Performance Overview of Image Fusion Techniques

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Abstract

In Multi-focus image fusion, multiple partially defocused images are combined into a new image with all the interested objects focused. Various techniques of Multi-focus image fusion already exist and still researchers in the area are introducing new algorithms for improved results. Different parameters like PSNR, Entropy can be used to evaluate the performance of these algorithms. In this paper we compute and evaluate performance measures for some of the techniques like Discrete Wavelet Transform, Simple Average Method, and Select Maximum etc. The comparative statement based on the evaluation of experimental results certainly helps to select a particular fusion method. Generally performance measures are dependent on defocused area of the image and size of input images is the major consideration in computation. Artificially defocused images are utilized for experiment purpose.

1. INTRODUCTION

Image fusion is the technique where multiple images are combined together into a single image which conveys more information than any of the input images. There are few promising advantages of fusion techniques like defocused areas of the input images can be made focused, visibility and peak signal to noise ratio can be improved and so on [1].

General issues related with captured pictures are the random occurrence of blur and defocused areas due to noise. These issues are very well handled by multi-focus image fusion methods. Here one of such methods has been proposed provided both input image show the same scene. Fusion rules can be designed to work on pixels, blocks as well as decision.

In pixel-level image fusion, statistical operations like simple average, select maximum have already proved their utility so far. Usually in block level fusion, input images are divided into different blocks or regions and one can experiment computation process to obtain the desired outcome [2].

However, few fusion techniques like Discrete Wavelet Transform utilize the features extracted from input images by decomposing image. Wavelet theory overcomes many drawbacks of traditional fusion methods as it retains time and frequency information of analyzed input [3].

Multi-focus image fusion can be implemented on different images with different modalities intending to deblur and focus the desired area of image. Many fusion methods have been introduced so far. Approach to the most efficient technique objecting to the best image quality must be inferred from experimental results of performance evaluation [3][4].

Fusion technique proposed in this paper considers average as the key parameter to distinguish input images. Input images are processed on pixel as well as block basis. Best possible average value includes the respective block from each image to reconstruct the image. However, performance evaluation of image fusion rules is still a challenge to achieve optimal image fusion.

2. RELATED WORK

In remote sensing, due to practical limitations of optical lens sensitivity and other constraints, image quality is bounded to a certain level. Quality improvement is the main task to have every object present in the image focused. In medical images also, every object is required to have good visibility and henceforth the implementation of suitable fusion technique is more important [5][6].
2.1 Averaging Method

Generally, low frequency components carry maximum of the image information. If multiple images of the same scene have different areas defocused then for same pixel of corresponding images the pixel values can be different. In such case region of image focused tends to be of higher pixel intensity than that for the same region of other image. Considering average of corresponding pixels of input images can solves the problem in better way. One can simply take the value of pixel P (i, j) of each input image and can divide it’s sum by total number of pixels, if the pixel value is not matching in order to obtain the average value [1][8].

2.2 Maximum Value Selection Method

It is well known that images carry high pixel intensity at the edges of an object present in the image. Consideration of highest value pixels out of the available pixels as high frequency coefficients can constitute an enhanced image in reconstruction process. Here, high frequency coefficients of both input images are divided into blocks and average value of corresponding blocks from both input images are compared. If any block shows it’s highness about pixel intensity that replaces low intensity block and further contributes in image fusion. [1][8].

2.3 Discrete Wavelet Transform

The original concept and theory of wavelet analysis came from Mallat in 1989 [1]. Feature of input images are extracted by using wavelet transform, which decomposes the image into its low frequency (LL) and high frequency (LH, HL, and HH) features. It also can be used to decompose 2-D gray-scale image signals into different resolution level. First 1-D DWT is performed on the rows and then columns of the data by separately filtering and down sampling. This results in one set of approximation coefficients and three sets of detail coefficients, which represent the horizontal, vertical and diagonal directions of the image, respectively [7][10].

<table>
<thead>
<tr>
<th>Vertical Coefficient</th>
<th>Diagonal Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL (cv, dv)</td>
<td>HH (cd, dd)</td>
</tr>
</tbody>
</table>

Figure 1. Low and High Frequency Components

In 2-D Discrete Wavelet Transform, a simple average fusion rule is applied to the approximation coefficients of input images and result is the approximation coefficients to be used for reconstruction of image along with remaining coefficients. Similarly, select maximum rule is applied to corresponding horizontal, vertical and diagonal coefficients of input images and their respective results are treated as horizontal, vertical, diagonal coefficients for reconstruction of image, which is called as fused image. Hence, the image fusion based on 1-D DWT can be expressed as the source images firstly undergo decomposition; the coefficients of both the low frequency and high frequency are then performed with a particular fusion rule (like averaging). After that, the fused image is obtained by performing the IDWT for the corresponding combined wavelet coefficients. The process used for the feature extraction is to extract the corresponding pixel values. [11].

Figure 2. Wavelet decomposition

3. PROPOSED METHOD

The proposed method is represented in the form of an algorithm:

Step 1: Read two defocused input images A and B to be fused.
Step 2: Perform wavelet decomposition on both the images.
Step 3: Only unmatched low-frequency coefficients of ca and da of input images A and B respectively, are averaged based on simple average method.
(1)
\[ \text{ave} = \text{avg} \{ \text{unmatched}(ca(i, j), da(i, j)) \} \]
\[ ca(i, j) = ca(i, j) \ldots \text{matched}(ca(i, j), da(i, j)) \] 

Step 4: Respective high frequency components of each image are divided into blocks of size N\*N, average of corresponding block from respective image is calculated and highest average value block is considered for reconstruction of fused image
\[ \text{maxh} = \max \{ \text{avg} (ch_{N\times N}), \text{avg} (dh_{N\times N}) \} \quad (3) \]
\[ \text{maxh} = \max \{ \text{avg} (cv_{N\times N}), \text{avg} (dv_{N\times N}) \} \quad (4) \]
\[ \text{maxh} = \max \{ \text{avg} (cd_{N\times N}), \text{avg} (dd_{N\times N}) \} \quad (5) \]

Step 5: Take inverse wavelet transform using ca, ch, cv, cd of image A as well as da, dh, dv, dd of image B and we get the fused image F1.
Step 6: Detect the boundaries of objects present in image and improve its contrast or pixel intensity to improve the quality of image.

4. PERFORMANCE MEASURE

The quantitative comparison of performance measures computed for different fusion methods is helpful to select a suitable fusion rule to be applied. Now a day’s a new trend of cascading multiple fusion rules has been introduced in order to improve the performance of overall image fusion process.

4.1 Information Measure (E)

The average information or Entropy of an image is given by
\[ E = -\sum_{i=1}^{M} P_i \log_2 P_i \] 
(6)

Where, M is the total of grey-scale levels present in an image, \( P = P_1, P_2, \ldots, P_M \) is the probability distribution of each level. Highest entropy of fused images indicates the improvement in information level as compared to other images.

4.2 Peak Signal to Noise Ratio (PSNR)

Computes peak signal-to-noise ratio (PSNR) between images
\[ \text{PSNR} = 10 \log_{10} \left\{ \frac{R^2 \times M \times N}{\sum_{M,N} [A(m,n) - B(m,n)]^2} \right\} \] 
(7)

Where, R is the maximum fluctuation in input image data type (R=255 for 8 bit grayscale image), A, B are input images.

4.3 Image Quality Index (IQI)

Similarity between two images can be measured using IQI. Its value lies between -1 and 1. IQI=1 indicates 100% similarity between two input images.
\[ IQI = \frac{\sigma_{ab}}{\sigma_a \sigma_b} \cdot \frac{2ab}{a^2 + b^2} \cdot \frac{2\sigma_a \sigma_b}{\sigma_a^2 + \sigma_b^2} \] 
(8)

Where, \( \sigma_a, \sigma_b \) represents standard deviation of image a, b respectively, a, b are mean values of input images respectively, \( \sigma_a^2, \sigma_b^2, \sigma_{ab} \) denotes variance of input image A, B and covariance of image A, B respectively.

5. RESULTS

5.1 Simulation Experiment 1

For experimental purpose artificially defocused images are utilized. Experimental results of used images for Entropy, PSNR, and IQI are mentioned below. All the algorithms in this paper are simulated on MATLAB.
For first simulation experiment Lena.tif image of size 512 X 512 is used. Here, left side image of Figure 3 shows defocused images A and its right side shows defocused image B. Similarly, left side image of Figure 4 is the fused image of simple average algorithm and its right side shows the fused image of select maximum algorithm.

Finally, left side image of Figure 5 is fused image of 2-D DWT method, where one can apply simple average and select maximum fusion rules as well as right side image of Figure 5 represents the fused image of proposed method.

Table 1. Performance measure of fusion methods

<table>
<thead>
<tr>
<th>Fusion Method</th>
<th>E</th>
<th>PSNR</th>
<th>IQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Average</td>
<td>4.1763</td>
<td>15.0899</td>
<td>0.5514</td>
</tr>
<tr>
<td>Select Maximum</td>
<td>7.4455</td>
<td>20.0001</td>
<td>0.7897</td>
</tr>
<tr>
<td>2-D DWT</td>
<td>7.5114</td>
<td>50.1659</td>
<td>0.8012</td>
</tr>
<tr>
<td>Proposed Method</td>
<td>7.4655</td>
<td>52.2012</td>
<td>0.8015</td>
</tr>
</tbody>
</table>

5.2 Simulation Experiment 2

In second simulation experiment cameraman.jpg image of size 512 X 512 has been artificially defocused. In figures given below, left side image of Figure 6 shows defocused images C and its right side shows defocused image D. Similarly, left side image of Figure 7 is the fused image of simple average algorithm and its right side shows the fused image of select maximum algorithm.

Table 2. Performance Measure of fusion methods

<table>
<thead>
<tr>
<th>Fusion Method</th>
<th>E</th>
<th>PSNR</th>
<th>IQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Average</td>
<td>3.4888</td>
<td>14.0192</td>
<td>0.4434</td>
</tr>
<tr>
<td>Select Maximum</td>
<td>7.0862</td>
<td>49.0621</td>
<td>0.7899</td>
</tr>
<tr>
<td>2-D DWT</td>
<td>6.9286</td>
<td>48.2699</td>
<td>0.7568</td>
</tr>
<tr>
<td>Proposed Method</td>
<td>7.0207</td>
<td>49.1010</td>
<td>0.7989</td>
</tr>
</tbody>
</table>
6. CONCLUSION

Two images of same scene, defocused at different areas can be decomposed into the feature coefficients and different fusion rules based on pixel level, block level, decision level can be applied on different features. The reconstructed image inhibits the improved quality, information level than input images.

7. ACKNOWLEDGMENTS

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8. REFERENCES


