ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 1, Issue 8, October 2012

A Survey on Multi-Focus ImageFusion Methods

A. Anish #,T. Jemima Jebaseeli *

#Department of Information Technology, Karunya University

*Department of Information Technology, Karunya University

***Abstract*—Thispaper deals with various Multi-Focus Image Fusion Techniques in image processing.It is based on the perspective that the blurred image looks peculiar because of the degradation of high frequency information. This is generally caused by the camera optics.The reason is that cameras suffer from limited depthoffield and this causes the image to be focused only on selected areas.The main intention of Multi-focus image fusion is to overcome the problem of depth of field[DOF] of cameras and to get an all-in-focus image.**

***Keywords*—Multi-focusImage Fusion, Morphological filtering, Focusinformation, Depth of Field.**

I. INTRODUCTION

Image fusion is a sub-field of image processing in whichtwo or more images of a scene are combined into a single composite image that is more informative and is more suitable for visual perception and for digital processing.Image fusion has been used in several areas like, camera applications, medical science, forensic and military, etc. We categorize the fusion methods based on the input data of the fusion process and also based on the purpose of fusion. Fusion can be classified as multi-view, multi-modal, multi-temporal, Multi-focus fusion and fusion for restoration.

Recently, many image fusion methods have been introduced to fuse multi-focus images. 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 domain method the images are first 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. Image fusion in pixel level refers to generating of fused image in which the pixel values are based on the pixel values of the source image.Feature-based fusion requires the extraction or segmentation 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 n. Then the obtained information is then combined applying the decision rules.[1]

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.

II. MULTI-FOCUS IMAGE FUSION

Multi-focus image fusion is the process of merging two or more images of a same scene into a single all-in-focus image[1].The fused image is more informative and is more suitable for visual perception and for processing.

The first and fore most step for all multi-focus image fusion algorithm is calculating the focus measure of the source images. For multi-focus image fusion, many distinctive focus measurements are used[4], for e.g. Histogram entropy(HE) method, Energy Of Image Gradient (EOG), Tenengrad, Spatial Frequency (SF) and Laplacian energy (EOL), M_2 focus measure, SML,Grey-level Variance (GLV) ,DCT-Based focus measures, etc which measure the variation of pixel frequency. Pixels with greater values of these measurements, when source imagesare compared, are considered to be in focus and selected as the pixels of the fused image.Once the focus measure is done, there are

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International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
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different fusion rules to fuse the images. One is selecting the sharp pixels in the spatial domain to Multi-Scale decomposition (MSD) transform image information in the high-frequency.

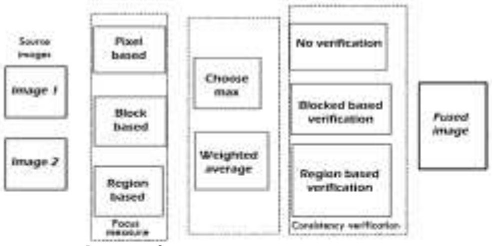

Fig. 1 A typical image fusion system

III. NON SUB-SAMPLED CONTOURLET TRANSFORM

NSCT is a fully shift-invariant, mult-iscale directional expansion to undergo frequency partioning[7].This method combines non-subsampled pyramids and non-subsampled digital filter banks and it is a shift-invariant version of the Contourlet transform (CT). In CT, the Laplacian pyramid and the direction filter banks are employed for multi-scale decomposition. In NCST directional decomposition takes place in order to get rid of the frequency aliasing of the Contourlet transform and to achieve shift-invariance.

A. Fusion scheme using the NCST

The initial step is the decomposition of the source images into their respective low pass and a number of high pass sub band elements. Then the focused regions in the image are calculated. And the fusion coefficients for the low pass sub band and each high pass sub band are determined.

Finally the fused image is obtained by taking an inverse of NSCT transform.

This method can successfully overcome the artifacts at the boundaries of the focused regions and Mis-registration during the fusion process.

IV. PCNN METHOD

PCNN(Pulse coupled neural networks) which was developed by Eckhorn in 1990 is a feedback network in which each neuron consists of three parts: the receptive field, the modulation field, and the pulse generator[13].In PCNN each neuron corresponds to a pixel of the input image, receiving its matching pixel's intensity value as an external input. The temporal series of outputs contain the information of input images and can be used for various image processing applications, such as image segmentation and feature extraction. 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. This method is based on dual-channel pulse coupled Neural Networks. PCNN is a biologically inspired Neural Network based fusion technique. [12]

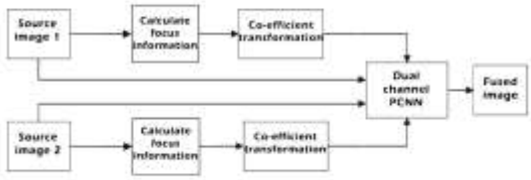

Fig. 2 Dual Channel PCNN [13]

This method overcomes the standard PCNN model by simplifying the process of image fusion in comparison with previous methods. Former methods usually employ a number of PCNNs or combination with various other algorithms such as DWT, while this method uses only one dual-channel PCNN for multi-focus image fusion.

This method stands out the existing methods in both visual effect and objective evaluation criteria. In practical applications, this method is more feasible. Since the method is simple andit works in real-time system platform.

V. WAVELET METHOD

A new statistical sharpness measure is explained in this method by utilizing the spreading of the wavelet coefficients distribution to measure the degree of the image's blur. In addition, the wavelet coefficient distribution is evaluated using a locally adaptive Laplacian mixture model[2]. The proposed sharpness measure is then exploited to perform fusion in wavelet domain.

A. Fusion process

Initiallywavelet decomposition is applied on each source image. For detailed subbands, the locally adaptive Laplacian mixture modelsare estimated and then the each coefficient of the detail sub-bandsis combined. Thencombine each coefficient using the rule defined in. Apply an inverse wavelet transform to get the fused image. If more than two

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International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
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source images are observed, they are combined one by one by repetitively applying the above steps.

The fused images obtained using the proposed method affords better image quality than that of conventional approaches. But this approach affords higher computational complexity than the other approaches.

VI. MULTIRESOLUTION METHOD

Combining the advantages of spatial as well as transform domain-based fusion methods, a new fusion method of Multi-Scale Transform (MST) to guide pixel combination has been proposed.

For image fusion algorithms in MST domain, one of the key considerations for improving fusion quality is the selection of suitable fusion rule[4], which would influence the performance of fusion algorithm remarkably.

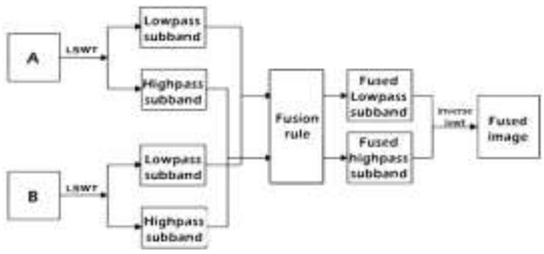

Fig. 3 Lifting Stationary Wavelet Transform[15]

LSWT(lifting stationary wavelet)transform possesses many advantages such as multi-scale, localization, and shift-invariance, which are more suitable for image fusion.

This reduces the complexity of the procedure and also increases the reliability of fusion results[11].Artifacts and erroneous, results at the boundary of the focused regions.

VII. SHEARLETS METHOD

The Shearlet transform is different from the traditional wavelet transform which does not possess the ability to detect directionality[9]. Shearlet has two parameters, the scaling and the translation parameter. The decomposition of shearlets is similar to that of contourlets, while the contourlet transform consists of an application of the Laplacian pyramid followed by directional filter bank. In shearlets the directional filtering is obtained by a shear matrix.

A. Image decomposition

First step is the Multi-direction decomposition of image using shear matrix.
Thenmulti-scale decomposition of each direction using wavelet packets decomposition is done.

B. Image fusion

The images to be fused first are registered to each other geometrically. Then the original images are transformed using shearlets with respect to their horizontal and vertical cones. Then fusion coefficients are used to obtain the fused image.

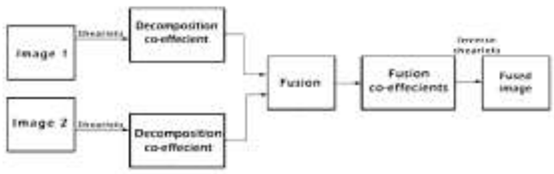

Fig. 4 Shearlet Transform[16]

Shearlet transform have more detail information and higher sharpness of the fused image than the contourlets and other methods.

VIII. INDEX OF FUZZINESS METHOD

A novel method to fuse images using Index of Fuzziness as a focus measure is proposed. A focus measure is initally applied to measure the fuzziness in the portions of the images or in the images as a whole. Various measures like Energy of Image Gradient(EOG), Histogram Entropy measure(HE), Energy of Laplacian of image(EOL), M_2 focus measure, Contrast Visibility, Sum Modified Laplacian(SML), Spatial Frequency(SF) Tenengrad measure, variance,etc[4] are used.

A. Index of Fuzziness:

The information level of the source image is quantified as the index of fuzziness (IF). For an M*N image block, the index of fuzziness can be calculated.Higher the IF,higher is the image quality.[8]

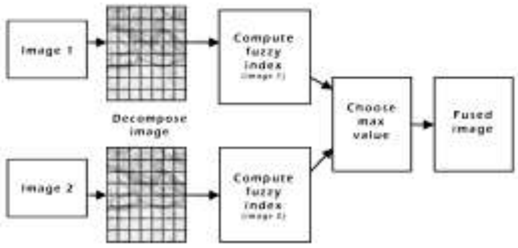

Fig. 5 Fusing process based on fuzzy index[6]

The algorithm consists of the following steps,

- Decomposing the two source images A and B into their respective sub blocks.
- Next is calculate the Index of Fuzziness value for each of the block in the source images A and B. Anneal the pixel values before computing the measure.
- Then the Index of Fuzziness values for the respective sub-blocks in images A and B are compared andthe block with the higher Index of Fuzziness are taken as the fused image.[14]

The advantage of this method is its computational simplicity and can be implemented in real time .

IX. REGION SEGMENTATION METHOD

In this fusion method the two source images A & B are initially fused by simple averaging of pixel values. Then the fused image is segmented using some segmentation method and the two source images are fused according to the segmenting result of the previously fused source image. Eventually, the segmented images are fused with reference to their spatial frequencies.

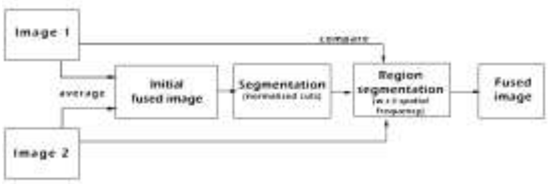

Fig. 6 Schematic diagram of the fusion process[14]

This method undergoes mis-registration or in other terms they are sensitive to noise.

X. IMAGE MATTING METHOD

Matting refers to the problem of preciselyfiguring the foreground of an image[10]. This separation of the background image from foreground is to finding out both full and partial pixel coverage. In this method the fusion process is divided into four phase: Focus Measure, Rough Segmentation, Image Matting and Fusion.

A. Focus Measure

The first stage in this method is to obtain the focus information map of each source image. In the proposed approach, we use morphological filtering to measure the focused regions or high frequency information of the source images.

B. Rough segmentation

With the focus information obtained above, the next stage of the proposed method is to construct the trimap[10] which roughly segments the source image into three regions ,the focused region, defocused region and unknown region. This trimap is then combined with the source image to construct the final fused image.

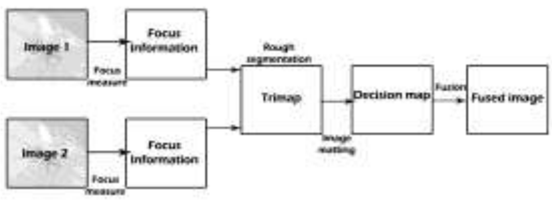

Fig. 7Fusion using image matting[10]

C. Image Matting and Fusion

The finalstep of this fusion methodis using matting technique to create the fused image by combining the focused regions of each source images A & B together.

The main advantage point of this method is, their performance does not degrade even when image patterns are complex.

TABLE I

COMPARISION OF VARIOUS APPROACHES OF IMAGE FUSION

Method		Performance	Type of scenes	Types of images
1.	NCST	Performance degrades for complex image patterns	Supports Static as well as dynamic scene images	Grayscale
2.	PCNN	Better performance	Only Static scene images	Grayscale
3.	Wavelet Transform	Higher Computational Complexity	Only Static scene images	Grayscale
4.	LSWT	Performance degrades for Complex Image patterns	Only Static scene images	Grayscale
5.	Shearlets Transform	Performance degrades for complex image patterns	Only Static scene images	Grayscale
6.	Index of Fuzziness	Better performance than spatial domain methods	Only Static scene images	Color as well as Grayscale
7.	Region Segmentation	Better performance	Only Static scene images	Grayscale
8.	Matting	Performances are good even when the image patterns become complex	Can fuse Dynamic Images	Supports Color Image

Table – I: Comparision of various approaches of Image Fusion

XI. CONCLUSION

Multi-focus image fusion solves the problem of limited depth of field in camera optics, which causes the image to be focused only on selected regions. This paper mainly focuses on various multi-focus image fusion techniques and its efficiency.

Most of these methods have better performance but does not show best result for images of dynamic scenes. To overcome this problem, certain methods like NCST or Image Matting can be used for merging multi-focus images in dynamic scenes.

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