A Novel Multi-Focus Image Fusion Algorithm Using Stationary Wavelet Transform

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Abstract— During this paper, by considering the most target of multi-focus image fusion and therefore the physical importance of wavelet coefficients, a stationary wavelet transform (SWT) based mostly fusion strategy with a completely unique coefficients choice formula is displayed. When the supply pictures square deteriorated by SWT, 2 completely different window-based fusion rules square measure severally used to join the low frequency and high frequency coefficients. Within the technique, the coefficients with in the low frequency area with most extreme sharpness focus live square measure chosen as coefficients of the combined image, and a greatest neighboring vitality based mostly combination set up is projected to vitality based mostly combination set up is projected to settle on high frequency sub-bands coefficients. Thus on make sure the homogeneity of the resultant coalesced image, a consistency confirmation technique is connected to the combined coefficients. The performance assessment of the projected technique was directed in each artificial and real multi-focus pictures. Experimental results exhibit that the projected technique will accomplish higher visual quality and objective analysis indexes than a number of existing coalesced ways, during this manner being an efficient multi-focus image fusion methodology.

Keyword—multi-focus image fusion, stationary wavelet transform coefficients, image sharpness, energy.

I. INTRODUCTION

Generally, many pictures of constant scene will be obtained to enhance the robustness of image process system. However, Series of pictures for viewing and analyzing aren't convenient and efficient. For that image fusion techniques square measure effective solution to resolve this drawback. Image Fusion Techniques combined the complementary, necessary and needed data from multiple pictures in to a fused image, that is incredibly helpful for human or machine perception. Today, several image fusion algorithms are developed and employed in several applications to merge multi-focus data into single composite image. we are able to think about these image fusion algorithms as classified. In 2 board categories: Transform domain fusion and spatial domain fusion [2]. The fore most unremarkably used transform domain fusion techniques square measure DCT (Discrete Cosine Transform), DWT (Discrete Wavelet Transform), Pyramid methodology, RDWT (Redundant DWT), SWT (Stationary wavelet Transform), DT-CWT (Dual Tree Complex wavelet transform) and then on. recently, some novel transform domain analysis ways, a skin to curvelet transform, Contourlet transform, log-Gabor wavelet transform, support value transform retina-inspired model and thin illustration also are applied to Image fusion [1]. Uaually, the transform domain ways perform 3 Common steps. First input pictures square measure regenerate in to transform domain to induce corresponding transform coefficients. Then transform coefficients square measure incorporated along per out lined fusion rule. Finally, the fused resultant image is obtained by acting inverse transform on incorporated constant. Not like the transform domain ways, spatial domain directly. Basically spatial domain fusion methodology divided into 2 categories: pixel level fusion ways and Region or feature level fusion ways. the elemental plan behind these 2 ways is to clearer the ultimate resultant image. In general, traditional Multi-focus image fusion Techniques offer satisfactory result on static scenes. however scientist found drawback with the multi-focus image fusion in dynamic scene with camera movements and object motion. For that reasons the contents within the same position of multiple pictures is also completely different from one another. with this sort of multi-focus pictures the transform domain fused techniques sometimes suffer from artifacts within the fusion image owing to inconsistent of image contents. In spatial domain fusion the main focus data calculable by spatial variance, image gradient or spatial frequency to see centered constituent or region. However, in dynamic scenes we tend to can't acquire focus directly whether or not constituent or region is blurred or not. the reason is that the constituent or region within .The same location of various supply pictures is also contained of various contents thanks to camera movement or object motion. Further as ancient spatial domain ways can not offer terribly correct fusion results once pattern in supply pictures become complex.

II. STATIONARY WAVELET TRANSFORM

The discrete wavelet transform is not a time invariant transform. The way to restore the translation invariance unchangeability to average some slightly totally different DWT, known as un-decimated DWT, to outline the stationary wavelet transform (SWT). It will thus by suppressing the down-sampling step of the decimated algorithmic program and instead up-sampling the filters by inserting zeros between the filter coefficients. like the decimated algorithmic program, the filters area unit applied to the rows so to the columns. During this case, however, though the four pictures made (one approximation and 3 detail images) area unit at 0.5 the resolution of the original; they're identical size because the original image. The approximation pictures from the undecimated algorithmic program area unit so diagrammatical as levels during a parallelepiped, with the special resolution changing into coarser at every higher level and therefore the size remaining identical. Stationary wavelet transform (SWT) is analogous to discrete wavelet transform (DWT) however the sole method of down-sampling is suppressed which means The SWT is translation-invariant. The 2-d SWT decomposition theme is illustrate in figure one.

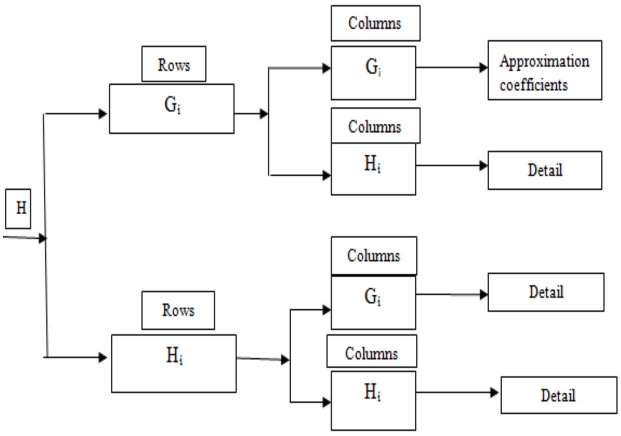

Figure 1: SWT decomposition scheme

The 2D stationary wavelet transform (SWT) relies on the thought of no decimation. It applies the discrete wavelet transform (DWT) and omits each down-sampling within the forward and up-sampling within the inverse stationary wavelet transform. Additional exactly, it applies the transform at every purpose of the image and saves the detail coefficients and uses the low frequency data at every level. The stationary wavelet transform decomposition theme is illustrated in figure one where ever Gi and Hi are a unit a supply image, low- pass filter and high-pass filter, severally. Figure one shows the detail results once applying SWT to a picture using at one to four levels.

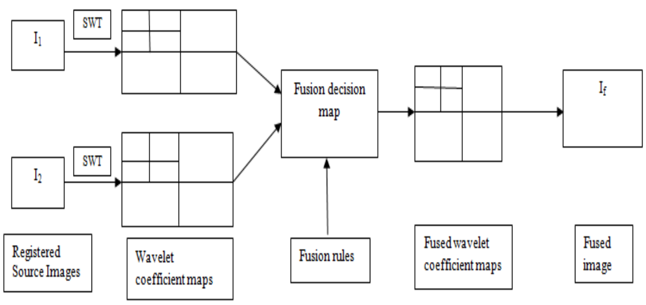

Figure 2 : SWT based image fusion

III. THE PROPOSED FUSION METHODOLOGY:

As denote previously, the key purpose of multi-focus image fusion is to determine that parts of every image are a unit in higher focus than their various counter parts with in the associated pictures then mix these regions to construct a well-focused image by certain fusion rules, that play a very important role in SWT primarily based fusion method. The window-based fusion rules typically consider the neighboring pixels in making decision choice , so that they are a unit superior to traditional pixel-based fusion rules. Additionally, since the coefficients in low frequency and high frequency bands have completely different physical Meanings, they must be treated by the mix formula through completely different procedures. supported the on top of analysis, the procedure of our new SWT primarily Based multi-focus image fusion methodology is then bestowed, that is summarizes in the basic plan of our methodology is to perform SWT on every supply image within the initial step; Then once taking into consideration the characteristics of multi-focus pictures and their decomposition sub-bands, this paper presents a brand new fusion rule that treats the coefficients of the low frequency and high frequency sub-bands on an individual Basis by victimization fusion schemes as: the previous are a unit performed by a most sharpness primarily based strategy where as the where as the latter is performed by a most energy primarily based strategy. so as to beat the presence of noise and guarantee the homogeneity of the fused image, all the coefficients area unit after performed by a window-based consistency verification method. Finally, the fused image is obtained by play acting the ISWT on the combined wavelet coefficients. It ought to be noted that the high frequency sub-bands include the vertical, horizontal, and diagonal high frequencies of the image, severally. Therefore, the Fusion method should be performed all together these domains.To alter the outline of the various alternatives out there in forming a fusion rule, as reference [16] we have a consider 2 supply pictures, X and Y, and also The fused image Z. the strategy will in fact be simply extended to over 2 pictures. Generally, a picture1 has its multi-scale decomposition (MSD) illustration denoted as DI. Let p=(m,n,k,l). Indicate the index comparable to a selected MSD constant, where ever m and n indicate the spatial position during a given band, k is that the decomposition level, and l is that the band of the MSD illustration. Therefore, DI (p) denotes the MSD price of the corresponding constant.

A. Fusion for low frequency sub-band coefficients

The low frequency sub-band is that the original image at the coarser resolution level, which may be thought of as a smoothened and sub sampled version of the initial image. Most data of their supply pictures is un broken within the low frequency sub-band. As we all know that for multi-focus pictures, every of them has some clear data regarding a similar scence however none of them is sufficient in terms of its data contents. the most plan of their fusion is to pick out sharply pixels from supply pictures and mix them along to reconstruct the superior image within which all the pixels is clearly targeted. Therefore, here we have a tendency to planned to use a sharpness focus live to pick out the coefficients in low frequency sub-bands. The sharpness live may be a Tenengrad perform Supported sobel operator, that conjointly thought of the neighborhood data of a picture element by a set window. This live is accustomed indicate the clarity of the image pixles, and a well-focused image is predicated to possess sharper information. The sharpnedd focus live is outlined as:

$$\nabla G(p) = [\nabla G_m(p)^2 + \nabla G_n(p)^2]^{1/2} \qquad (1)$$

where ∇Gm(p) , ∇Gn(p) can be express by

$$\nabla G_m(p) = \begin{Bmatrix} -D(m-1,n-1,k,l) - 2D(m-1,n,k,l) \\ -D(m-1,n+1,k,l) + D(m+1,n-1,k,l) \\ +2D(m+1,n,k,l) + D(m+1,n+1,k,l) \end{Bmatrix} \qquad (2)$$

$$\nabla G_n(p) = \begin{Bmatrix} D(m-1,n-1,k,l) + 2D(m,n-1,k,l) \\ +D(m+1,n-1,k,l) - D(m-1,n+1,k,l) \\ -2D(m,n+1,k,l) - D(m+1,n+1,k,l) \end{Bmatrix} \qquad (3)$$

After getting the sharpness of all pixels of the low frequency sub-bands, a most theme of it's then performed. Because, for multi-focus image fusion, the targeted pixels ought to turn out most sharpness live, however the defocused pixels ought to turn out minimum sharpness live on the contrary. The fusion theme of the coefficients in low frequency sub-band is then outlined as:

$$D_Z(p) = \begin{Bmatrix} D_X(p) \nabla G_X(p) \geq \nabla G_Y(p) \\ D_Y(p) \nabla G_X(p) < \nabla G_Y(p) \end{Bmatrix} \qquad (4)$$

B. Fusion for high frequency's sub-band coefficients

The high frequency sub-bands contain the detail coefficients of a picture, that typically have large absolute values correspond to sharp intensity changes and preserve salient data within the image. So if the rule mentioned on top of for low frequency sub-bands is adopted here, the fused results are blocked. Besides, in keeping with the transform remodel theory, we all know that the energy of the the high frequency coefficients of a transparent image is way larger than that of a blurred one. supported this analysis and considering that the transform constant is said to its neighboring region, we have a tendency to propose a fusion theme by computing the neighboring energy most to pick out the high frequency coefficients. The neighboring energy feature is outlined as:

$$NE(p) = \sum_{(i,j)\in W} H(i,j) D^2(m+i, n+j, k, l) \qquad (5)$$

where W is that the three × three neighboring size, and H(i, j) denotes the weighted model, that is employed to focus on the middle picture element of the window and is about as:

$$H(i,j) = \begin{bmatrix} 0 & 1/8 & 0 \\ 1/8 & 1/2 & 1/8 \\ 0 & 1/8 & 0 \end{bmatrix} \qquad (6)$$

Then we have a tendency to perform a most choice rule on the coefficients in high frequency sub-bands, that choose the coefficients with higher energy into the fused image. The fusion theme used for its expressed as:

$$D_Z(p) = \begin{cases} D_X(p) & NE_X(p) \geq NE_Y(p) \\ D_Y(p) & NE_X(p) < NE_Y(p) \end{cases} \qquad (7)$$

C. consistency verification

As is seen from on top of subsections all the coefficients of each low frequency and high frequency bands are a unit chosen by the most choice schemes, however as we all know that the most choice technique are incoming just in case of noise. Moreover, since we have a tendency to handle the coefficients on an individual basis, this methodology cannot guarantee the homogeneity with in the resultant fused image. Therefore, a consistency verification theme is then performed, which may conjointly make sure the dominant options are a unit incorporated as utterly as doable in to the fused image [7]. the thought of this try is probably going to be a majority filter. during this paper, we have a tendency to apply a window-based verification (WBV) to the coefficients with in the composite MSD. The WBV employs a tiny low window targeted at the present constant position. The WBV rule is that if the middle composite MSD constant comes from image X, however the bulk of the encompassing coefficients with in the window return from image Y, then the middle sample is modified to come back from Y, then the middle sample is modified to come back from Y, and contrariwise. Within the implementation, this rule is applied to a binary call map, then it's followed by the appliance of a majority filter. The amalgamate coefficients area unit finally obtained by the new binary call map. This method is developed as follows.

$$D'_X(p) = \min_{w \in W}(|D_X(p,w)|),$$

$$D'_Y(p) = \min_{w \in W}(|D_Y(p,w)|) \qquad (8)$$

$$q_X(p) = \begin{cases} 1, & D'_X(p) > D'_Y(P) \\ 0, & otherwise \end{cases} \qquad (9a)$$

$$q_\downarrow Y(p) = \{\blacksquare(1, \quad D_\downarrow Y^{\uparrow\prime}(p) \geq D_\downarrow X^{\uparrow\prime}(p) @ 0, \quad otherwis$$

$$q_X(p) = \begin{cases} 1, & \sum q_X(p) \geq 5 \\ 0, & otherwise \end{cases} \qquad (10a)$$

$$q_X^*(p) = 1 - q_X^*(p) \qquad (10b)$$

$$D_Z(p) = q_X^*(p)D_X(p) + q_Y^*(p)D_Y(p) \quad (11)$$

$$\text{RMSE}=\left(\frac{1}{MN}\sum_{n=1}^{N}\sum_{m=1}^{M}(x_R(n,m)-x_F(n,m))^2\right)^{1/2} \quad (12)$$

Once all the coefficients area unit achieved from the on top of 3 procedures, the ISWT is then performed on them, the amalgamate image is so made.

IV. ALGORITHM STEPS :

Procedure:

Input: The aligned supply pictures to be fused.
Step 1): Decompose the pictures by SWT into low frequency sub-bands and high frequency sub-bands.

Step 2): perform completely different fusion rules to pick out the coefficients in low frequency sub-bands and high frequency sub-bands: the previous area unit fused by a most sharpness primarily based theme, and also the latter area unit fused by a most energy primarily based theme.
Step 3): All the coefficients area unit performed by a window-based consistency verification method.

Step 4): The ISWT is applied to the ultimate fused coefficients.

Output : The fused image.

V. PARAMETERS :

A. Standard Deviation (STD):

It's the degree of deviation between the gray levels and its norm for the image is high.

B. Information Entropy (IE) :

It measures the richness of knowledge in a picture is high.

C. Metric (Qabf) :

Metric reflects the standard of visual data obtained from the fusion of input pictures is high.

D. Root Mean Square Error (RMSE) :

The RMSE is lower value of better fused result.

$$\text{RMSE}=\left(\frac{1}{MN}\sum_{n=1}^{N}\sum_{m=1}^{M}(x_R(n,m)-x_F(n,m))^2\right)^{1/2}$$

E. Fusion Factor (FF) :

Given two images a and b, and their fused image f, the fusion factor (FF) is

$$FF=I_{AF}+I_{BF}$$

Where IAF and IBF are the mim values between input images and fused image. A higher value of ff indicates that fused image.

F. Fusion Symmetry (FS) :

Fusion symmetry (FS) is a sign of the degree of symmetry within the data content from each the pictures.

$$FS=abs[I_{AF/}I_{BF}+I_{BF}-0.5]$$

The quality of fusion technique depends on the degree of fusion symmetry. FS ought to be as low as doable in order that the fused image derives options from each input pictures.

G. Fusion Index (FI) :

The fusion symmetry and fusion factor is called fusion index (FI) is defined as

$$FI=I_{AF/}I_{BF}$$

Where IAF is the mutual information index between multispectral image and fused image and IBF is the mutual information index between panchromatic image and fused image. The quality of fusion technique depends on the degree of fusion index.

VI. RESULTS AND ANALYSIS:

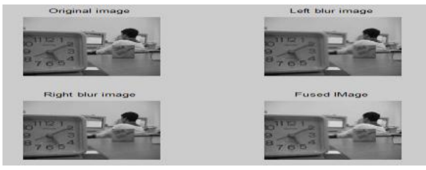

Figure :3 SWT based image fusion for clock image

Figure :4 SWT based image fusion for bus image

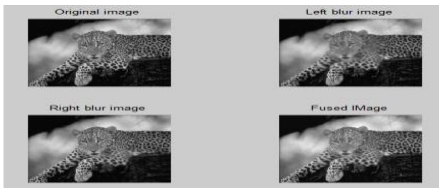

Figure :5 SWT based image fusion for leopard image

Figure :3 SWT based image fusion for house image

Table1: Comparison between Different Images In DWT and SWT

Images	Parameters	Existing	Proposed
		DWT (Discrete Wavelet Transform)	SWT (Stationary Wavelet Transform)
Bus	STD(Standard Deviation)	54.9487	55.9699
	IE(Information Entropy)	7.3174	8.3198
	Qabf(Metric)	0.091	0.0924
	FF(Fusion Factor)	4.6120	5.2369
	FS(Fusion Symmetry)	6.9805	7.6237
	FI(Fusion Index)	1.1096	2.1335
Clock	STD(Standard Deviation)	45.4453	46.4677
	IE(Information Entropy)	7.0376	8.0478
	Qabf(Metric)	0.0736	0.0839
	FF(Fusion Factor)	5.1869	6.2841
	FS(Fusion Symmetry)	9.6012	8.5423
	FI(Fusion Index)	1.1436	2.1630
House	STD(Standard Deviation)	50.1242	52.1333
	IE(Information Entropy)	7.6471	8.6485
	Qabf(Metric)	0.057	0.0774
	FF(Fusion Factor)	4.4208	4.5457
	FS(Fusion Symmetry)	11.0063	12.8795
	FI(Fusion Index)	1.2055	1.3079
Leopard	STD(Standard Deviation)	63.0773	64.9717
	IE(Information Entropy)	7.4541	7.6598
	Qabf(Metric)	0.0175	0.0378
	FF(Fusion Factor)	4.5822	5.5955
	FS(Fusion Symmetry)	8.9522	9.9804
	FI(Fusion Index)	1.1515	2.1693

Table2: Comparison between Different Images In RMSE

Image	RMSE(DWT)	RMSE(SWT)
House	37.627	33.6454
Bus	18.4017	18.0339
Leopard	13.1158	12.37
Clock	11.7489	11.4417

VII. CONCLUSION:

The results shown on application of SWT (Stationary Wavelet Transform) in multi-focus image fusion gives better then DWT (Discrete Wavelet Transform). The improvement is observed in the quality of multi-focus images. The quality parameters STD, IE QABF, FF, FS, FI, are increased and RMSE is decreased.

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