Implementation and Comparison of Different Transform Techniques using Kekre's Wavelet Transform for Image Fusion

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ABSTRACT

Image fusion combines several images of same object or scene so that the final output image contains more information. In this paper many advanced pixel level fusion techniques like Kekre's wavelet transform, DCT Kekre's wavelet transform, Hadamard Kekre's wavelet transform, Walsh Kekre's wavelet transform techniques for image fusion are proposed and compared. These methods have main advantage that they can be used for images whose sizes are not necessarily integer power of 2.

General Terms

Image Fusion, algorithm

Keywords

DCT Kekre's wavelet, Hadamard Kekre's wavelet, Walsh Kekre's wavelet, image fusion.

1. INTRODUCTION

Image fusion is the technology that combines several images of the same area or the same object under different imaging conditions. In other words, it is used to generate a result which describes the scene "better" than any single image with respect to relevant properties; it means the acquisition of perceptually important information. The main requirement of the fusion process is to identify the most significant features in the input images and to transfer them without loss of detail into the fused image. The final output image can provide more information than any of the single images as well as reducing the signal-to-noise ratio.

The objective of image fusion is to obtain a better visual understanding of certain phenomena, and to enhance intelligence and system control functions. The data gathered from multiple sources of acquisition are delivered to preprocessing such as denoising and image registration. This step is used to associate the corresponding pixels to the same physical points on the object. In this method, the input images can be compared pixel by pixel. The post-processing is applied to the fused image. Post-processing includes classification, segmentation, and image enhancement.

Many image fusion techniques pixel level, feature level and decision level are developed. Examples are like Averaging technique [4] [7], PCA [7], [8], [11] pyramid transform, wavelet transform, neural network, K-means clustering, etc. Several situations in image processing require high spatial and high spectral resolution in a single image. For example, the traffic monitoring system, satellite image system, and long range sensor fusion system, land surveying and mapping, geologic surveying, agriculture evaluation, medical and weather forecasting all use image fusion.

Like these, applications motivating the image fusion are:

Image Classification, Aerial and Satellite imaging, Medical imaging, Robot vision, Concealed weapon detection, Multi-

focus image fusion, Digital camera application, Battle field monitoring, etc [10].

2. PIXEL LEVEL FUSION TECHNIQUES:

2.1 Averaging Technique [4] [7]:

This technique is a basic and straight forward technique and fusion could be achieved by simple averaging corresponding pixels in each input image as

$$F(m,n) = (A(m,n) + B(m,n)) / 2 \quad (1)$$

2.2 Principal Components Analysis [8] [11]:

In this method the eigenvector and eigen values of input image vector are Computed and the eigenvectors corresponding to the larger eigen value obtained, and

The fused image is:

$$I_f(x,y) = P_1 I_1(x,y) + P_2 I_2(x,y) \quad (2)$$

where P_1 and P_2 are the normalized components and its equal to $P_1 = V(1) / \sum V$ and $P_2 = V(2) / \sum V$ where V is eigen vector and $P_1 + P_2 = 1$.

2.3 Discrete Cosine Transform Technique:

In this technique images are divided into blocks then we calculate the DCT representations and take their average for corresponding blocks. Finally taken the inverse discrete cosine transform to reconstruct the fused image. Actually, this image fusion technique is called the DCT + average; modified or "improved" DCT technique [5][11].

2.4 Discrete Wavelet Transform Technique with Haar [1] based fusion:

It uses fast Mallet's transform [1], the algorithm first decomposes both input images to get an approximate image and a detail image. Images are fused using the fusion rules. The resulting fused transform is reconstructed to fused image by inverse wavelet transformation

The Haar wavelet is the first known wavelet. The 2×2 Haar matrix that is associated with the Haar wavelet is

$$H_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (3)$$

4x4 Haar transformation matrix is shown below.

$$H_4 = \frac{1}{\sqrt{4}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \sqrt{2} & -\sqrt{2} & 0 & 0 \\ 0 & 0 & \sqrt{2} & -\sqrt{2} \end{bmatrix} \quad (4)$$

3. KEKRE'S TRANSFORM [6] [9]:

Kekre's transform matrix can be of any size NxN, which need not to be an integer power of 2. All upper diagonal and diagonal elements of Kekre's transform matrix are 1, while the lower diagonal part except the elements just below diagonal is zero. Generalized NxN Kekre's transform matrix can be given as shown in (5)

$$\begin{bmatrix} 1 & 1 & 1 & \dots & 1 & 1 \\ -N+1 & 1 & 1 & \dots & 1 & 1 \\ 0 & -N+2 & 1 & \dots & 1 & 1 \\ \vdots & \vdots & \vdots & \dots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & 1 & 1 \\ 0 & 0 & 0 & \dots & -N+(N-1) & 1 \end{bmatrix} \quad (5)$$

The formula for generating the element Kxy of Kekre's transform matrix is,

$$K_{xy} = \begin{cases} 1 & : x \leq y \\ -N + (x - 1) & : x = y + 1 \\ 0 & : x > y + 1 \end{cases} \quad (6)$$

Kekre's Wavelet Transform [6] [9]:

Kekre's Wavelet transform is derived from Kekre's transform. From NxN Kekre's transform matrix, we can generate Kekre's Wavelet transform matrices of size (2N)x(2N), (3N)x(3N),....., (N2)x(N2). For example, from 5x5 Kekre's transform matrix, we can generate Kekre's Wavelet transform matrices of size 10x10, 15x15, 20x20 and 25x25. In general MxM Kekre's Wavelet transform matrix can be generated from NxN Kekre's transform matrix, such that M = N * P where P is any integer between 2 and N that is, $2 \leq P \leq N$. Consider the Kekre's transform matrix of size NxN shown in Figure 1.

Figure 2 shows MxM Kekre's Wavelet transform matrix generated from NxN Kekre's transform matrix. First N numbers of rows of Kekre's Wavelet transform matrix are generated by repeating every column of Kekre's transform matrix P times. To generate remaining (M-N) rows, extract last (P-1) rows and last P columns from Kekre's transform matrix and store extracted elements in to temporary matrix say T of size (P-1) x P. Figure 3 shows extracted elements of Kekre's transform matrix stored in T.

K ₁₁	K ₁₂	K ₁₃	...	K _{1(N-1)}	K _{1N}
K ₂₁	K ₂₂	K ₂₃	...	K _{2(N-1)}	K _{2N}
K ₃₁	K ₃₂	K ₃₃	...	K _{3(N-1)}	K _{3N}
.	.	.	...	.	.
.	.	.	...	.	.
.	.	.	...	.	.
K _{N1}	K _{N2}	K _{N3}	...	K _{N(N-1)}	K _{NN}

Figure 1 Kekre's Transform (KT) matrix of size NxN

K _{(N-P+2) (N-P+1)}	K _{(N-P+2) (N-P+2)}	...	K _{(N-P+2) N}
K _{(N-P+3) (N-P+1)}	K _{(N-P+3) (N-P+2)}	...	K _{(N-P+3) N}
.	.	...	.
.	.	...	.
.	.	...	.
K _{N (N-P+1)}	K _{N (N-P+2)}	...	K _{NN}

Figure 3 Temporary matrix T of size (P-1) x P

In the same way DCT kekre's wavelet Technique, Hadamard kekre's wavelet Technique and Walsh kekre's wavelet Technique are implemented. In these techniques instead of using Kekre's transform matrix as base matrix the respective transform matrices are used as base matrices and then wavelet matrix is generated by the above illustrated technique

1st column of kekre's transform repeated P times 2nd column of kekre's transform repeated P times Nth column of kekre's transform repeated P times

K_{11}	K_{11}	...	K_{11}	K_{12}	K_{12}	...	K_{12}	...	K_{1N}	K_{1N}	...	K_{1N}
K_{21}	K_{21}	...	K_{21}	K_{22}	K_{22}	...	K_{22}	...	K_{2N}	K_{2N}	...	K_{2N}
K_{31}	K_{31}	...	K_{31}	K_{32}	K_{32}	...	K_{32}	...	K_{3N}	K_{3N}	...	K_{3N}
$\vdots$	$\vdots$	...	$\vdots$	$\vdots$	$\vdots$	...	$\vdots$	...	$\vdots$	$\vdots$	...	$\vdots$
K_{N1}	K_{N1}	...	K_{N1}	K_{N2}	K_{N2}	...	K_{N2}	...	K_{NN}	K_{NN}	...	K_{NN}
$K_{(N-P+2)}$ (N-P+1)	$K_{(N-P+2)}$ (N-P+2)	...	$K_{(N-P+2) N}$	0	0	...	0	...	0	0	...	0
0	0	...	0	$K_{(N-P+2)}$ (N-P+1)	$K_{(N-P+2)}$ (N-P+2)	...	$K_{(N-P+2) N}$	...	0	0	...	0
		$\vdots$				$\vdots$		$\vdots$				
0	0	...	0	0	0	...	0	...	$K_{(N-P+2) (N-P+1)}$	$K_{(N-P+2)}$ (N-P+2)	...	$K_{(N-P+2) N}$
$K_{(N-P+3)}$ (N-P+1)	$K_{(N-P+3)}$ (N-P+2)	...	$K_{(N-P+3) N}$	0	0	...	0	...	0	0	...	0
0	0	...	0	$K_{(N-P+3)}$ (N-P+1)	$K_{(N-P+3)}$ (N-P+2)	...	$K_{(N-P+3) N}$	...	0	0	...	0
		$\vdots$						$\vdots$				
0	0	...	0	0	0	...	0	...	$K_{(N-P+3) (N-P+1)}$	$K_{(N-P+3)}$ (N-P+2)	...	$K_{(N-P+3) N}$
		...				...		...			...	
		...				...		...			...	
$K_{N (N-P+1)}$	$K_{N (N-P+2)}$	...	K_{NN}	0	0	...	0	...	0	0	...	0
0	0	...	0	$K_{N (N-P+1)}$	$K_{N (N-P+2)}$	...	K_{NN}	...	0	0	...	0
		$\vdots$						$\vdots$				
0	0	...	0	0	0	...	0	...	$K_{N (N-P+1)}$	$K_{N (N-P+2)}$	...	K_{NN}

Figure 2 Kekre's Wavelet transform matrix of size $M \times M$ generated from Kekre's transform matrix of size $N \times N$. Where $M = N * P, 2 \leq P \leq N$.

4. PROPOSED ALGORITHM

Averaging and PCA methods are applied on 9 set of images as described and for all other transform techniques algorithm is given as follows:

1. Take as input two images of same size and of same object or scene taken from two different sensors like visible and infra red images or two images having different focus.
2. If images are colored separate their RGB planes to perform 2D transforms.
3. Perform decomposition of images using different new transforms like Kekre's Wavelet transform, DCT Kekre's Wavelet transform, Hadamard Kekre's Wavelet transform and Walsh Kekre's Wavelet transform etc.
4. Fuse two image components by taking average [2].
5. Resulting fused transform components are converted to image using inverse transform.
6. For colored images combine their separated RGB planes.
7. Compare results of different methods of image fusion using various measures like entropy, standard deviation, mean, mutual information, etc.

5. RESULTS AND ANALYSIS

Above mentioned techniques are tried on pair of three RGB images and six gray images as shown in fig. 4 and results are compared based on measures like entropy, mean, standard deviation and mutual information [3] [11]. Figure 5 shows Image fusion by different techniques for visible and infra red

scenery images. Figure 6 shows Image fusion by different techniques for hill images with different focus. Figure 7 shows Image fusion by different techniques for gray clock images with different focus. Performance evaluation based on above mentioned four measures for color image is given in table 1. Table 2 presents performance evaluation for gray images.

Visible and Infra red Scenery images

Brain Images

Clock Images

Book Images

Medical Images

Hill images with different focus

MRI Images

Visible and Infra red gray images

CT and MRI images

Figure 4 Sample images

Figure 5 Image fusion by different techniques visible and infra red images

Figure 6 Image fusion by different techniques for hill images with different focus

f)Haar wavelet fused image

g)Kekre's wavelet fused image

h)DCT Kekre's wavelet fused image

i)Hadamard Kekre's wavelet e fused image

j)Walsh Kekre's wavelet fused image

Figure 7 Image fusion by different techniques images with different focus

Table 1 Performance evaluation for color images

		Averaging	DCT	PCA	Haar wavelet	Kekre's wavelet	DCT-Kekre's wavelet	Hadamard Kekre's wavelet	Walsh Kekre's wavelet
Hill Images	Mean	90.7652	134.150	134.325	134.3870	134.4092	134.3305	134.5729	134.5729
	SD	49.6320	90.2325	90.3185	90.3282	90.2632	90.3409	90.3158	90.3158
	Entropy	3.6091	7.2593	7.2654	7.3650	7.2610	7.2657	7.2514	7.2514
	MI	0.3465	0.4836	0.4892	0.4693	0.4849	0.4831	0.4870	0.4870
Scenery images	Mean	74.0107	88.6090	91.6637	88.9377	88.8765	88.8145	89.0465	89.0465
	SD	41.5931	64.3474	69.9428	64.5921	64.3860	64.3535	64.3578	64.3578
	Entropy	5.6304	7.4882	7.4915	7.5192	7.4905	7.4900	7.4894	7.4894
	MI	0.2573	0.3619	0.3781	0.3305	0.3651	0.3566	0.3657	0.3657
Book images	Mean	70.6272	83.8643	84.0590	84.2179	84.0735	84.0661	84.2984	84.2984
	SD	48.6626	69.3611	69.3732	70.8419	69.3877	69.3626	69.3716	69.3716
	Entropy	5.6613	7.4697	7.4783	7.4319	7.4802	7.4803	7.4876	7.4876
	MI	0.3217	0.5140	0.5140	0.4908	0.5115	7.4803	0.5137	0.5137

Table 2 Performance evaluation for gray images

		Averaging	DCT	PCA	Haar wavelet	Kekre's wavelet	DCT-Kekre's wavelet	Hadamard Kekre's wavelet	Walsh-Kekre's wavelet
Clock images	Mean	89.5221	96.3092	96.4922	96.6174	96.4766	96.5136	96.7419	96.7419
	SD	40.6857	48.9355	48.9555	49.3393	49.0089	48.9689	48.9795	48.9795
	Entropy	5.4238	7.3062	7.3066	7.3338	7.3087	7.3088	7.3057	7.3057
	MI	0.4316	0.5185	0.5202	0.4954	0.5182	0.5148	0.5206	0.5206

CT MRI images	Mean	32.1246	32.2862	51.9930	32.5318	32.4113	32.4366	32.6745	32.6745
	SD	32.7642	34.8291	53.4098	36.0796	34.8212	34.7672	34.7752	34.7752
	Entropy	5.7703	5.9090	6.5409	5.9799	5.9108	5.9231	5.8901	5.8901
	MI	0.5744	0.5674	0.7256	0.3982	0.5541	0.5544	0.5901	0.5901
Medical images	Mean	51.9185	51.7076	53.2289	51.9811	51.9424	51.8908	52.1328	52.1328
	SD	36.3854	36.8805	37.4420	38.1760	36.9228	36.9002	36.8938	36.8938
	Entropy	6.5385	6.6353	6.6308	6.7429	6.6412	6.6385	6.6298	6.6298
	MI	0.2693	0.2702	0.2832	0.2290	0.2690	0.2659	0.2768	0.2768
Brain images	Mean	48.8479	49.3843	49.4806	49.5519	49.5237	49.5185	49.6522	49.6522
	SD	49.4465	50.7464	50.8346	51.7821	50.8597	50.8453	50.9315	50.9315
	Entropy	4.9575	5.1872	5.1890	5.2598	5.2020	5.2105	5.2308	5.2308
	MI	0.3862	0.3959	0.3968	0.3844	0.3967	0.3965	0.4019	0.4019
MRI images	Mean	55.6803	62.5453	65.4645	62.7818	62.6141	62.6906	62.8733	62.8733
	SD	58.9193	68.3032	71.1772	69.3133	68.4042	68.3605	68.4069	68.4069
	Entropy	3.7671	5.6055	5.7225	5.7143	5.5988	5.6298	5.6648	5.6648
	MI	0.3426	0.3807	0.4064	0.3567	0.3807	0.3815	0.3876	0.3876
Visible & infra red gray images	Mean	89.5235	90.3802	102.5909	90.6947	90.6901	90.6423	90.8800	90.8800
	SD	19.7397	23.1171	48.0841	24.5829	23.1241	23.0979	23.1082	23.1082
	Entropy	2.9728	3.2780	3.0784	5.3974	3.7169	3.7410	3.2382	3.2382
	MI	0.1829	0.1991	0.5718	0.1777	0.2046	0.2004	0.1987	0.1987

From table 1 it is observed that for hill and book images mean indicating brightness is maximum for Hadamard Kekre's wavelet and Walsh Kekre's wavelet technique, while for scenery images it is maximum for PCA. And standard deviation gives clarity and contrast is maximum using DCT-Kekre's wavelet technique for hill images, while for book images Haar wavelet technique and for scenery images PCA gives best results. Entropy indicating amount of information is carried by the fused image is maximum using Haar wavelet technique for hill and scenery images, while for book images Hadamard Kekre's wavelet and Walsh Kekre's wavelet technique gives best results. Mutual information is maximum by PCA technique for hill and scenery images meaning that quality of fused image is better using this technique, while for book images DCT-Kekre's wavelet technique gives best results.

From table 2 it is observed that for clock and brain images mean and MI are maximum by Hadamard Kekre's wavelet

and Walsh Kekre's wavelet technique. Standard deviation and Entropy are maximum using Haar technique. For CT-MRI and MRI images PCA gives best results in terms of all measures. For medical images mean and MI are maximum using PCA technique and SD and entropy are maximum using Haar wavelet technique. For visible and infra red gray images mean, SD and MI are maximum using PCA technique while entropy is maximum using Haar technique.

In all these images if we observe the output of the Kekre's wavelet technique in different combinations it gives best results for some images and for some images it is very close to the output and the major advantage of the matrix is that it can be used for images which are not integral power of 2.

6. CONCLUSION

In this paper many pixel level techniques like Kekre's wavelet technique and its combination with Kekre's transform, DCT, Hadamard and Walsh are implemented and their results are compared with basic techniques such as averaging, PCA, DCT, Haar wavelet. It is observed that the new Kekre's wavelet transform when used for image fusion gives comparatively good results, just closer to the best result and the added advantage is that it can be used for images of any size, not necessarily integer power of 2.

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