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Image Fusion Techniques Based On DCT Using Energy Coefficients And Contrast Measure

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Abstract: - *For the fusion process of two different image discrete cosine transform (DCT) is used. For image fusion process two different multi-focus images are utilized. Different fusion methods are used and their output is evaluated [2,3]. Fusion output is not satisfactory when utilizing methods with a block size of less than 64x64 and also a block size of 256x256 and 512x512. Some fusion methods using contras measure, amplitude, and energy coefficients accomplished well. The fused images are similar with the reference image. The image size is taken into consideration. The blurring percentage is not considered.*

Keywords: DCT, amplitude, contrast measure, energy measure.

I -INTRODUCTION

The image fusion at pixel-level is a signal-level image fusion which constitutes the lowest processing level fusion, that is maximum or mean(average) operations are put in to the pixel values of the source images to result in the fused image. In image processing the input is an image and the output may be either an image or a set of image characteristics. Mostly images of two-dimensional signals are used as input, and standard image processing techniques are applied to it. The performance of process of image fusion is satisfactory for multi-focus and multi-sensor images of the same scene. The physical objects in the scene that are near to the camera are in focus and the far physical object gets blurred in multi-focus images. Opposite to it, when the long distant physical objects are focused then the nearer objects get blurred in the image. Different image fusion techniques are evolved. Three important image fusion methods are used in this paper. Mean of pixels of the source images gives unacceptable effects in the fused image which includes decreased contrast and sharpness. To overcome these side effects new fusion techniques like multi-resolution [3, 6-7], multi-scale [8, 9], and statistical signal processing [10, 11] based image fusion are developed. To fuse the out-of-focus images a contrast-based image fusion algorithm in the DCT domain has been presented [9]. Local contrast is measured by 8x8 blocks. The fusion performance for different block sizes is also evaluated by using evaluation metrics such as fusion quality index, mean absolute error, psnr, ssim, spatial frequency, structural content to analyze the performance of fusion techniques.

In this paper a simple grayscale image is used. Fusion is done by using two blurred images. Blurring percentages is not considered.

II- DISCRETE COSINE TRANSFORM

Discrete cosine transform (DCT) is an effective transform It used in digital image processing. Excellent energy compactness properties of large DCT coefficients which are concentrated in the low-frequency region having [1, 10]. The discrete cosine transform (2D) of an image or signal of size is defined as

$$X(k1,k2) = \alpha(k_1)\alpha(k_2)$$

$$\sum_{n_1=0}^{N_1-1}\sum_{n_2=0}^{N_{2-1}} x(n_1,n_2)cos\left(\frac{\pi(2n_1+1)k_1}{2N_1}\right)cos\left(\frac{\pi(2n_2+1)k_2}{2N_2}\right)$$

$$0 \le k_1 \le N_1 - 1$$

$$0 \le k_2 \le N_2 - 1$$

where

$$\alpha(k_1) = \begin{cases} \frac{1}{N_1}, & k_1 = 0 \\ \sqrt{\frac{2}{N_1}}, & 1 \le k_1 \le N_1 - 1 \end{cases}$$

$$\alpha(k_2) = \begin{cases} \frac{1}{N_2}, & k_2 = 0 \\ \sqrt{\frac{2}{N_2}}, & 1 \le k_2 \le N_2 - 1 \end{cases}$$

k_1 and k_2 are individually separate and distinct frequency variables, (n_1, n_2) pixel index. Similarly, the inverse discrete cosine transform (2D) is defined as:

$$x(n_1, n_2) = \alpha(k_1)\alpha(k_2)$$

$$\sum_{k_1=0}^{N_1-1} \sum_{k_2=0}^{N_{2-1}} X(k_1, k_2) cos\left(\frac{\pi(2n_1+1)k_1}{2N_1}\right) cos\left(\frac{\pi(2n_2+1)k_2}{2N_1}\right)$$

$$0 \le n_1 \le N_1 - 1$$

$$0 \le n_2 \le N_2 - 1$$

III - IMAGE FUSION

Image processing has different sub-fields. Image fusion is one of them. In Image fusion part of two or more images is fused resulting in an image having all in focus objects. Image fusion application in medical science, forensic, and defense departments is of remarkable importance. Multi-sensor and multi-focus images of the same scene are used for the process of image fusion. [16-19]. To remove all the shortcomings in multi-focus images, and to achieve an image having all the objects are in focus, the process of image fusion is performed either in the spatial or transformed domain.

IV- FUSION METHODS

Three fusion algorithms or rules are used in the image fusion process [2]. Let the X_1 be the DCT coefficients of the image block of size N x N from image I_1. *S*imilarly let the X_2 be the DCT coefficients of the image block of size N x N from image I_2. Assume X_f be the fused DCT coefficients.

A. DCTae

Averaging of DC components is done. Largest energy frequency band AC coefficients are chosen.

B. DCTamc

Averaging of DC components is done and largest magnitude lowest AC components are chosen and remaining AC coefficients with the largest contrast measure are chosen. The contrast [8, 12-15] is measured as

$$C(k_1, k_2) = \frac{X(k_1, k_2)}{\sum_{j=0}^{m-1} E_j}$$

Where $E_j = \frac{\sum_{j=t+p} |X(p,t)|}{Y}$

and

$$Y = \begin{cases} j + 1, & j < N \\ 2(N-1) - j + 1, & j \ge N \end{cases}$$

E_j is the average amplitude over a. j^{th} spectral band.

C. DCTame

Averaging of DC components is done and the largest contrast measure, lowest AC components are chosen and largest energy measure; the remaining AC coefficients are chosen.

FUSION METRICS

If a reference image is available following metrics can be utilized.

A. PSNR [2, 3, 5]

PSNR determines the degree of resemblance between reference images and output fused images. A high value shows fusion result of high quality..

$$\text{PSNR} = 20 \log 10 \left[\frac{L^2}{\sqrt{\frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} \left[I_r(x,y) - I_f(x,y)\right]^2}} \right]$$

B. Mean absolute error (Mae) [6]

The Mae between the fused output image and the reference image is defined as

$$\text{mae(F,R)} = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} |R(m,n) - F(m,n)|^2$$

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C. SSIM [2

The resemblance between the fused and the reference images is measured by SSIM. The range of SSIM is from -1 to 1. When both the images are identical the SSIM value is 1. High SSIM fused image would be considered. The SSIM is computed as

$$SSIM = \frac{\left(2\mu_{I_t}\mu_{I_f} + c_1\right)\left(2\sigma_{I_tI_f} + c_2\right)}{\left(\mu_{I_t}^2 + \mu_{I_{tf}}^2 + c_1\right)\left(\sigma_{I_t}^2 + \sigma_{I_f}^2 + c_2\right)}$$

D. Structural content [5]

Structural Content gives quality of image. The image is of good quality if the value of Structural Content is low. SC is defined as follows

$$\text{SC}= \sum_{m=1}^{M}\sum_{n=1}^{N} x(m,n)^2 = \sum_{m=1}^{M}\sum_{n=1}^{N} x^{\wedge}\,(m,n)^2$$

E. Spatial frequency [2, 3, 5, 15]

The overall activity level in the fused image is indicated by spatial frequency. Pixel index is (x, y). The high SF fused image would be considered. Spatial frequency calculates the frequency changes vertically and horizontally along the image. Spatial frequency is measured using the equation

$$\text{SPF}=\sqrt{(RF)^2 + (CF)^2}$$

Where

$$RF=\sqrt{\frac{1}{MN}\sum_{x=1}^{M}\sum_{y=2}^{N}\left[I_f(x,y) - I_f(x,y-1)\right]^2}$$

$$\text{CF}=\sqrt{\frac{1}{MN}\sum_{y=1}^{M}\sum_{x=2}^{N}\left[I_f(x,y) - I_f(x-1,y)\right]^2}$$

F. Quality index [16]

It gives information present in the image. Its value is in between -1 to 1. Fused image contains all the information from the source images if the value of this index is 1. It is defined as

$$Q = \frac{4\sigma_{xy}\overline{xy}}{\left(\sigma_x^2+\sigma_y^2\right)[(x)^2 + (y)^2]}$$

V- RESULTS AND DISCUSSION

The reference image (transport) is shown in Fig-1. By blurring the source image the complementary source images (images to be fused) are generated as shown in Fig-2. In Fig-4 to Fig-6, the output fused and the difference error images using the originated image fusion techniques are shown. The error image is the difference between the reference and the output fused image.

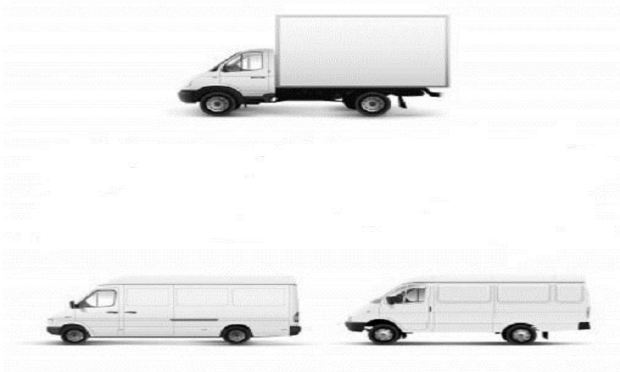

Figure 1: Reference image -transport

Figure 2: Complimentary Source image-transport1

Figure 3: Complimentary Source image-transport2

The error image shows that the fusion rule DCTae provides excellent fusion results among all fusion techniques. Newly originated DCTamc and DCTame fusion rules give comparatively acceptable results with DCTae. The fusion quality evaluation metrics are shown in Table-1 and 3.

Figure 4: The output fused and error image using the DCTae fusion rule

Figure 5: The output fused and error image using the DCTamc fusion rule

Figure 6: The output fused and error image using the DCTame fusion rule

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The evaluation metrics values are

Table 1: DCTae

	2X2	4X4	8X8	16X16	32X32	64X64	128X128	256X256	512X512
PSNR	55.692	57.2035	60.2745	63.1178	65.5799	67.1846	**67.3391**	65.5597	50.7717
Mae	5.8207	5.4918	4.9273	4.3806	3.8293	3.7228	**3.7834**	4.4095	7.9779
SC	1.0368	1.0358	1.0321	1.0302	1.0293	1.0287	1.0281	1.0272	1.0318
SF	8.6056	10.4586	11.137	11.3012	11.2119	11.162	11.1623	11.1564	8.8379
SSIM	0.969	0.9755	0.9793	0.9796	0.988	0.9884	0.9892	**0.9908**	0.8487
QI	0.3249	0.3196	0.3191	0.3187	0.3472	0.3654	0.3898	**0.4178**	0.1685

Table 2: DCTamc

	2X2	4X4	8X8	16X16	32X32	64X64	128X128	256X256	512X512
PSNR	55.1608	55.688	57.1885	60.1289	62.6879	65.1482	66.9022	67.2561	**65.6207**
Mae	5.7298	5.611	5.2852	4.6398	4.1299	3.7875	3.641	3.6111	**4.0112**
SC	1.0373	1.0368	1.0358	1.052	1.0321	1.0301	1.0287	1.048	**1.048**
SF	5.4669	8.6051	10.4686	11.1838	11.3447	11.2497	11.1686	11.1706	**11.1601**
SSIM	0.979	0.979	0.9855	0.9891	0.9885	0.9963	0.9865	0.9898	**0.9907**
QI	0.3486	0.3433	0.3415	0.3413	0.3411	0.3609	0.3873	0.3916	**0.3968**

Table 3: DCTame

	2X2	4X4	8X8	16X16	32X32	64X64	128X128	256X256	512X512
PSNR	55.1608	55.689	57.1682	60.1186	62.6645	65.1242	66.8561	67.2333	**65.6185**
Mae	5.9498	5.8311	5.4881	4.8634	4.3545	3.9930	3.8684	3.8261	**4.0213**
SC	1.0553	1.0548	1.0538	1.052	1.0501	1.0492	1.0486	1.048	**1.048**
SF	6.6669	9.801	11.6687	12.3844	12.5483	12.4503	12.3696	12.1905	**12.36**
SSIM	0.979	0.979	0.9854	0.9887	0.9883	0.9961	0.9852	0.9896	**0.9964**
QI	0.3486	0.3403	0.3391	0.3366	0.3405	0.3601	0.386	0.3826	**0.3973**

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The above result shows that DCTae fusion rules would provide good fused images. With block sizes less than 64x64 and 512x512, fusion performance is not good. For 512x512 image block size, DCTamc and DCTame give good results. Image block size decides fusion quality.

VI -CONCLUSION

Three different types of image fusion rules dependent on discrete cosine transform (DCT) are used. Image fusion is done and evaluation metrics are used to evaluate fused image quality. For a block size of less than 64x64 and also a block size of 512x512 fusion result is not good using the three fusion rules. DCTae-based image fusion rule resulted well. For 512x512 image block size DCTamc and DCTame produced good result. Different evaluation metrics give results with slight change.

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