A MODIFIED PARTITION FUSION TECHNIQUE OF MULTIFOCUS IMAGES FOR IMPROVED IMAGE QUALITY

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ABSTRACT
This paper presents a modified Partition fusion technique for multifocus images for improved image quality. In the conventional partition fusion technique image sub blocks are selected for fused image based on their clarity measures. The clarity measure of an image sub block can be determined by second order derivative of the sub image. The performance of these clarity measures is insufficient in noisy environment. In the modified technique, before dividing the image into sub images, it is filtered through linear phase 2-D FIR low pass digital filter to overcome the effect of noise. The modified technique uses choose max selection rule to select the clearer image block from the differently focused source images. Performance of the modified technique is tested by calculating the value of RMSE. It is found that EOL gives lowest RMSE with unequal block sizes while SF gives lowest RMSE with equal block sizes when used as clarity measure in modified partition fusion technique.

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. 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 quite 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. Proposed modified technique for obtaining low RMSE fused image is discussed in Sections 3 and Sections 4 presents results of the proposed method in comparison with existing methods.

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 satisfies 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.

The conventional focus measures used to measure the clarity of the images are variance, EOG, EOL, and SF. These focus measures are expressed as following for an M × 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:
   \[
   \text{variance} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} (f(x, y) - \mu)^2
   \]
   Where \( \mu \) is the mean value and is given as
   \[
   \mu = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} f(x, y)
   \]

2. **Energy of image gradient (EOG)**: This focus measure is computed as:
   \[
   \text{EOG} = \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} (f_x^2 + f_y^2)
   \]
   Where
   \[
   f_x = f(x + 1, y) - f(x, y)
   \]
   \[
   f_y = f(x, y + 1) - f(x, y)
   \]

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.
   \[
   \text{EOL} = \sum_{x=2}^{M-1} \sum_{y=2}^{N-1} (f_{xx} + f_{yy})^2
   \]
   Where
   \[
   f_{xx} = f(x-1,y-1) - 4f(x,y) + f(x+1,y+1)
   \]
   \[
   f_{yy} = f(x-1,y-1) + 4f(x,y) + f(x+1,y+1)
   \]

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:
   \[
   \text{SF} = \sqrt{RF^2 + CF^2}
   \]
   Where RF and CF are row and column frequencies respectively.

5. **Visibility (VI)**: This focus measure is inspired from human visual system, and is defined as
   \[
   V I = \sum_{m=1}^{M} \sum_{n=1}^{N} \frac{|f(m,n) - \mu|}{\mu^{\alpha+1}}
   \]
   Where \( \mu \) is the mean intensity value of the image, and \( \alpha \) is a visual constant ranging from 0.6 to 0.7.

3. **MODIFIED TECHNIQUE FOR LOW RMSE**

   Most of the focus measures are based on the idea of emphasizing high frequency contents of the image and measure their quantity. This comes from an idea that blurring suppresses high frequencies regardless of particular Point Spread Function. [13]

   Considering the performance of various focus measures, EOL found to be the best among all [8]. Laplacian of an image is determined by second order derivative of the image. The performance of the second order derivative decreases if noise is present in the source images as show in Fig-1

![Fig-1](image-url)
Fig-1(A) shows ramp edges profile of an image separating black region and white region. The entire transition from black to white represents a single edge. In fig-1(A) image is free of noise and its grey level profile is sharp and smooth. Fig-1(B-D) are corrupted by additive Gaussian noise with zero mean and standard deviation of 0.1, 1.0 and 10.0 intensity levels respectively and their respective grey level profile shows noise added on the ramp by ripple effects. The images in the second column are the second derivatives of the images on the left. Fig-1(E) shows two impulses representing presence of edge in the image. Fig-1(F-H) shows that as the noise increases in the image the detection of impulses becomes difficult making it nearly impossible to detect the edge in the image. This shows that the focus measure using the second order derivative also fails to decide about the best focused image in noisy environment. Thus for selection of best focused image removal of noise is essential before applying fusion technique to obtain best focused image.

The proposed focusing technique uses the linear-phase 2-D FIR low pass digital filter to remove the noise from the differently focused images. Filter uses Parks-McClellan algorithm [19], [20]. The Parks-McClellan algorithm uses filter with Equiripple 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. These filters are used in existing fusion algorithm before partitioning the image as shown in fig-3. The source images are passed through 2D FIR low pass filter of order 4 and having characteristic as shown in fig-2. For these low pass filtered images conventional focus measure such as Variance, Energy of Gradient, Energy of Laplacian, Spatial frequency are computed.

Fig.2. Perspective plot of linear phase 2-D FIR Lowpass digital filter

**Setup for proposed algorithms**

A schematic diagram for proposed image fusion method is shown in Fig-3. The paper proposes modification for obtaining best focus measure in noisy environment by use of filter at step -2 in the existing algorithms used by Li et al [8]. 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.** Filter the images through a 2D FIR low pass filter for removal of noise.

**Step 3.** Compute the focus measure of each block, and denote the results of $A_i$ and $B_i$ by $M_i^A$ and $M_i^B$ respectively.

**Step 4.** Compare the focus measure 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 5.** Compute root mean square error (RMSE) for the composite image with a reference image.
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 then filtered images are fused using Li’s algorithm for various focus measures. The performance of existing and modified algorithm is compared qualitatively by calculating RMSE of fused images.

RMSE is defined as:

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

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

Table-1 shows the RMSE of fused images using different focus measures and for equal block size of images. Table-2 shows the RMSE of fused images for unequal block size of source images. Table-1 shows that fused images using SF as focus measures gives lowest RMSE values and Table-2 shows that for unequal block size of images EOL perform better then other clarity measures when used in modified partition fusion technique. The analysis of Table-1 shows that RMSE of fused image decreases with increase in the block size of sub image only with SF. Analysis of Table-2 shows that RMSE of fused image decreases with increase in the block size of sub image for all clarity measures because the larger image block gives more information for measuring the clarity of image block. However using a block size too large is undesirable because larger block of sub image may contain two or more objects at different distances from the camera, and consequently will lead to a less clear image.

The experimental results in table-1 and table-2 show that the performance of proposed method for all the focus measures improves with reduced RMSE with nearly one forth of RMSE of existing algorithm. Visual analysis is shown form fig-4 to Fig-14. Fig-7 is the reference image taken all parts focused. Fig 8 to Fig 11 shows the fused images while considering different focus measures with existing partition fusion method. Fig 12 to Fig 14 shows the fused images while considering different focus measures with proposed modified algorithm of partition fusion with 2-D low pass filter.

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. 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.

### Table-1
**Evaluation of different focus measures with equal block sizes on basis of RMSE**

<table>
<thead>
<tr>
<th>Block size</th>
<th>Focus measure</th>
<th>Partition fusion method</th>
<th>Modified Partition fusion Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Variance</td>
<td>EOG</td>
</tr>
<tr>
<td>4×4</td>
<td></td>
<td>4.5814</td>
<td><strong>3.9383</strong></td>
</tr>
<tr>
<td>8×8</td>
<td><strong>4.3658</strong></td>
<td>4.0264</td>
<td>3.1466</td>
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<tr>
<td>16×16</td>
<td>4.7037</td>
<td>4.7720</td>
<td>3.4659</td>
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<tr>
<td>32×32</td>
<td>4.4221</td>
<td>4.6485</td>
<td>3.0888</td>
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<tr>
<td>64×64</td>
<td>4.6588</td>
<td>4.6000</td>
<td>3.8727</td>
</tr>
</tbody>
</table>

Numbers in bold and italic indicate the lowest RMSE obtained over different block sizes.
Table-2
Evaluation of different focus measures with unequal block sizes on basis of RMSE

<table>
<thead>
<tr>
<th>Block size</th>
<th>Focus measure</th>
<th>Partition fusion method</th>
<th>Modified Partition fusion Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>variance</td>
<td>EOG</td>
<td>EOL</td>
</tr>
<tr>
<td>4×8</td>
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<td>4.0106</td>
<td>3.3199</td>
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<td>3.5020</td>
<td>3.5630</td>
</tr>
</tbody>
</table>

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

REFERENCES:


Fig. 4 left focused image

Fig. 5 right focused image

Fig. 6 middle focused image

Fig. 7. All focused image (reference image)

Fig. 8. Fused images formed from variance

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

Fig. 10. Fused images formed from EOL (32×64)

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

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)