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Evaluation of Image Fusion of Multi Focus Images in Spatial and Frequency domain

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ABSTRACT

In the recent past, due to advancement in the image acquisition and storage, number of images captured has increased tremendously. Same scene is captured multiple times, which results in the set of similar images which vary with respect to their geometric or photometric transformation. Image fusion deals with the construction of a single image by integrating the content from set of images belonging to a scene. As the same picture is captured at different focal lengths, the appearance of an object in the image changes. The aim is to select the best portions, to get final informative or revised image. In image fusion process, all the images should be spatially aligned using image registration. We have used feature based registration where in SURF features are extracted from each image and homography found from good matches. Fusion is performed from the set of registered images using spatial and transformation methods. For the selection of the best patch, statistical measures have been used both in spatial and frequency. In the spatial method, we use entropy as a measure for selection and DCT coefficients in transformation. For evaluation, we have used blind-referenced image assessment metrics like EMEE and NIQE.

Keywords: DCT, Evaluation Metrics, Fusion and Homograph, Image Registration, Image matching, SURF.

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I. INTRODUCTION

The goal of image fusion [1][2][3] is to integrate complementary images to get a new single image. Fused image contains more information by electing the best content from the multiple images and it has the more information rather than multiple image sources. Inputs which are taken from the multi sensors, multi temporal and multi view data. **Multi view:** Methods which work on images taken from different views. Applications are in various fields as multi dimensional data analysis [4]. Medical application's [5], remote sensing. **Multi temporal:** An image is taken in different times under different conditions. Some of the applications are landscape planning, automatic change detection for security monitoring, motion tracking. **Multi Sensors [6]:** An image is taken from the different sensors, which is used mainly in multi modal analysis. Some of the applications include medical domain ex: MRI and CT, PET, SPECT, MRS [7]. **Scene model restoration:** An image of a scene and a model of the scene are registered, to localize the image in the scene to compare them. It can be used in applications as target template matching with real-time images [8], automatic quality inspection, and Medical imaging ex: comparison of patient's image with digital anatomical. **Multi focus:** Capture an image scene with different focuses, which are used mainly in natural images, to get a more informative images rather than input images. When fusing the multiple focused images a challenging task arises when good and more informative image has to be identified and constructed from a multi-focus image set. Many algorithms have been developed in recent years using various approaches for different applications. In this paper, we have worked on image fusion of multi focused images in spatial and frequency domains. Fusion can be done in two steps as image registration and image fusion.

II. BACKGROUND WORK

Image fusion is to fuse two or more images to get one single informative image by combining the relevant content from multiple images. Image fusion has applications across several areas such as medical imaging [9] [10], microscopic imaging, remote sensing application [11] and satellite images. Based on the application, image fusion is achieved using different approaches. Image fusion can be broadly divided into two categories as shown in figure 1:

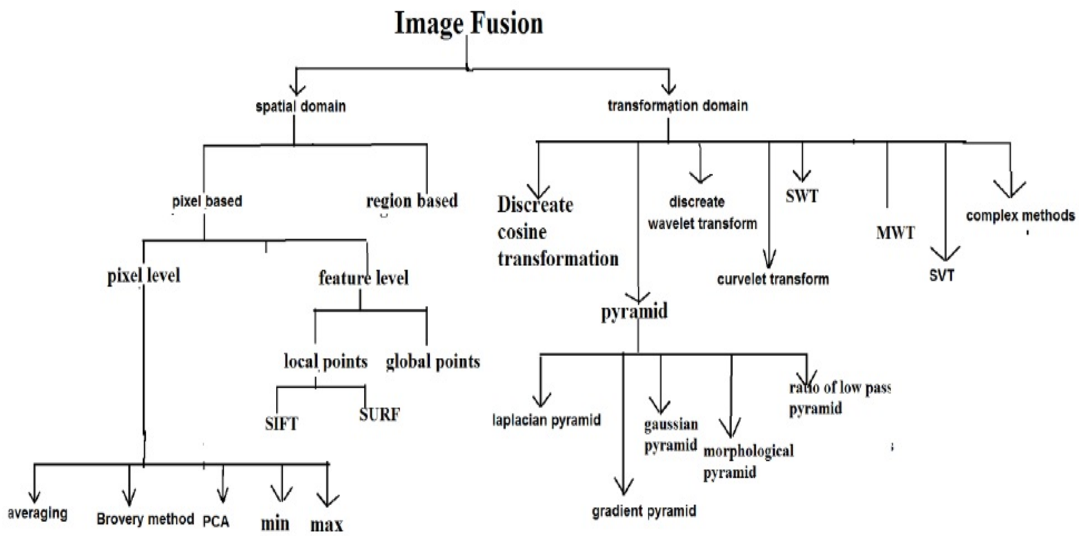

Fig. 1: Categories of Image Fusion

Author&year	Method for fusion	Kind of images	Application	Comments
Rohan Ashok Mandare(2013)	Pixel level (bravery)	LANDSAT MS, LANDSAT PAN	Multi sensor images (Satellite imaging)	Better preserve the spectral characteristics of multi-spectral bands
Jie-Lun Chiang(2013)	Pixel level (PCA,knowledge based)	PAN images of SPOT4	Multi-resloution Satellite images	PCA transforms number of correlated variable into number of uncor- related variables, this property can be used in fusion. But in the spatial domain fusion may be produce spectral degradation.
Firouz Abdullah Al- Wassai(2011)	Pixel level (IHS)	Multispectral &Panchromatic	Multi resolution (improve the sharpening)	To Improve the spatial & spectral information
Chetan K Solanki1(2011)	Pixel based methods(max)	Natural images	Multi sensor (object motion)	Pixel fusion is done by using the original information leads to undesirable side effects such as reduced contrast.
Shivsubramani Krishnamoorthy-10	Pixel level max,average,pca	Medical image	Multi-dimensional CT & MR	pixel selection, addition, subtraction or averaging. These methods are not always effective
Firouz Abdullah Al- Wassai, (2009)	Pixel level (Feature-Level)	Original PAN & satellite images	Multi-sensor Images (satellite images)	Based on the feature selection, images will be merged
R.Maruthi,(2007)	Region based (statistical)	Natural images	Multi-focused Images	Improving the spatial and visibility of an image. Chance to failure when we are using multi sensor data.
Shutao Li, (2006)	Region based (segmentation)	Natural images	Multi-focused images	Segmentation will be using The simple average method. Averaging of two images gives the bluer effects when have low contrast pixels.
Manfred Ehlers,(2006)	Pixel level (decision based)	SPOT-5, Kompsat1, Landsat-ETM	Multi-sensor images (satellite images)	No salt-and pep- per effects appear. easy to identify the landmarks in satellite images. and Complex to use.

TABLE I : Spatial Domain Methods

Author &year	**Method for fusion**	**Kind of images**	**Application**	**Comments**
HuipingZhu-13, PareshRawat-11, YAO Wanqiang	Wavelet based. (multi-focus, multi scale,multi-spectral, multi resolution)	Natural,Medical,satellite images. Landsat.	Medical imaging, Satellite images etc..	Wavelet- based fusion given the good results with spatial resolution. These are not the most significant in representing objects with singularities along lines &in the spectral information wavelet performance is poor
GGeetha,(2012)	Pyramid (Gradient)	Natural images	Multi-focus	Multi spectral bands which have the best Gradient values are selected to fuse
Rohan Ashok Mandhare,(2012)	Discrete wavelet transformation	Natural images	Multi-focus images	It also provide better signal noise ratio than pixel based approach. In this method final fused image have a less spatial resolution
VPS Naidu,(2012)	DCT	Natural images	Multi images	DCT are concentrated in the low frequency region
LiqiangGuo-12	Quaternion curvelet	Natural images	Multi-focused	Deal with the problem of image blurs
Wencheng Wang,2011	Pyramid-Laplacian	Natural images	multi-focused	After fusing images contain blocking artifacts in the regions where we have multi sensor data.
Sheng Zheng, 2007	Support Value Transform	Natural images	Multi- focused	SVT is an undecimated transform. Vector is series of support value filters.
L. Alparone, 06	curvelet transform	very-high resolution MS + Pan Quick Bird image	MS,(MRA)	Curve lets is its capability of representing a curve based on the Ridge let transform

TABLE II : Frequency Domain Methods

A. Spatial domain :

Spatial domain refers to the image plane and fusion approach works directly on intensity level operations. Spatial domain techniques operate directly on the pixels of an image. B(x,y)=C(B(x,y)). B(x, y) is input pixel and C is the operation on the specific pixel and its neighborhood pixels. That output is equal to C(x, y). Spatial based methods are lowest possible technique in image fusion. In the spatial domain we have two different type of approaches which are pixel based and region based operations. **Pixel based operation:** The lowest possible technique in image fusion is the pixel level. It is also called as nonlinear method. Some of the statistical approaches for pixel based image fusion **Selection based pixel operations: I) Averaging method:** The primary step for image fusion is to take the average of the two images pixel by pixel. Averaging work well when the images to be fused are from the same type of sensor and contain additive noise[12]. **II) Maximum:** Find the maximum value from a region. **III) Minimum:** Find the minimum value from a specific region. 4. **Brovery method:** Color normalized fusion is based on the chromatic transformation and the intensity modulation. This method can also be helpful to fuse the images which are captured from multi sensors. It can protect the relative spectral contributions of each pixel but replaces its overall brightness with the high spatial resolution image. The Brovey transformation[13] was developed to avoid the disadvantages of the multiplicative method. Pixel level fusion may conduct to contrast reduction. **5. Feature level:** The feature level[14] operates based on extraction of salient features such as size, shape, edge etc. Features can be local and global. Local based method are SIFT[15] and SURF. **Region based:** In the spatial domain, region based on application are liner methods and a lot of research has been done in the region based on image fusion. A simple image fusion starts with dividing the source images into sub regions and then calculating the measure of information level in the regions.[16][17]. Region based methods are more flexible where adapting to intelligent fusion rules than pixel based approaches. Also these methods circumvent the common problems of noise sensitivity and blurring associated with pixel based schemes. Pixel based approaches are more preferable when working on original images data. Averaging methods are more complicated when the images are blurred. It effects the contrast of the image. A lot more work was evaluated on the particular area as medical imaging and satellite images with the help of transformation domain.

B. Transformation Domain:

Transform domain techniques map each image into the transform mode. It gives coefficient values with help of frequency distribution, then later applies inverse transformation to get final image based on the rules. There are many different type of techniques such as **1. Pyramid based**: Pyramid is helpful to work on the multi-resolution images and to fuse them. Image pyramid proposed by Burt and Adelson in 1983. The basic principle of this method is to decompose the original image into pieces of sub-images with different spatial resolutions through some mathematical operations, there we have different pyramids as Laplacian[18] Gaussian pyramid[19], gradient pyramid [20][21], morphological pyramid[23], ratio of low pass filters pyramid.2. Discrete wavelet transformation and wavelet transformation [24][25][26] 3.Curvelet transformation[27][28]. This fusion method provides higher information in the spatial and spectral domains simultaneously. 4. Contour transformation[29] 5. Support vector transformation[30] 6. Complex methods such as high pass filters[31] and low pass filters and mixed spatial and frequency domain for fusion. Decision level: This is the highest level of image fusion deals with symbolic representations of the images and it processed individually for content extraction and applying decision rules[32] to get a fused image. Intensity Hue Saturation (IHS): The IHS based method processes the source images in a pixel-by-pixel manner, this mainly helpful method in remote sensing based on the RGB-IHS conversion model[33][34], In this method three MS bands R, G and B of low resolution Image are first transformed into the IHS color coordinates, and then the histogram matched high spatial Presolution image substitutes the intensity image which describes the total color brightness.

III. IMAGE FUSION

We have registered set of images before fusing them. We have to follow feature based registration. Image registration [35][36] is helpful to avoid misalignment. Pixels are spatial aligned in the registration. Registration process have different steps as feature extraction, feature matching, image re transformation. Here we are extracting the features with the help of SURF[37]. SURF is speed-up robust feature. Extracting the features. Will get detector and descriptors values. From those points, find the best matching points with the help of Flann based approach [38]. Find the homography with the help of good matches. Homography is simply mapping between any two projections planes with the same center of projection. Final stage is image re-transformation, it helps to get target image or registered image obtained with the homography matrix. Observation When we are changing the threshold value. It will effects on registered image as well as fused image. Select the best registered images to get an effective results. After registration, image fusion can be done in spatial and frequency domain. **Mainly fusion can be done in these steps: i)** Registered images are divided into sub-sampled images. **ii)** Find the contrast for each sub-sampled image. **iii)** Elect the best sub-sampled images based on the contrast values. **iv)** From all the best sub images construct to get a single informative image. In frequency domain as shown fig 2. **i)** Set of registered images are split into three different channels as R,G,B. **ii)** Those channels are divide into sub-sampled images. **iii)** Then after applying DCT on each sub image, is transformed into frequency coefficients. **iv)** Compare and based on choosing rules image will be fused by applying inverse discrete cosine transformation. Selection is done based on the rules as minimum, maxi- mum and averaging frequency coefficients.

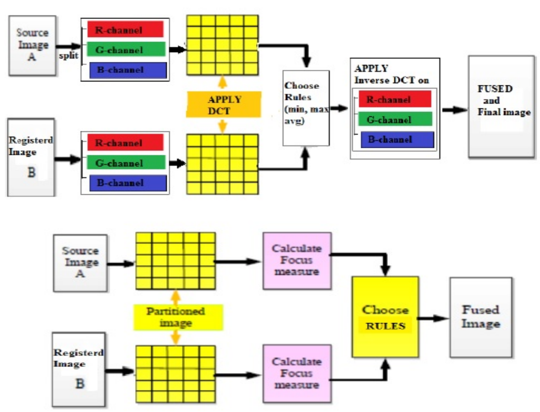

Fig. 2: Basic Approach for Image Fusion based on Color and Spatial

I) Spatial Based Image Fusion:

Multi focus image set is have an image with same scene with different focuses. If focus changed image content will be appeared sharped or blurred, by fusing those set of images to get a single informative and constructed as rich content image. In this spatial fusion approaches is divide into two steps as image registration and image fusion. Selection process is done either used maximum contrast or threshold based contrast to select the best sub images. MAX-contrast based fusion is done by selecting the best sub images which have the maximum contrast value. In Threshold Based fusion, to get a threshold value, find an absolute difference in between the all sub sampled images and finally, average them. Based on the threshold, two conditions are applied as: (a) where the absolute contrast difference is above or equal to the threshold. In that situation, select the best content which sub-sample images have the maximum contrast value. (b) Where the absolute contrast difference is below the threshold. take the average of sub-sampled images as best content. Collect the best content from those conditions. Combine them to get a single image as fused image or final image.

II) Frequency Based Image Fusion:

Image fusion techniques is done in the frequency domain technique as DCT [39][40]. A discrete cosine transform (DCT) expresses a sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. It can be useful in development of numerous applications in science and engineering. DCT is explained briefly as follows:

$$Z(u,v) = \alpha(x)\alpha(y)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} Z(x,y)\cos\left(\frac{\pi(2x+1)u}{2M}\right)\cos\left(\frac{\pi(2y+1)v}{2N}\right),\ 0 \le u \le M-1,\ 0 \le v \le N-1$$

$$\text{where } \propto(u) = \begin{cases} \frac{1}{\sqrt{M}}, & u = 0 \\ \sqrt{\frac{2}{M}}, & 1 \le u \le M-1 \end{cases} \text{ and } \propto(v) = \begin{cases} \frac{1}{\sqrt{N}}, & v = 0 \\ \sqrt{\frac{2}{N}}, & 1 \le v \le N-1 \end{cases}$$

$$Z(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} \propto(u)\propto(y) Z(u,v)\cos\left(\frac{\pi(2x+1)u}{2M}\right)\cos\left(\frac{\pi(2y+1)v}{2N}\right),\quad 0 \le x \le M-1,\ 0 \le y \le N-1$$

u & v are discrete frequency variables (x, y) pixel index Similarly, the 2D inverse discrete cosine transform is defined as

IV. EVALUATION METRICS

Finally, fused images evaluation can be done using subjective and objective evaluation. Subjective evaluation is given importance and decides on human interpreter with its own visual analysis. Objective metric's are evaluating based on applying the mathematical or statistical approaches to know image measure's. Objective metrics had two methods as Referenced based image evaluation, is simply having an referenced image to evaluate measures and no-referenced image evaluation, is depended only upon the single and final image.

1. EME & EMEE

EME[43] is measure of enhancement, EMEE[41][42] is measure of enhancement by entropy. they have been developed by Agaian et. al. give an absolute measure to each image on the basis of image contrast processed with Fechners Law relating contrast to perceived brightness or the entropy concept.

$$EME(e) = \frac{1}{B1 \times B2}\sum_{i=1}^{B1}\sum_{j=1}^{B2} 20\ln\frac{I_{max}^{(i,j)}}{I_{min}^{(i,j)}},\ EMEE(e) = \frac{1}{B1 \times B2}\sum_{i=1}^{B1}\sum_{j=1}^{B2} \propto \left[\frac{I_{max}^{(i,j)}}{I_{min}^{(i,j)}}\right] \propto \ln\frac{I_{max}^{(i,j)}}{I_{min}^{(i,j)}}$$

here the image divided into B1,B2 blocks, a=0.2 is a constant, $\frac{I_{max}^{(i,j)}}{I_{min}^{(i,j)}}$ are the max & mini values of the pixels in each block of the enhanced image.

2. NIQE:

The quality of the distorted image is expressed as the distance between the quality aware NSS feature model and the MVG fit to the features extracted from the distorted image[43]: where v1, v2 and S1; S2 are the mean vectors and covariance matrices of the natural MVG model and the distorted images MVG model.

$$D(v1, v2, \Sigma1, \Sigma2) = ((v1 - v2)^T (\frac{(\Sigma1+\Sigma1)}{2})^{-1}(v1 - v2)$$

V. RESULTS

Dataset: Multi focused images data set, it is available [44]. Taken images with the help of Nikon D5000 camera, and 27 pairs. 7 pair with .bmp files. Remaining all are .jpg files for research oriented data shown in fig 4. **Subjective evaluation:** After that fuse them by electing the best sub-sampled image to get the single fused image. improve the number of patches as 9,20,30,42. figure shows **III** spatial fusion methods. figure shows **IV**

frequency fusion methods. **Objective evaluation:** In this paper objective evaluation is done with some of no referenced image metrics like EME, EMEE, NIQE. **table V** shows spatial fusion evaluation and **table VI** shows Frequency fusion evaluation. In the table T refers Threshold contrast based fusion.

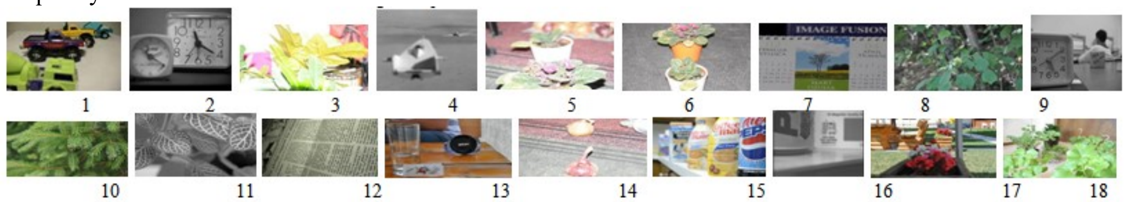

Fig. 4: Dataset

Patches	9		20		30		40
Methods max Contrast	Threshold	max Contrast	Threshold	max Contrast	Threshold	max Contrast	Threshold

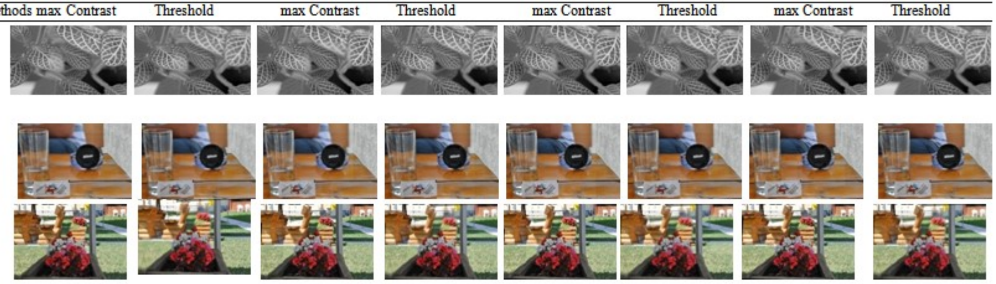

TABLE III: Subjective Evaluation of Spatial Domain Methods

Images	11			13			17	
Min	Max	Avg	Min	Max	Avg	Min	Max	Avg

TABLE IV: Subjective Evaluation of Frequency Domain Methods

Metric	Patches		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
EME	9	max	11.284	21.594	3.620	28.552	17.813	10.732	9.924	18.524	46.719	0	31.353	6.017	32.949	28.519	19.929	17.952	16.024	26.004
		T	15.803	23.61	15.354	19.005	38.405	26.275	23.222	32.711	48.438	17.945	33.028	14.688	33.965	26.403	57.449	16.480	35.535	40.981
	20	max	4.30E+	26.996	6.5333	31.530	29.206	16.251	13.778	27.561	30.525	19.485	24.846	14.922	43.546	27.852	29.730	21.061	16.680	29.974
		T	8.6975	19.438	16.421	25.064	28.677	19.208	34.840	34.411	30.912	43.370	28.841	15.88	42.187	24.159	39.734	16.148	40.859	31.597
	30	max	7.874	20.373	14.427	24.890	24.059	26.739	14.366	21.783	27.344	18.062	22.042	13.640	43.984	22.095	37.493	18.203	22.898	29.413
		T	9.156	23.313	21.726	21.770	30.646	23.051	26.959	32.842	25.465	29.125	30.545	21.223	41.974	23.334	39.506	14.964	43.999	31.043
	42	max	11.510	18.573	20.633	18.011	23.581	23.519	17.997	28.324	26.443	21.245	22.686	15.614	38.745	21.563	31.607	14.285	23.001	26.558
		T	12.291	16.647	20.879	14.311	24.159	22.968	28.976	34.523	25.231	37.314	28.272	25.162	38.564	22.042	34.386	13.674	37.496	31.654
EMEE	9	max	0.095	0.074	1.18E	0.126	0.118	3.02E	4.77E	0.168	0.247	0	0.125	3.26E	0.201	0.177	0.125	0.051	0.120	0.178
		T	0.099	0.090	0.075	0.067	0.239	0.129	0.128	0.194	0.277	0.158	0.131	0.065	0.212	0.097	0.463	0.045	0.294	0.235
	20	max	0.0131	0.1532	0.0325	0.1537	0.2094	0.0591	0.0469	0.1884	0.1397	0.1589	0.0855	0.0847	0.2634	0.1492	0.2062	0.0915	0.1042	0.1725
		T	0.0529	0.0584	0.0875	0.1146	0.1541	0.0785	0.1858	0.1875	0.1388	0.3368	0.1201	0.0792	0.2473	0.0845	0.2554	0.0344	0.2846	0.1377
	30	max	0.0385	0.0922	0.0629	0.1223	0.1522	0.1413	0.0501	0.1180	0.1174	0.1268	0.0738	0.0720	0.2603	0.0834	0.2149	0.0558	0.1527	0.1379
		T	0.0587	0.0860	0.1022	0.0972	0.1695	0.0925	0.1299	0.1677	0.0896	0.1910	0.1345	0.1285	0.2451	0.0777	0.2245	0.0276	0.2972	0.1429
	42	max	0.0559	0.0806	0.0997	0.0790	0.1275	0.1210	0.0732	0.1562	0.1066	0.1475	0.0869	0.0849	0.2138	0.0771	0.1592	0.0265	0.1446	0.1193
		T	0.0565	0.0595	0.0837	0.0496	0.1038	0.0952	0.1386	0.1709	0.0993	0.2262	0.1089	0.1587	0.2001	0.0695	0.1731	0.0235	0.2281	0.1443
NIQE	9	max	39.800	39.799	5.2608	39.798	4.5891	6.0993	10.503	4.2903	39.799	4.7193	5.8223	7.6473	5.2863	10.118	4.6292	39.798	6.3547	3.709
		T	39.801139.79994.8921			39.79884.6788		6.0679	10.64045.0386		39.79945.0632		6.3112	9.0107	5.532	9.8367	4.8341	39.79876.8561		3.6527
	20	max	39.801239.79995.1495			39.79884.5939		6.0993	10.42794.0517		39.79944.4516		6.438	8.7107	4.9054	10.11824.4926		39.79837.1658		3.3252
		T	39.801139.80024.6348			39.79884.2737		6.006	8.3967	4.825	39.79914.3506		6.4093	9.0852	4.4237	9.3126	4.3605	39.79896.7316		3.665
	30	max	39.801339.80015.1085			39.79864.5909		6.0993	9.7646	3.9045	39.79944.7222		6.2506	8.6383	4.8075	10.11824.4076		39.79897.2797		3.612
		T	39.801139.80035.1239			39.79884.5545		5.2315	9.8264	4.7801	39.79934.8684		6.2803	8.7983	4.3603	9.2263	4.2648	39.79916.8396		3.5384
	42	max	39.801139.8		6.056	39.79874.6171		6.2426	9.6253	4.7419	39.79934.9568		6.4477	7.9371	5.2745	10.11824.3846		39.799	7.166	3.3261
		T	39.801139.80025.116			39.79874.038		5.0325	9.0427	5.1424	39.79934.8886		6.3444	8.6032	4.2278	9.2331	4.3304	39.79866.7288		3.6979

TABLE V: Spatial Domain Objective Evaluation

Metric	Rule	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NIQE	MIN	39.801	39.799	5.1284	39.800	3.4245	4.7436	4.2523	4.8686	39.800	5.761	5.6075	8.6199	3.6249	9.0191	4.7453	39.799	5.6148	4.7057
	MAX	39.800	39.800	5.8037	39.800	4.0118	5.9488	4.2558	4.824	39.800	6.5724	5.7964	7.9615	3.9818	7.9347	4.7309	39.799	5.516	4.5676
	AVG	39.801	39.799	4.9748	39.798	5.2697	5.0107	7.9552	5.4935	39.799	4.9943	5.8083	8.7762	4.4192	6.938	4.5889	39.798	6.3119	4.175

TABLE VI: Frequency Domain Objective Evaluation

VI. CONCLUSION

Image fusion has been performed in two domains, spatial and frequency, using the Image Registration. Here fusion in spatial domain, by dividing the images into sub images. Based on contrast values we select the best sub sampled images to get a single fused image. We studied the elect of varying the number of sub samples on the fused image by choosing different sub samples (9,20,30,42....). For frequency we have used DCT. Obtained with DCT, images are convoluted into frequency domain. Based on the rules, selection procedure takes place to fuse the images. We studied the elect of varying the frequency on the fused image by choosing different rules (min,max,avg). Finally evaluation is on subjectively and objectively, when we observes a final image as my perception, some of the image regions are giving improvement in the image and some of the regions are giving noise in the image. We did the objective evaluation with the help of no-referenced image metric as EME,EMEP,NIQE. As for the subjective evaluation, we got image improvement. If we can increase the number of sub sampled images, the content will also improved and we observed some distortions and seeming positions in the image. Our future work will focuses to decrease the seeming, fuse the sub- sampled images based on the different contrast measures, Compare with other image fusion techniques. We also would like to test the method for other kinds of source images.

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