A modified technique for low RMSE multifocus image fusion

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ABSTRACT

This paper presents a modified technique for multifocus image fusion for low RMSE. In the conventional partition fusion technique using image sub blocks, RMSE obtain is high for different block sizes; which are insufficient to obtain better visual effect. In the modified technique, before dividing the image into subbands it is filtered through linear phase 2-D FIR low pass digital filter. The modified technique is tested by different focus measures and applying choose max selection rule and it is found that EOL outperforms and gives the lowest RMSE for different block sizes of sub images.

Keywords: EOL, RMSE, MI, FIR.

1. Introduction

The images are the real description of objects. When these images are taken from camera there are some limitations of a camera system. One of which is the limitation of depth of focus. Due to this an image cannot be captured in a way that all of its objects are well focused. Only the objects of the image with in the depth of field of camera are focused and the remaining will be blurred. To get an image well focused everywhere we need to fuse the images taken from the same view point with different focus settings. The term image fusion is used for practical methods of merging images from various sensors to provide a composite image which could be used to better identify natural and manmade objects. In the recent research works the researchers have used various techniques for multi-resolution image fusion and multi focus image fusion. **.** Li' et al.,(2001-2002) introduced a method based on the selection of clearer image blocks from source images[8,9].In this method, image is first partitioned into blocks then focus measure is used as activity level measurement. Based on activity level, best image block is selected by choosing image block having maximum value of activity for fused image. The advantage of this method is that it can avoid the problem of shift-variant, caused by DWT. Also according to the analysis of the image blocks selection method, the implementation is computationally simple and can be used in a real-time. The limitation of this method is of its robustness to noise. This method does not perform quit well for noisy images. To overcome this limitation preprocessing of the image has been done with the help of a low pass filter.

The measure of clarity plays an important role in this kind of fusion method. A better measure results in a superior fusion performance. However, little work has been done on the image clarity measures in the field of multi-focus image fusion. The image clarity measures, namely focus measures, are deeply studied in the field of autofocusing. The paper also considered the fact that the background information lie in low frequency component of the image; so while using different focusing parameters the method proposed will be able to extract the features of background information when the image is passed by a low pass filter. This paper is organized as follows. A brief description of focus measures is given in Section 2. An evaluation of focus measures is presented in Sections 3 and Sections 4 gives some concluding remarks.

2. Focus measures

A value which can be used to measure the depth of field from the acquired images can be used as focus measure. Depth of field is maximum for the best focused image and generally decreases as the defocus increases.

A typical focus measure should satisfy following requirements:

1. Independent of image content;
2. monotonic with respect to blur;
3. The focus measure must be unimodal, that is, it must have one and only one maximum value;
4. Large variation in value with respect to the degree of blurring;
5. Minimal computation complexity;
6. robust to noise.

A number of different focus measures used to test the proposed modified algorithm are variance, EOG, EOL, and SF to measure the focus measure of an M X N image with f(x, y) be the gray level intensity of pixel (x, y).

1. Variance: The simplest focus measure is the variance of image gray levels. The expression for the M × N image f(x, y) is:

$$\text{variance} = \frac{1}{\mathrm{M}\times\mathrm{N}}\sum_{x=1}^{\mathrm{M}}\sum_{y=1}^{\mathrm{N}}(\mathrm{f}(x,y)-m)^2$$

, Where $m = \frac{1}{\mathrm{M}\times\mathrm{N}}\sum_{x=1}^{\mathrm{M}}\sum_{y=1}^{\mathrm{N}}\mathrm{f}(x,y)$

2. Energy of image gradient (EOG): This focus measure is computed as:

$$\mathrm{EOG}=\sum_{x=1}^{\mathrm{M}-1}\sum_{y=1}^{\mathrm{N}-1}(\mathrm{f}_x{}^2+\mathrm{f}_y{}^2)$$

Where

$$\mathrm{f}_x = \mathrm{f}(x+1,y)-\mathrm{f}(x,y)\ \&$$
$$\mathrm{f}_y = \mathrm{f}(x,y+1)-\mathrm{f}(x,y)$$

3. Energy of Laplacian of the image (EOL): It is used for analyzing high spatial frequencies associated with image border sharpness is the Laplacian operator.

$$\mathrm{EOL}=\sum_{x=2}^{\mathrm{M}-1}\sum_{y=2}^{\mathrm{N}-1}(\mathrm{f}_{xx}+\mathrm{f}_{yy})^2$$

Where

$$\mathrm{f}_{xx}+\mathrm{f}_{yy}=-\mathrm{f}(x-1,y-1)-4\mathrm{f}(x-1,y)-\mathrm{f}(x-1,y+1)-4\mathrm{f}(x,y-1)$$
$$+20\mathrm{f}(x,y)-4\mathrm{f}(x,y+1)-\mathrm{f}(x+1,y-1)-4\mathrm{f}(x+1,y)-\mathrm{f}(x+1,y+1)$$

4. Spatial frequency (SF): Strictly speaking frequency is not a focus measure. It is a modified version of the Energy of image gradient (EOG). Spatial frequency is defined as:

$$\mathrm{SF}=\sqrt{\mathrm{RF}^2+\mathrm{CF}^2}$$

Where RF and CF are row and column frequencies respectivly:

$$\mathrm{RF}=\sqrt{\frac{1}{\mathrm{M}\times\mathrm{N}}\sum_{x=1}^{\mathrm{M}}\sum_{y=2}^{\mathrm{N}}(\mathrm{f}(x,y)-\mathrm{f}(x,y-1))^2}$$

$$\&\quad \mathrm{CF}=\sqrt{\frac{1}{\mathrm{M}\times\mathrm{N}}\sum_{x=2}^{\mathrm{M}}\sum_{y=1}^{\mathrm{N}}(\mathrm{f}(x,y)-\mathrm{f}(x-1,y))^2}$$

5. Visibility (VI): This focus measure is inspired from human visual system, and is defined as in [18]

$$\mathrm{VI}=\sum_{\mathrm{m}=1}^{\mathrm{M}}\sum_{\mathrm{n}=1}^{\mathrm{N}}\frac{|\mathrm{f}(\mathrm{m},\mathrm{n})-m|}{m^{a+1}}$$

Where µ is the mean intensity value of the image, and α is a visual constant ranging from 0.6 to 0.7.

3. Proposed Focusing techniques and Experimental Setup

Setup.1 for Existing Algorithms

A schematic diagram for image fusion used by Li is shown in Fig-1.it used chooses maximum combination method with no consistency verification process is used for fusion operation.

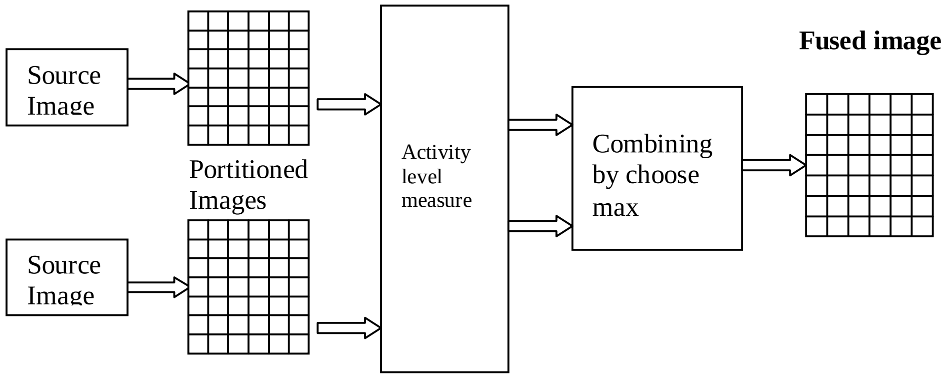

Fig.1: A general schematic for fusion of multifocus images based on selection of image blocks from source images

The fusion method consists of the following steps:

Step **1**. Decompose the differently focused source images into blocks. Denote the ith image block of source images by A_i and B_i respectively.

Step **2**. Compute the focus measure or SF of each block, and denote the results of A_i and B_i by M_i^A and ,M_i^B respectively.

Step **3**. Compare the focus measure or SF of two corresponding blocks A_i , and B_i and construct the ith block D_i of the composite image as

$$D_i = \begin{cases} A_i & M_i^A > M_i^B \\ B_i & M_i^B > M_i^A \end{cases}$$

Step 4. Compute root mean square error (RMSE) for the composite image with a reference image.

The proposed focusing technique uses the linear-phase 2-D FIR low pass digital filter to filter the differently focused images. Filter uses Parks-McClellan algorithm [19], [20].The Parks-McClellan algorithm uses filter with Equiripple or least squares approach over sub-bands of the frequency range and Chebyshev approximation theory to design filters with an optimal fit between the desired and actual frequency responses. The filters are optimal in the sense that the maximum error between the desired frequency response and the actual frequency response is minimized. Filters designed this way exhibit an equiripple behavior in their frequency responses and are sometimes called equiripple filters. Filters exhibit discontinuities at the head and tail of its impulse response due to this equiripple nature. For these low pass filtered images simplest focus measure such as Variance, Energy of Gradient, Energy of Laplacian, Spatial frequency is computed.

Setup.2 for proposed algorithms

A schematic diagram for proposed image fusion method is shown in Fig-2.A 2-D FIR low pass filter is used before partitioning the image in 32 x 32 blocks:

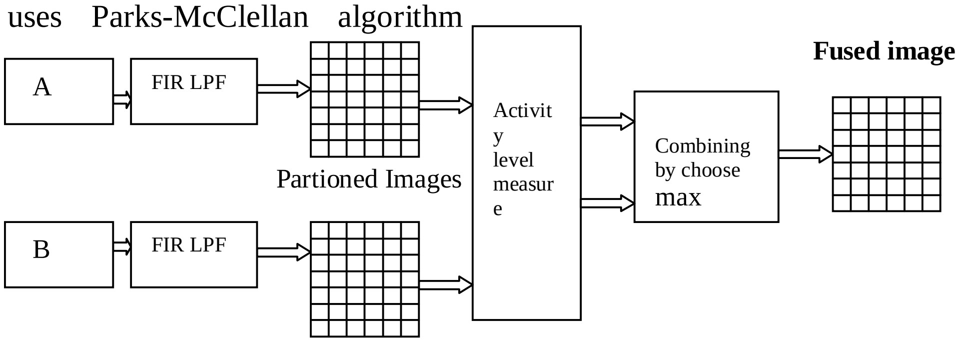

Fig.2: **S**chematic diagram for evaluating proposed focusing technique in Multi-focus image fusion

The source images are passed through 2-D FIR low pass filter of order 4 and having filter characteristics as shown in Fig.3.the filtered images are than fused using Li's method.

To evaluate the performance of modified algorithm RMSE of the fused image calculated.

RMSE is defined as:

$$\text{RMSE}=\sqrt{\frac{\sum_{x=1}^{M}\sum_{y=1}^{N}\{R(x,y)-F(x,y)\}^2}{M\times N}}$$

Where R and F are reference image and composite image respectively, with size M × N pixels.

4. Results:

The experiment is performed on toy image of size 512×512. The multifocus images used for fusion are left focused, right focused and middle focused as shown in Fig 4, 5 and 6 respectively. These multifocus images are filtered through linear phase 2D FIR low pass digital filter to reduce low frequency noise and then fused using Li's and modified algorithm for various focus measures. The performance of existing and modified algorithm is compared qualitatively by calculating RMSE of fused images.Table-1 shows the RMSE of fused images using different focus measures and for different block size of images. The analysis of Table-1 shows that RMSE decreases with increase the block size. As a larger image block gives more information for measuring the blocks focus or clarity. However using a block size too large is undesirable because if the block size is too large, particular block may contain two or more objects at different distances form the camera, and consequently will lead to a less clear image. .

The experimental results show that the performance of all the focus measures improves with reduced RMSE when filtered image is used for fusion .Also the experiments shows that EOL gives low RMSE with unequal block sizes while SF gives low RMSE with equal block sizes.**F**ig-7 is the reference image taken all parts focused. **F**ig 8 to Fig 12 shows the fused images while considering different focus measures. **F**ig 13 and **F**ig 14 shows the fused images while considering different proposed focus measures.

5. Conclusion:

In this paper modified method of image fusion was used considering various focus measure capabilities of distinguishing clear image blocks form blurred image blocks. Experimental results show that preprocessed, 2-D FIR low pass filtered image in modified method provide better performance in terms of low RMSE than the previous methods of information fusion. Also from the results it is concluded that performance of the image fusion method depends on block size taken during the partitioning of source images. Also the experiment shows that EOL gives low RMSE with unequal block sizes while SF gives low RMSE with equal block sizes. This is an issue that will be investigated in future on adoption methods for choosing the image block size.

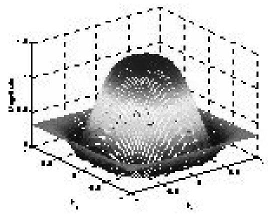

Fig.3.**P**erspective plot of linear phase 2-D FIR Lowpass digital filter

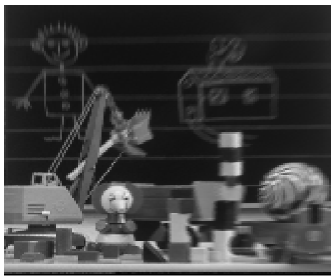

Fig. 4 **l**eft focused image

Table-1

Evaluation of different focus measures with different block sizes on basis of RMSE (Fig.8-14)

Block size	Focus measure								
	variance	EOG	EOL	SF	VI	Variance of LPF images	EOG of LPF images	EOL of LPF images	SF of LPF images
4×4	4.5814	***3.9383***	3.6437	3.9383	4.1383	0.9514	0.9514	0.9301	0.9514
4×8	4.5447	4.0106	3.3199	4.0118	4.2340	0.9626	0.9626	0.9073	0.9626
8×8	***4.3658***	4.0264	3.1466	3.9292	4.2110	0.9606	0.9373	***0.8686***	0.9373
8×16	4.4089	4.0035	3.1806	4.0407	4.1160	0.9346	0.9284	0.8843	0.9255
16×16	4.7037	4.7720	3.4659	4.0517	3.9574	1.1872	1.1820	1.1561	***0.8827***
16×32	4.6329	4.0159	***3.8220***	3.9351	3.9399	***0.9119***	***0.8923***	0.8776	0.8889
32×32	4.4221	4.6485	3.0888	***3.8506***	3.6183	1.2043	1.1382	1.1531	0.8949
32×64	***4.2559***	***3.9797***	***3.5020***	3.8944	3.5630	***0.9066***	***0.8893***	***0.8715***	0.8874
64×64	4.6588	4.6000	3.8727	***3.8927***	***3.4368***	1.2194	1.2248	1.2013	***0.8744***

Numbers in bold and italic indicate the lowest RMSE obtained over different block sizes

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Fig. 5 right focused image

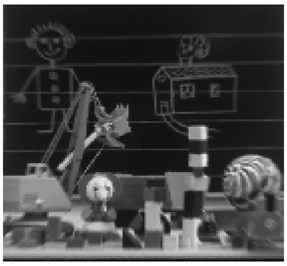
Fig. 6 **m**iddle focused image


Fig.7.**A**ll focused image


Fig .8. Fused images

Formed from variance


Fig.**9**.Fused images formed From **EOG**(16×32)


Fig.**10**. Fused images formed from **EOL**(32x64)

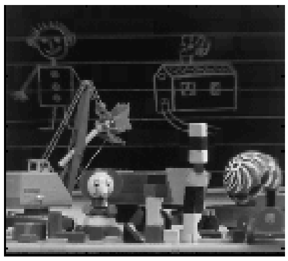
Fig.**11**.Fused images formed from **SF** (32x 64)


Fig.**12**.Fused images formed from LPF and SF (32×32)


Fig.**13**.Fused images formed from LPF and **EOG**(16×32)


Fig.**14**.Fused images formed from LPF and **EOL**(64×64)