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Performance Assessment of Image Fusion Algorithms using Statistical Measures in Slant Transform Domain

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Abstract*: *The important information is collected from multiple input images and formed fused one which has extra quantitative content. Image fusion is executed either in spatial or transform platforms. In spatial domain spectral information is distributed in the entire image. In this work image fusion is implemented in transform domain. Slant Transform effectively represents linear brightness changes. Statistical measure discriminates the important blocks of the image efficiently. Smoothness measure identifies less noisy blocks efficiently. Hence, in this work image fusion in Slant Transform domain using smoothness is proposed. Smoothness of slant transformed blocks are compared to select the important block from multiple images. The eminence of the fused image can be judged using various performance metrics such as Feature Similarity (FSIM) index, Mutual Information (MI), Normalized Cross Correlation (NCC), and Edge Strength Orientation preservation (ESOP).Proposed method is suitable for multi-focus image fusion.

Index Terms: Image fusion; mean; variance; smoothness; Slant Transform;

I. INTRODUCTION

Best possible image from the visual information collected from various input images is possible in image fusion. It is executed in both spatial [1] and transform platforms. Effective methods to store and transmit are available in the transform domain. Image fusion can be applied directly in the transform domain. So that conversion from spatial domain can be avoided. Hence, spatial domain methods may not appropriate for real time applications. So, the fusion schemes are implemented in the transform domain.

Some of the transforms are Discrete Cosine Transform (DCT), Discrete Sine Transforms (DST), Walsh Transforms, Hadamard Transforms (HT), and Slant Transforms. Haghighat et al. [2] presented the DCT algorithms using variance and consistency verification to get optimal results. Slant Transform [3] has a saw tooth basis vectors. Fast computational algorithm is possible with this transform. The feature of the Slant Transformed images is better than when compared with other transforms such as Hadamard and DCT for textured images. Energy preservation is good for the Slant Transform (ST). ST is simpler and faster. The image fusion process is performed by replacing the traditional methods with the Statistical measures [4, 5, 6, 7,11,12,13] In this work, image fusion using smoothness based statistical measure in Slant transform domain is proposed. Further, all results are compared with mean and variance based methods.

The organisation of this paper is as follows: The basics of ST, variance & mean in Slant domain are discussed in section II. Smoothness measure in Slant domain is discussed in section III. Smoothness based image fusion is discussed in section IV. Results are presented and examined in section V. In section VI, conclusions are presented.

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II. SLANT TRANSFORM

A. Slant Transform

ST is applied for various applications, viz. image watermarking, compression and video processing. Let $[g]$ is the input image. Let $[G]$ be the transformed image. Two dimensional forward & inverse transforms is expressed as

$$[G] = \frac{A_S[g]A_S}{n} \quad (1)$$

$$[g] = \frac{A_S[G]A_S}{n} \quad (2)$$

where A_S is Slant block. Second order ST matrix is given below.

$$A_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Like this we can generate any order Slant transform matrix any order. ST satisfies the orthonormal property. First row is a constant gathering. Second row is a slant gathering. ST is product of sparse matrices. It leads to implement a fast algorithm. It has sequency, variable size, and high energy compaction properties.

B. Mean in ST

Mean is the simple measure in transform domain.

$$M = G(0,0) = \frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} g(x,y) \quad (3)$$

Mean value in ST domain is given above .In Equation (3), G(0,0) is the DC coefficient.

Others are AC coefficients. Where (x, y) represents the spatial coordinates. It is the average of the all the pixels in that block/image.

C. Variance in ST

Variance is spread among pixel values. It is high when changes in pixel values are high. It is low when changes in pixel values are low. Variance value in ST domain is given below.

$$\sigma^2 = \frac{1}{N^2}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1} G(u,v) - G^2(0,0) \qquad (4)$$

where (u, v) represents the transform coordinates.

III. SMOOTHNESS MEASURE IN SLANT TRANSFORM DOMAIN

Less noisy blocks are identified using Smoothness based statistical measure. This measure ranges from 0 to 1. The steady pixel intensities approach 0 and 1 for higher expedition in the pixel intensities of the image. AC coefficients are only considered here to estimate smoothness. DC coefficient is discarded. It is not important in identifying the Smoothness. Changes in image blocks are identified with the AC coefficients. Changes can be either positive or negative. Hence, absolute of AC coefficients is taken. Changes in each part is worked out by equation below

$$V = \sum_{u,v} |G(u,v)| \qquad (5)$$

where $u \neq 0, v \neq 0$. Hence, the Smoothness (S) of each block is estimated by transform coefficients. It is the absolute sum of the AC coefficients. S is high when V is low and vice versa.

IV. SMOOTHNESS BASED IMAGE FUSION IN SLANT TRANSFORM DOMAIN

To test the proposed method, multi focused images are considered. The statistical measures like Mean, Variance, and Smoothness are calculated to Slant coefficients. In general multiple numbers of source images can be considered for fusion process. The statistical measures given in eq. (3), (4), and (5) are calculated for each n x n sub blocks of Slant coefficients. Maximum level of sub block is selected and placed in to an empty image. The selection of maximum level is shown in *Fig. 1.* Smoothness of the transformed block is measured for both the input images. Maximum valued blocks are considered for fusion. Image fusion block diagram is shown in the *Fig. 2.* Two source/ input images are taken for fusion. Both the source images are equally divided in to n x n sub blocks. ST is applied to each n x n sub block. Hence, transform coefficients are generated. Then fusion rule is applied to select the appropriate coefficients.

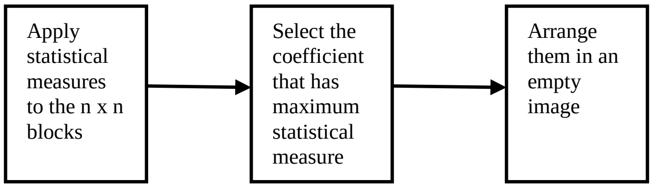

Fig. 1 Decision process

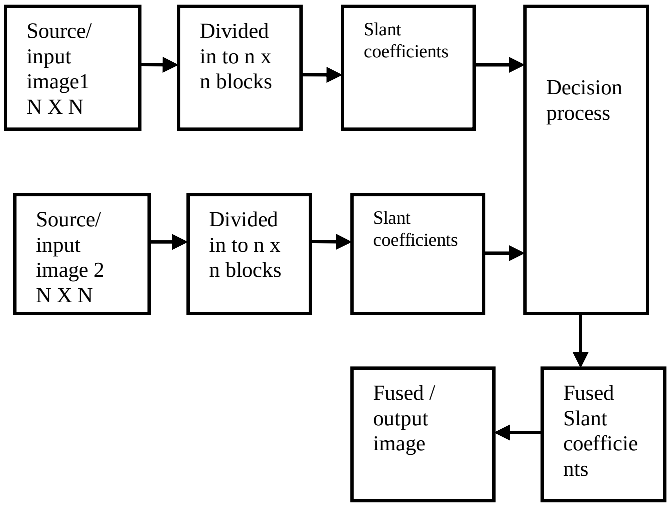

Fig. 2 Block Diagram for Fusion Process

Compute inverse transform to get the fused image. Various performance metrics are applied to test the performance of the proposed algorithm. The fused image contains all the selected sub blocks. This algorithm can be applied for multi-focus, satellite and medical image fusion.

V. EXPERIMENTAL RESULTS

Some of the standard images considered for experimentation are given in *Fig.3*. Testing part is limited for multi-focus images. Input images are generated using filters by considering the benchmark images to do experimentation. Some parts of images are made unfocused using low pass filter with convolution of Gaussian filters. The performance evaluation and comparisons are made with Mean, Variance and DCT domain [2]. The results of the ST+mean, ST+variance & ST+smothness methods are given in TABLE I. Various performance measures are tested to investigate the fused images quality and quantity. The amount of visual information contained in fused one is evaluated with MI .The MI is explored by Qu and Zhang [8]. The statistical dependence of 2 random variables is calculated using MI. Xydeas [9] presented edge based assessment. Hence, edge strength is calculated using a fusion metric Edge Strength and Orientation Preservation (ESOP). These metrics are well proven to test the quality of the fused image. In the Objective fusion process most of pixel information is associated with edge information. Lin et al. [10] discussed the Feature Similarity Index for quality check. NCC [7] is significant to make a decision on the regions that are same. In the digital image processing the visibility of image can vary due to the lighting and brightness.

By normalize the brightness of an image; the problem of varying luminance across the sequence of imaging should be avoided for some extent. Score is a measuring parameter to estimate the amount of blurring. Block based processing is adopted in this work. Every 8X8 block Slant transform is applied. It results blocking artifacts. Hence, Score is used to assess

Fig.3 Images for Experimentation

The blocking artifacts. Experiments are performed by considering only two multi focus images. This can be extended for any number of images as per the requirement.

Results are presented in TABLE I . As per the results in TABLE I, proposed method (ST+smoothness) gives better results than mean and variance based statistical measures. MI, ESOP, NCC and Score values are better for the proposed method than other methods. Various quality metrics of Clock and Disk image are presented in Fig.5 and Fig.6 respectively. Results indicate that visual quality is better with the proposed method. Images point of view both i.e, subjective and objective qualities are important. ST+smothness give superior results in objective and subjective point of view. Proposed method works better with the noisy images. Clock, Disk, Pepsi, Books, Toy, Paper, Lena, and Cameraman images are considered to do experimentation. Considerable improvement in MI value is observed with the proposed method. FSIM improvement is marginal. Considerable improvement in ESOP value is observed with the proposed method. NCC is better with the proposed. Score value clearly indicates the less blocking artifacts with the proposed method.

TABLE I. EXPERIMENTAL RESULTS IN ST DOMAIN

Image	Fusion	MI	ESOP	FSIM	NCC	Score
Clock	M	4.393	0.905	0.999	0.999	19.36
	σ^2	4.44	0.907	0.999	0.998	20.79
	S	4.569	0.914	0.999	0.999	21.79
Disk	M	3.317	0.879	0.999	0.997	20.09
	σ^2	3.819	0.882	0.999	0.995	21.4
	S	4.168	0.903	0.999	0.998	22.53
Pepsi	M	3.873	0.881	0.999	0.998	22.17
	σ^2	4.081	0.885	0.999	0.998	23.33
	S	4.509	0.914	0.999	0.999	24.42
Books	M	3.62	0.823	0.999	0.994	18.51
	σ^2	3.797	0.845	0.999	0.992	20.76
	S	4.217	0.879	0.999	0.998	21.79
Toy	M	3.297	0.861	0.999	0.997	21.17
	σ^2	3.303	0.86	0.999	0.996	22.24
	S	3.607	0.878	0.999	0.999	23.22
Paper	M	2.954	0.862	0.999	0.984	19
	σ^2	3.119	0.843	0.998	0.972	20.26
	S	3.927	0.895	0.999	0.992	20.32
Lena	M	3.746	0.87	0.999	0.997	19.52
	σ^2	3.895	0.865	0.999	0.995	19.33
	S	4.331	0.893	0.999	0.998	20.63
Cameraman	M	3.697	0.84	0.999	0.997	19.95
	σ^2	3.768	0.84	0.999	0.995	21.38
	S	4.174	0.874	0.999	0.998	22.33

In TABLE II, the comparisons between existing method in DCT domain [2] and the proposed methods in Slant domain are given.

TABLE II. RESULTS OF DCT AND ST

Image	Fusion Rule	MI	ESOP	FSIM	NCC	Score
Clock	DCT+ Mean	4.393	0.905	0.9997	0.9991	21.3
	Slant +Mean	4.393	0.905	0.9997	0.9991	21.3
	DCT + Variance [2]	4.534	0.9149	0.9997	0.9992	21.7
	Slant+ Variance	4.44	0.9076	0.9997	0.9989	21.3

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	Proposed	4.609	0.9159	0.9997	0.9993	21.7

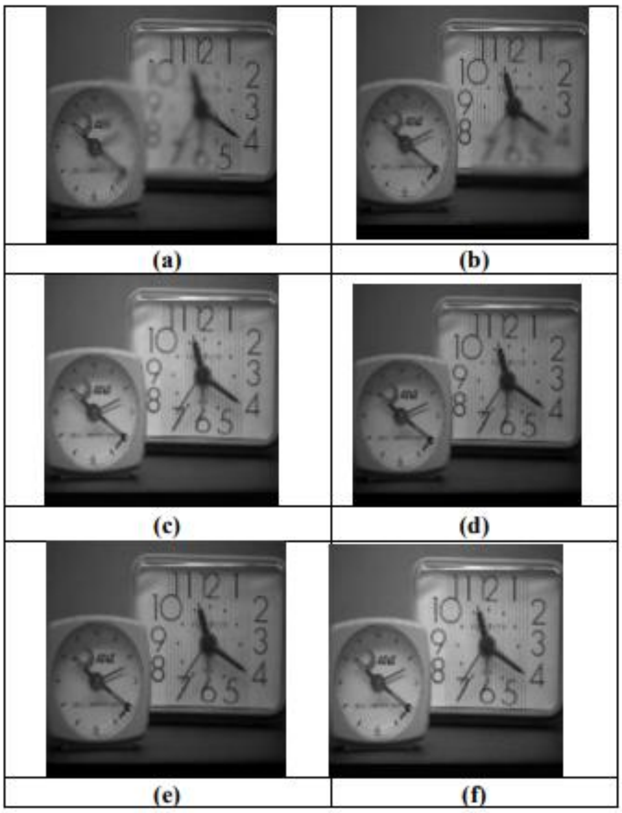

Fig. 4. (a) left side blurred image (b) right side blurred image (c)benchmark image (d)Mean result (e) Variance result (f) Smoothness result

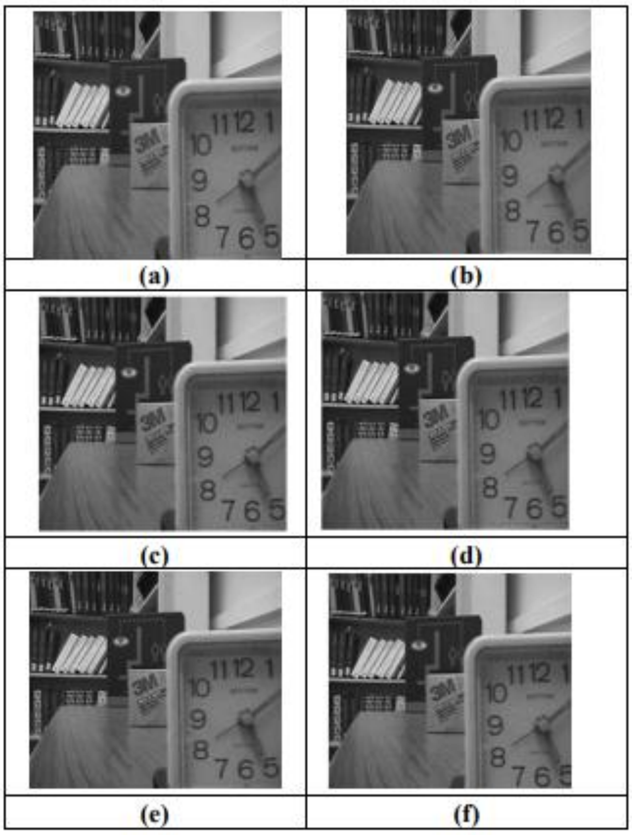

Fig.5. (a) left side blurred image (b) right side blurred image c) benchmark image (d) mean result (e) Variance result (f) Smoothness result

Resulted fused images of Clock and Disk are shown in *Fig 4* and *5* respectively. MI, ESOP, and NCC are better for the proposed method than the existing method. FSIM and Score are same for the both the methods. ST gives a significant gain in terms of hardware implementation & processing time when compared with DCT and DWT methods. The ST has additional helpful high & middle frequency bands. Even other published papers on watermarking indicate that ST is better than other block based transforms. In *Fig.6*, the performance assessment results of fusion algorithms in Slant domain are clearly represented in graphical representation. MI is better with the proposed method than other methods.

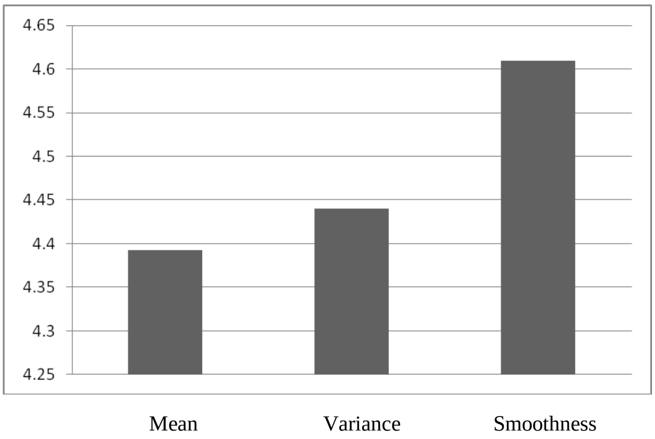

Fig.6 Graphical representation of performance measures (MI) in Slant domain

VI. CONCLUSION

This work discusses image fusion algorithm in ST domain. Smoothness based statistical measure is explored for image fusion. Fusion process is clearly explained. Smoothness measured identifies less noisy blocks for image fusion. Performance of ST+smoothness is superior to other methods. MI, ESOP, and NCC values are better for the proposed method than the existing method. ST is more helpful in putting regular changes in an image. The Smoothness in Slant domain surpasses the previous block based transform methods in both subjective and objective quality. Conclusions are made based on the experiments on multi-focus images. Extension can be done by considering satellite and medical images.

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