Image Gradient For Fusion Of Multi-Focus Images

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Abstract

This paper presents a hybrid approach for fusingenhanced depth of field pictures using differently focused images. This method uses spatial image gradients as focus measure and soft decisionwhich enables smooth transitions across region boundaries. The key feature of this method is its robustness for overcoming noise and other optical effects.A Graphical User Interface(GUI) is developed for image fusion mainly for research purpose. To utilize the GUI function without MATLAB software, an executable standalone application is also developed.

Keywords: **Image gradients, Focusinformation, Depth of Field, Soft decision, optics.**

1. Introduction

Image fusion is a sub-field of image processing wheretwo or more photographs of the same scene are fused into a single image which has more useful information and is more suitable for visual perceptual experience.Image fusion is implemented inseveral areas such us, photography applications, medical science, forensic, Remote sensing and military, etc. We categorize the fusion with respect to the type of images used such as visible, Infrared, etc.and also based on the purpose of fusion. Based on these factors fusion can be classified as multi-view, multi-modal, multi-temporal, Multi-focus fusion and fusion for restoration.

Lately, many multi-focus image fusion methods have been introduced. In general, these methods can be classified into two groups: spatial domain, transformed domain[3]. In spatial domain techniques fusion directly takes place on the pixel values. But in transformed domainthe images are transformed into multi resolution components.Image fusion is generally carried out at four different levels: signal level, pixel level, feature, and decision level[5].

In signal-based fusion, signals from different cameras are fused to create a new signal which has a better SNR value than the original signal. Whereas pixel level while generating fused image the pixel values are based on the source image.Featurebased fusion requires the separation of various features of the source images.And thefusion process is based on those extracted features of the source images. In decision level fusion multiple algorithms are combined to get the final fused image. Then the obtained information is then combined by applying the decision rules.[1] There are various image fusion methods that are developed for image fusion, they are:

(1) Intensity-Hue-Saturation (IHS) Transform
(2) Principal Component Analysis (PCA)
(3) Arithmetic Combinations
(4) Multi-Scale Transform Based Fusion
(5) Total Probability Density Fusion
(6) Biologically Inspired Information Fusion

However, all these fusion techniques blur the sharp edges or leave the blurring effects in the fused image. The key challenge of multi-focus image fusion is to obtainthe fused image without blurring.

2. Multi-Focus Image Fusion

Multi-focus image fusion is the process of mergingof two or more images of thesame scene into a single sharp image[1].The fused image is more informative and is more suitable for visual perceptual experience and for processing.

The first step for multi-focus image fusion algorithm is to calculate the focused region of the source images. For multi-focus image fusion, many distinctive focus measurements are used[2], whichcan measure the changesin pixel frequency.

When the source images are compared, pixels with greater values of these measurements, are considered to be in focus and selected as the pixels of the fused image.Once the focus measure is done, there are different fusion rules can be applied for image fusion.

3. Studyon Image Fusion methods

A study has been done on a various multi-focus image fusion methods and their pros and cons are listed below.

*A Non Sub-sampled Contourlet Transform:*This method combines the non-subsampled pyramids [17] and non-subsampled digital filter banks and it is a shift-invariant version of the Contourlet transform (CT) for fusing multi-focus images. Even though this method is efficient and can work in real-time system platform, exact reconstruction of the fused image is not possible.

PCNN(Pulse Coupled Neural Network) method: PCNN is a biologically inspired[19] neural network based image fusion technique in which each neuron corresponds to the pixel of the input image.Compared with formal methods, they have several significant advantages such as hardiness against noise, independence of geometric variations in input patterns, capability of bridging minor intensity variations in input patterns, etc. However, those methods are still complicated and time-consuming.

*Wavelet-based statistical sharpness measure:*This method uses the spreading of wavelets co-efficient to determine to amount of blur in the input image. It uses two Laplacian mixture models and three metrics Chi-square, Kolmogorov and Kullback-Lieble[18] to compare the empirical Probability Density Function(PDF) with the wavelet co-efficients. Eventhough the fused image yields better quality, this approach yields higher computational complexity.

Image matting for fusion of multi-focus images in the dynamic scenes: This method uses image matting technique to combine the focus information and correlation between neighbouring pixels [12]. It has three steps: First, morphological filteringis performed on each source image to measure the focus. Then, the focus information is forwarded to image matting to find the focused object accurately. At last, the obtained focused objects of different source images are fused together to construct the fused image.

Image fusion scheme using focused region detection and multiresolution: Integrating the advantages of spatial domain based fusion methods and transformed domainbased fusion methods, this technique of focused region detection and a new fusion method of Multi-Scale Transform (MST) to guide pixel combination has been used.

*PCAfor image fusion:*The PCA uses a mathematical procedure to transform the number of correlated variables into a number of uncorrelated variables called the principal components.In this method, the two dimensional discrete cosine transform of multiple input images are calculated.Theobtained measurements are multiplied with sampling filter, so compressed images are obtained. Then the inverse discrete cosine transform is performed. Finally, PCA fusion[8] method is used to get the fused image. However the fused image obtained by this method has a little quality loss.

*Fusion using Index of Fuzziness:*This method uses Index of Fuzziness as a focus measure to fuse images. A focus measure is applied to measure the information level in the portions of the images or in the images as a whole. Various measures like energy of Image Gradient(EOG), Energy of Laplacian of Image(EOL), [15]contrast visibility, etc. are used.The algorithm consists of the following steps: First the source images are decomposed into a number of blocks. Then compute the index of Fuzziness for each block. Finally the computed values of each blocksis compared and the highest index values are taken as the focused regions. This method shows artefacts on the fused image.

4. Proposed Fusion Method

In this scheme, the fusion output is obtained by decomposing the input image using wavelets and then calculating the focus measure of the two input images using Image Gradient algorithm.

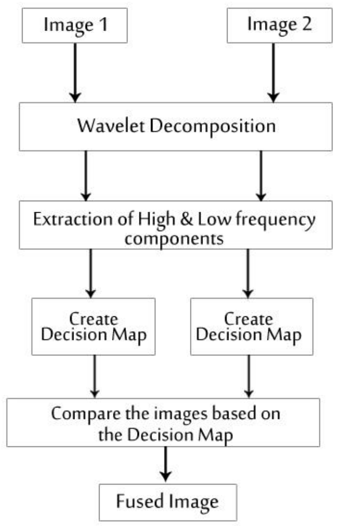

Fig. 1 Gradient Image Fusion Algorithm

A. Wavelet Transform

For the Discrete wavelet transform various types of wavelet functions areused. These wavelets are orthogonal or bi-orthogonal and they are characterized by a number of lowpass, high-pass analysis and synthesis filter banks [6].From these filter banks a wavelet function Ψ(t) and scaling function ɸ(t) can bederived.Some typically used categories for the DWT are Daubechies, coiflets, Haar, symlets and Bi-orthogonal.

Daubechiesare orthogonal wavelet which has the scaling function of order 1 to8. Coiflets are also orthogonal wavelet which are more symmetric and also have more vanishing moments. Symlets are compactly supported orthogonal wavelets have the scaling functions of the order 2 to 8. Symlets are symmetric in nature and have the properties similar to that of the daubechies.bi-orthogonal family of wavelets contains thebi-orthogonal splinesandexact reconstruction is possible with this type of wavelets.

B. Calculation of the Decision Map

The next step in the algorithm is to obtain the focus Information Map (Decision Map)for the source images. In order to obtain the Decision Map morphological filters are used to measure the high frequency information. The procedure for calculatingthe decision map has two steps: first is to define the classes according to the discrimination features and second is to setthe procedure for the partitioning. In anideal classification process,the classes have few probability distribution functions called the priori.

An active contour model is selected for the partioning process in which {Ω i}i=1,...,K Ω is a family of sets and K is the number of input channels [15]. Based on the type of fusion process {Ω i}i=1,...,K has to cover the whole image. Finally this segmentation process becomes a minimization problem which contains three conditions:

(i)Partion condition: [9]

$$F^{A}(\{\Phi_i\}) = \alpha/2\int_{\Omega}(1-\sum_i H(\Phi_i(x))^2 dx, \quad (1)$$

where H is the Heaveside function.

(ii)Length shortening:[9]

$$F^{B}(\{\Phi_i\}) = \beta \int_{\Omega}(\delta(\Phi_i(x))|\nabla\Phi_i|dx, \quad (2)$$

Fig. 2aInput image Fig. 2b Calculated Decision Map

Furthermore, most of the methods for autofocusing are global or semi-global in scale.[16] Hence, corroboration from neighbouring pixels of decision choices becomes necessary to maintain robustness of the algorithm. Adding this corroboration while maintaining pixel-level decisions requires summing the M(x; y)'s over a k £ k region surrounding each decision-point. This yields a new focus measure.

$$Gi(x;y) = \left|\frac{dI_i(x,y)}{dx}\right| + \left|\frac{dI_i(x,y)}{dx}\right| \quad (3)$$

where i, j correspond to two differently focusedimages. Thus, M(x; y) > 0 indicates the pixel value at location (x; y) in image i should be chosen else wechoose j.

C. Majority Filtering

The uses of Image Gradients in the fusion process can make decisions vulnerable to large fluctuations dependent on the sensor, optics and scene. Therefore in order to maintain the robustness, it is necessary to make decision choices from neighbouring pixels.So a sigmoid function is applied to the resultant focus measure.[16]

$$\acute{M}(x,y) = 1/(1+e^{-\beta\acute{M}(x,y)}) \quad (4)$$

whereβis a constant.

D. Image Gradient Fusion

The Final stage of the fusion process is to construct the fused image by fusing the focused region of the two source images. In order to obtain the focused area of the image, the obtained decision map[12]is compared with the source images. More specifically, each part of the image is compared with the obtained decision map pixel by pixel in order to get the high frequency information.Then the average of both the image are calculated based on the Decision Map. Eventually, based on the assumption the obtained fused image is the All-in-focus image.

5. GUI For Fusion

A GUI (Graphical User Interface) is a pictorial interface to a program which helps the user to do tasks interactively with the use of controls such as slidersand buttons[10]. In MATLAB R2010a GUI tools enables us to the perform tasks such as creating and customizing plots, Fitting curves & surfaces and also to analyseand filter signals.

A. GUIfor Image Fusion

A GUI environment is designed for the proposed fusion method usingMATLABguide.The environment has buttons to load the input images as well as to select the fusion method. Once the image is loaded, the fused image can be obtained by pressing the fuse button. The Fused image can also be saved as .bmp image file.

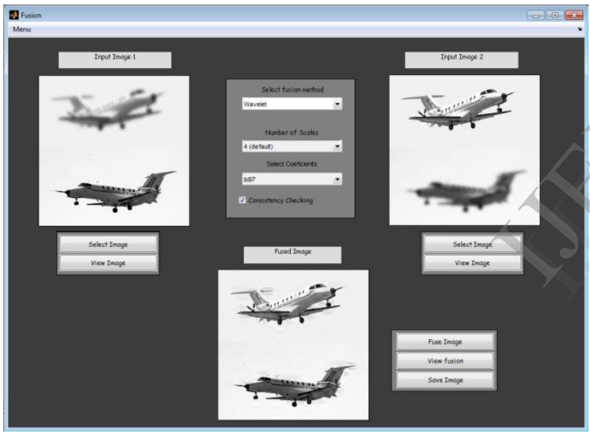

Fig. 3 Image Fusion GUI

6. Experimental Results

To present the effectiveness of the proposed fusion method, the method is compared with many image fusion techniques and applied overa pair of multi-focus opticalas well as multi-focus medical images. With respect to the quality of fused image, it is seen that the proposed gradient fusion method yields the sharper fused image.

Figure.4 (a) is the Fly image with front part being focused and Figure.5 (b) is the Fly image with back part being focused


Fig. 4(a) Input image 1


Fig. 4(b)Input image 2


Fig. 4(c) Proposed method


Fig. 4(d) SWT fusion


Fig. 4(e) PCA method

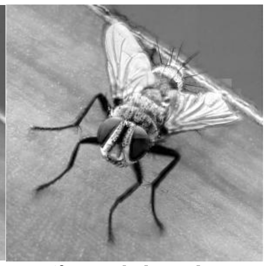
Fig. 4(f) Morphological pyramid

By carrying out the fusion schemes, we get the following results. Figure.4(a) & Figure.4(b) are the source images, Figure.4(c) is the proposed method, Figure.4(d) based on SWT, Figure.4(e) based on PCA method, Figure.4(e) based on morphological pyramid. The experimental results for these methods are tabulated below.

Fusion Method	PSNR
Average	23.5670
Select Maximum	26.7963
Morphological pyramid	26.9812
PCA method	53.2370
SWT fusion	59.1387
Gradient Image Fusion	67.0832

Table1. Statistic results of different fusion methods

The Graph below is plotted in MS Excel. The graph shows the PSNR value of various fusion methods.

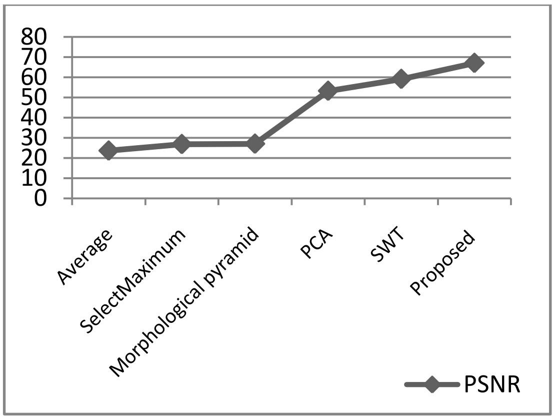

Fig. 5 PSNR values of various Image Fusion methods

7. Conclusion

This paper presents a hybrid approach of image fusion based on wavelets and gradient image for multi-focus images.This paper expresses the image fusion as an optimisation problem for which a solution is obtained by the proposed fusion method.

The proposed method is successfully examined using a set of multi-focus optical as well as multi-focus medical (CT-scan) images. This hybrid method outperforms simple wavelet fusion method in preserving the image quality.

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