, and so on, has prompted a rising interest of related quality evaluation instruments keeping in mind the end goal to contrast the outcomes got and diverse calculations or to get an ideal setting of parameters for a particular combination calculation [4]. In remote sensing and in cosmology, multisensory combination is utilized to accomplish high spatial and ghostly resolutions by joining images from two sensors, one of which has high spatial determination and the other one high ghastly determination. Various combination applications have showed up in therapeutic imaging like contrast assessment of CT, MRI, or potentially PET images. A lot of uses which utilize multi sensor combination of noticeable and infrared images have showed up in military, security, and reconnaissance territories. Image combination procedures are likewise broadly utilized as a part of building high dynamic range (HDR) images by joining various low dynamic range (LDR) images taken with various exposures [5]. These HDR images are helpful in numerous applications incorporating into vehicle cameras, observation in night vision, camera-guided air ship docking, high-differentiate photograph advancement, and robot vision. Optical focal points of imaging sensors, particularly those with long central lengths, just have restricted profundities of field. Therefore, iit is difficult to have all articles with fundamentally extraordinary separations from the sensor to be in great concentration in the meantime. Along these lines, another generally perceived utilization of image combination is to blend numerous images of a similar scene yet with various concentration focuses. Such multi-focus image combination techniques that well-save significant data from the first information is profoundly attractive in numerous machine vision and image preparing assignments.

Because of the expansive number of utilizations and the decent variety of combination procedures, significant endeavors have been made to create target execution measures for image combination. Generally, the appraisal of a combination conspire is done by subjective assessment, which is known to be moderate, costly, and above all, can't be implanted into mechanized structures for framework and parameter enhancements. A profitable contrasting option to subjective assessment is target image combination measures that are reliable with human visual perception. The appraisal and blend of the three basic and corresponding components lead us to a novel Fusion Quality Index (FQI). The motivation behind the present work is to build up a target quality model for multi-exposure multi-focus image combination. The general approach of our technique is to isolate the issue into the evaluation of three imperative parameters of fused image - contrast preservation, sharpness, and structure preservation.

II. OBJECTIVE QUALITY ASSESSMENT METHOD

As cameras have a fixed focal length when an image contains objects in various separations the camera profundity of-field is constrained, making a few questions in the scene be out-of-focus. In some different situations when the luminance of a scene changes drastically crosswise over spatial areas huge data misfortune in the darkest as well as brightest districts, recorded as underexposed or overexposed values.

These two normal sorts of issue in photography can be alleviated with image fusion. Cases of sets of images with synchronous multi-exposure and multi-focus impacts are appeared in Fig. 1. Also, Fig. 2.

The assignment is to incorporate information images with various central focuses as well as various exposures to create one fused image with more keen highlights and clearer basic subtle elements when contrasted with the source images. Accept we have L input images {Al} = {A1, A2,A3,… … .AL} which are combined to create image F. We found that three attributes contrast preservation, sharpness, and structure conservation is fundamentally essential in representing the visual nature of F given {Al}.

Fig. 1. Multi-Exposure Image

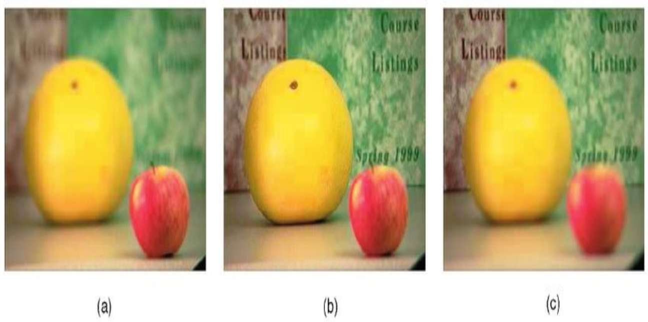

Fig 2. Multi-focus Image

A. Contrast Preservation Assessment

Simple Basic strategy is to incorporate the foundation luminance in the whole condition as the normalized factor for contrast preservation. This prompts applying a similar normalized factor to wherever in the image. Utilizing just the standard deviation without a normalized factor prompts a basic, helpful, and strong neighborhood contrast measure. We will measure contrast preservation locally utilizing a sliding window approach, which brings about a guide that shows the spatial variety of local contrast preservation. The inconvenience is that on account of numerous information images, various info image patches are accessible at each spatial area, which may have distinctive differences in contrast. A helpful suspicion is that the info image fix that has the most noteworthy contrast is the most instructive, and the differentiation of the fused image fix ought to be near the difference of the most informative image fix. Figure 3. Shows the procedure of the proposed contrast preservation strategy together with image cases for the instance of two info images. Let us suppose $a_{l;k}$ and f_k be the k-th image patches of the l-th input and fused images, respectively. The local contrast similarity assessment function is defined as

$$c(\{a_{l,k}\}; f_k) = \frac{2\sigma_{f_k}\max\{\sigma_{a_{l,k}}\}+c_1}{\sigma_{f_k}{}^2+\left(\max\{\sigma_{a_{l,k}}\}\right)^2+c_1} \quad (1)$$

where $\boldsymbol{\sigma}_{al;k}$, and $\boldsymbol{\sigma}_{fk}$ are the standard deviations of local image patches in the l-th input and fused images, respectively, max $\{\boldsymbol{\sigma}_{al;k}\}$ is the maximum standard deviation of all $\boldsymbol{\sigma}_{al;k}$ for l = 1, 2,……L and C_1 is a positive stabilizing constant. The neighborhood measure is connected utilizing a sliding window that runs over the picture space, prompting a contrast conservation outline limited in the vicinity of 0 and 1, where a higher esteem relates to better difference protection. Averaging is then connected to pool the image into a single contrast preservation measure.

$$Q_c(F|\{A_l\}) = \frac{1}{N}\sum_{k=1}^{N} c(\{a_{l,k}\}; f_k), \quad (2)$$

where N is the total patches

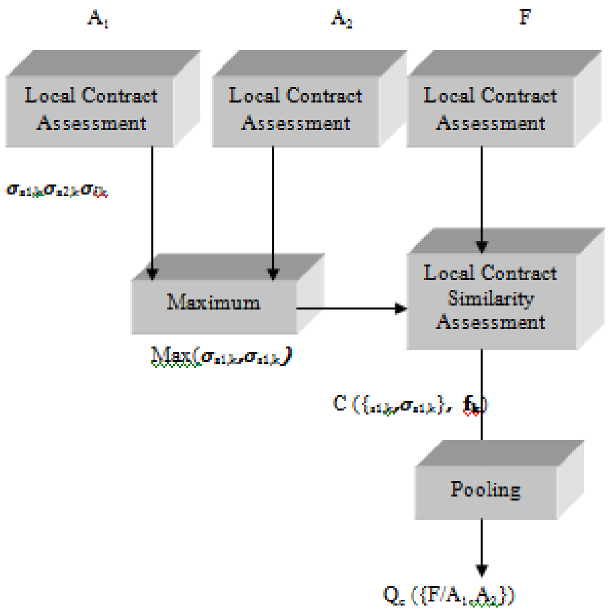

Fig 3: Block diagram for contrast preservation

B. Sharpness Assessment

Sharpness is an imperative determinant in visual view of picture quality. Here we apply the LPC-SI way to deal with the combined picture, which is first gone through a progression of N-scale M-introduction complex log-Gabor channels with no consequent down-sampling process. LPC-SI delivers a thick sharpness map that shows the spatial varieties of perceptual sharpness, an element that is deficient in different sharpness measures [7].Let c_{ijk} be the complex coefficient at the i-th scale, the j-th orientation, and the k- th spatial location. The sharpness measure at the k-th location is given by

$$H_k = \frac{\sum_{j=1}^{M} |c_{1jk}| \cos(\varphi\{\prod_{i=1}^{N} c_{ijk}^{w_i}\})}{\sum_{j=1}^{M} |c_{1jk}| + c_2} , \qquad (3)$$

Where φ{.} is angle of a complex number, w_i is the optimal set of variables to relate the phases across different scales, $\cos(\varphi\{\sum_{i=1}^{N} c_{ijk}^{w_i}\})$ is the phase coherence at the j-th location and the k-th spatial location, and a constant C2 to dodge shakiness if there should arise an occurrence of small coefficients. The sizes of the finest scale coefficients c1jk across various orientation j are utilized as weighting factor, where higher greatness prompts higher weight. The accumulation of LPC measures figured for the fused picture H_k (F) at all spatial areas constitutes a sharpness map of the intertwined picture. The general picture sharpness is found by pooling the LPC values by a weighted averaging of LPC $H_{(k)}$ (F) as

$$Q_{sh}(F) = \frac{\sum_{k=1}^{K} u_k H_k(F)}{\sum_{k=1}^{K} u_k} , \qquad (4)$$

where u_k is the value of the k-th LPC value $H_{(k)}(F)$ and is an exponentially decaying function given by [22]

$$u_k = \exp\left[-\left(\frac{k-1}{K-1}\right)/\beta_k\right] , \qquad (5)$$

which assigns a value 1 to the greatest LPC value and the decaying rate is under the control of parameter β_k. Figure 4 shows the block diagram of the procedure for sharpness assessment process.

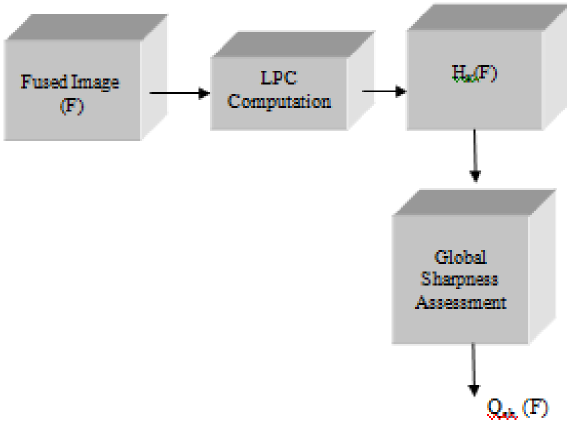

Fig. 4: Framework of sharpness assessment

C. Structure Preservation Assessment

The SSIM strategy gives helpful outline guideline and a straightforward powerful demonstrates to quantify the similarity in structure utilizing a sliding window method with various patches which will prompt a guide that will preserve the structure. Each value is calculated by contrasting the input image and the fused one. Figure 4 demonstrates the procedure of the proposed structure preservation evaluation calculation for two input images. Let $a_{l,k}$, and f_k be the k-th neighborhood image in the l-th input and fused image, separately, the structural fidelity assessment is done for every one of the input image patches and their combination result:

$$S(a_{l,k}, f_k) = \frac{\sigma_{a_{l,k} f_k} + C_3}{\sigma_{a_{l,k}} \sigma_{f_k} + C_3} \qquad (6)$$

Where $\sigma_{a_{l,k} f_k}$ is the cross correlation between the two corresponding patches, $\sigma_{a_{l,k}}$ and σ_{f_k} are the standard deviations of the local image patches, respectively, and C_3 is a constant. The accumulation of $S(a_{l,k}, f_k)$ at all the area will hold the value L structure preservation values that will give the data about structure preservation in the fused picture. Multi-center pictures, there will be opposite sharp regions in multi-center pictures where the regions having more sharper region have a tendency to be in focus and along these lines have a superior structure conservation. We utilize the LPC based sharpness measure to make maps in view of sharpness as in figure 5. These maps are then therefore weighed to discover the structure preservation from both the input pictures. The general structure conservation is given by :

$$Q_s(F\{A_l\}) = \frac{1}{L}\sum_{l=1}^{L} \frac{\sum_{k=1}^{K} H_k(A_l) S(a_{l,k}, f_k)}{\sum_{k=1}^{K} H_k(A_l)} , \qquad (7)$$

Where the LPC map of the l-th input image A_l is given by $H_k(A_l)$. Since the structure preservation value measure is upper-limited by 1, the estimation of $Qs(F|\{A_l\})$ is likewise upper-limited by 1.

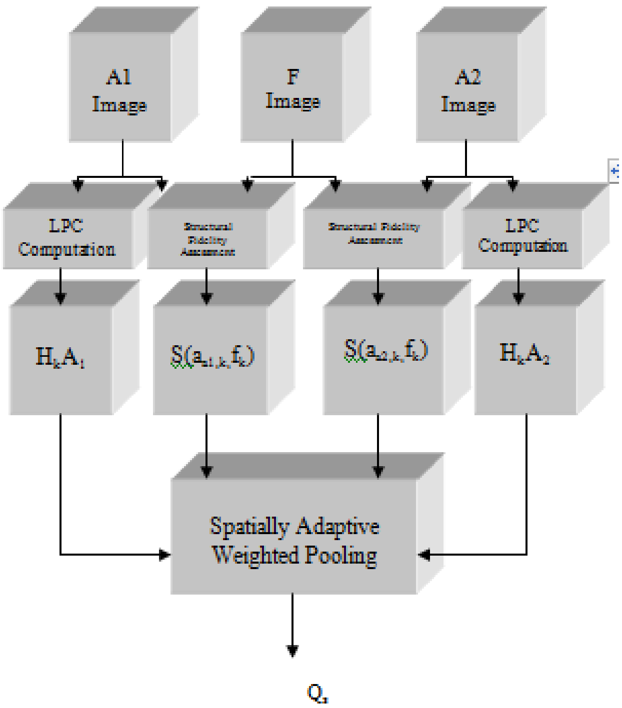

Figure 5: Structure Preservation Assessment block diagram

D. Overall Quality Assessment Value

The qualities acquired above in the contrast preservation, sharpness and structure conservation are summed up to locate the general image fusion quality index (FQI). The FQI esteem is given by

$$Q(F|\{A_l\}) = Q_c(F|\{A_l\}) + Q_{sh}(F) + Q_s(F|\{A_l\}) \quad (8)$$

Since all the three parts acquired i.e. Q_c, Q_{sh}, Q_s are in the vicinity of 1 and 0, the last esteem is additionally in the vicinity of 1 and 0. The esteem 1 compares to idealize contrast preservation, sharpness and structure.

III. SUBJECTIVE QUALITY ASSESSMENT

The picture toward the end is seen by the people along these lines, subjective trial is considered as the most encouraging and dependable technique to locate the nature of melded picture. A few tests have been led utilizing diverse techniques for the assessment of melded picture. Three strategies have been talked about. Two fold jolt straight out rating, constrained decision match insightful correlation and Pair shrewd closeness judgments. The constrained decision correlation strategy was observed to be the most precise among the three strategies. This technique was additionally observed to be the most-time proficient. In this technique, the spectators are demonstrated a couple of pictures (of a similar scene) comparing to various conditions and solicited to show a picture from higher quality.

Table 1: Parameters and FQI value for 3 input images

S.no	Images	Contrast Preservation Assessment	Sharpness Assessment	Structure Preservation Assessment	fusion quality index (FQI)
1.	Balloons	0.6418	5.7614e-06	0.0046	0.6464
2.	Belgium House	0.6354	5.0863e-06	0.0051	0.6405
3.	Cadik Lamp	0.6370	5.0863e-06	0.0042	0.6412
4.	Candle	0.7038	5.3657e-06	0.0186	0.7224
5.	Cave	0.5835	5.0863e-06	0.0095	0.5930
6.	Chinese garden	0.5908	5.7445e-06	0.0100	0.6007
7.	Farmhouse	0.6413	5.7276e-06	0.0073	0.6486
8.	House	0.6340	5.7445e-06	0.0118	0.6459
9.	Kluki	0.6281	5.7276e-06	0.0235	0.6516
10.	Lamp	0.6793	5.7109e-06	0.0245	0.7038
11.	Landscape	0.6732	5.7276e-06	0.0157	0.6889
12.	Lighthouse	0.6617	5.7445e-06	0.0178	0.6796
13.	Madison Capitol	0.6630	5.0863e-06	0.0053	0.6683
14.	Memorial	0.6789	5.7276e-06	0.0085	0.6874
15.	Office	0.6340	5.7445e-06	0.0118	0.6459
16.	Tower	0.6218	5.7276e-06	0.0168	0.6387
17.	Venice	0.6353	5.7276e-06	0.0166	0.6519
18.	Average	0.6437	5.56E-06	0.01244	0.6561

Observers are constantly compelled to pick one picture, regardless of whether they see no distinction between them (in this way a constrained decision plan). There is no time point of confinement or least time to settle on the decision. [6]. To the best of our insight, right now there is no openly accessible subject-appraised picture combination database that can be specifically utilized to test and look at calculations produced for picture combination quality evaluation.

IV. RESULTS FOR OBJECTIVE QUALITY ASSESSMENT

To approve the proposed FQI measure, we initially inspect how the three values . Q_c, Q_{sh}, Q_s changes by using different number of input images. Table I and Table II shows the values of Q_c, Q_{sh}, Q_s and FQI for a total of two and three input images respectively in each case. The average value is computed at the end of the graph. The graph of the tables below are plotted in figure 6 and figure 7 respectively.

The average values for contrast preservation assessment, sharpness assessment, structure preservation assessment and the FQI value were calculated using MATLAB program for eighteen image sets for 3 images each in a set. The average values were found as 0.6437 for contrast preservation assessment, 5.56E-06 for sharpness assessment, 0.01244 for structure preservation assessment and 0.6561 for FQI. The same was repeated again for the same eighteen image sets but this time with two input images was taken an input for fusion. . The average values were found as 0.6632 for contrast preservation assessment, 5.7102E-06 for sharpness assessment, 0.01192 for structure preservation assessment and 0.6752 for FQI.

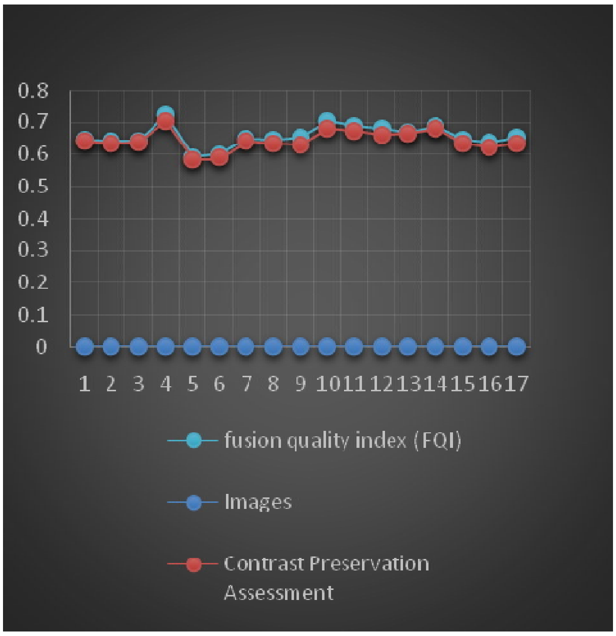

Figure 6: Graph when 3 input images are used

V. CONCLUSION

This method can be applied for objective assessment for multi-exposure multi-focus image fusion. The FQI values are calculated for different set of input images and the multiple number of images are taken as input (The code is verified by taking 1 to N number of images). Then, the average values for the above three parameters are obtained.
The average values are obtained for the two kind of process,

By taking two images as input and By taking three images as input.

The obtained FQI average values are compared in the above two processes. Hence, the FQI value ishigh in the case of two input images.

Obtained FQI values of a set of images is compared with the different quality assessment method values in the base paper. Other assessment methods include NMI, EW-SSIM, EIP, SW-SSIM, ES, MEP, and SWCP. The values for these methods are0.0667, 0.4667, 0.4667, 0.2333, 0.0667, 0.3333, and 0.6000respectively. FQI value was obtained 0.6519 which is greater than all other values. From this comparison we conclude that FQI is a better method for objective assessment of multi exposure, multi focus fused images

Table 2: Parameters and FQI value for 2 input images

S. no	Images	Contrast Preservation Assessment	Sharpness Assessment	Structure Preservation Assessment	fusion quality index (FQI)
1.	Balloons	0.6753	5.7614e-06	0.0044	0.6797
2.	Belgium House	0.6476	5.0863e-06	0.0048	0.6524
3.	Cadik Lamp	0.6650	5.0863e-06	0.0041	0.6691
4.	Candle	0.7146	5.3657e-06	0.0163	0.7309
5.	Cave	0.5912	5.0863e-06	0.0110	0.6022
6.	Chinese garden	0.6001	5.7445e-06	0.0114	0.6115
7.	Farmhouse	0.6912	5.7276e-06	0.0058	0.6970
8.	House	0.6855	5.7445e-06	0.0072	0.6927
9.	Kluki	0.6414	5.7276e-06	0.0170	0.6584
10.	Lamp	0.6835	5.7109e-06	0.0193	0.7028
11.	Landscape	0.6847	5.7276e-06	0.0183	0.7030
12.	Lighthouse	0.6741	5.7445e-06	0.0214	0.6956
13.	MadisonCapitol	0.6854	5.0863e-06	0.0051	0.6905
14.	Memorial	0.6817	5.7276e-06	0.0087	0.6905
15.	Office	0.6855	5.7445e-06	0.0072	0.6927
16.	Tower	0.6304	5.7276e-06	0.0213	0.6516
17.	Venice	0.6377	5.7276e-06	0.0195	0.6572
18.	Average	0.6632	5.7102e-06	0.01192	0.6752

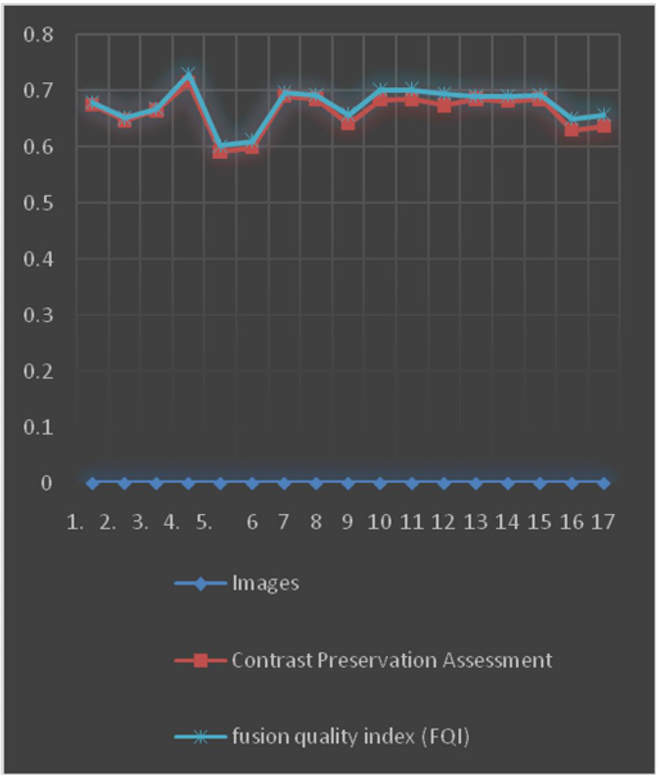

Figure 7: Graph when 2 input images are used

VI. FUTURE ENHANCEMENT

This method has been carried out for grayscale image as calculating the values for RGB image is very complex. So, in the future this project can be done for a 3X3 matrix i.e. RGB image. This method can be applied for high resolution images like satellite image, medical image in the future.

We can use other mathematical parameters such as derivatives or mean values to find contrast, So that better values can be obtained for FQI.

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