Multifocus Image Fusion Using Focus Measure of Fractional Differential and NSCT

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Abstract — In this paper, a new multifocus image fusion scheme based on fractional differential and NSCT is proposed. Firstly, in virtue of the properties of fractional differential, a novel focus measure in nonsubsampled contourlet transform (NSCT) domain is presented and used to determine which coefficient is from the focused region. Then, based on the imaging principle of the multifocus image and the focus measure, a new selection principle for the lowpass subbands coefficients is developed. Meanwhile, focus measure maximum choosing scheme, namely select the coefficient with maximum focus measure value as the corresponding coefficient of the fused image, is applied to the high-frequency subbands. Finally, the inverse NSCT is employed to reconstruct the fused image and a pleasing fused result is generated. The experimental results show that the proposed method outperforms the conventional multifocus image fusion methods in both subjective and objective qualities.

Keyword: image fusion, fractional differential, focus measure, nonsubsampled contourlet transform.

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1. INTRODUCTION

Image fusion can combine substantial information from several source images of the same scene and produce a fused image, which has a better description of the scene than any single source image. The fused image is very suitable for human and machine perception or further image processing tasks such as image segmentation [1] and fault diagnosis [2], etc. Multifocus image fusion is one branch of the multi-source image fusion techniques. It can be used to overcome the defects of the optical lenses which cannot acquire an image that contains all relevant objects in focus.

In multifocus image fusion, multiscale transform (MST)-based technique is one of the well-known methods. Two factors, namely multiscale decomposition and reconstruction tools and fusion rules, are great important to improving the fusion quality. The usually used MST methods include the discrete wavelet transform (DWT) [3], lifting stationary wavelet transform (LSWT) [4], contourlet transform [5, 6], nonsubsampled contourlet transform (NSCT) [7–10], etc. However, the traditional wavelet cannot represent the edges directions because it can only capture limited directional information. Compared with the wavelet transform, the contourlet transform and NSCT both can offer a flexible multiresolution and directional decomposition for images and thus can represent edges and other singularities along curves much more efficiently. For this reason, they have been successfully used in image fusion [6, 8–10], and output a satisfactory fusion result. Unfortunately, the contourlet lacks the shift-invariance, which easily produces pseudo-Gibbs phenomena around singularities. In order to make up for the deficiency, the NSCT is proposed by Cunha in 2006 [7]. It not only inherits the perfect properties of contourlet, but also possesses the shift-invariance. Therefore, the NSCT is a good choose for image fusion.

Apart from the MST, the focus measure used to determine which coefficient is from the focused region is other emphasis in the research of MST-based image fusion method. In recent years, some useful focus measures, such as sum-modified-Laplacian (SML) [11], spatial frequency (SF) [12], energy of image gradient (EOG) [13], etc., are proposed and used to decide whether a pixel or coefficient is blurred or not. Coefficients with greater values of these focus measures are more possible from the clear part. Therefore, the corresponding coefficient of the source image can be selected out to building the fused image. However, most of these focus measures are designed based on the first or second-order differential. Once the order is determined, it is difficult to be adjusted according to the image content. This characteristic has a negative effect on improving fusion performance.
To overcome the disadvantage of the above-mentioned focus measure, a new focus measure is designed based on fractional differential. In this measure, the order can be adjusted according to image content, expeditiously. In view of the above facts, two novel and effective selection principles for lowpass and highpass subbands are developed respectively in virtue of the imaging principle of multifocus image and the property of fractional differential. Experimental results demonstrate that our proposed method outperforms the traditional fusion methods in visual perception and quantitative measurement.

The rest of this paper is organized as follows. Section 2 describes the NSCT theory in brief. In Section 3, the proposed fusion strategy is described. Experimental results and discussion including performance analysis are presented in Section 4. Finally, some conclusions are given in Section 5.

2. THE NONSUBSAMPLED CONTOURLET TRANSFORM

Similar to contourlet transform, the NSCT is also constructed by the laplacian pyramid filter banks (LPFB) and the directional filter banks (DFB). The LPFB is used to capture the point discontinuities, and the DFB employed by the NSCT and contourlet transform is used to link point discontinuities into linear structure, so as to realize the multiscale and multidirection decomposition. What makes these two transforms different is that the filter banks employed by them. In NSCT, the LPFB and DFB are all nonsubsampled, thus it can get rid of the frequency aliasing of the contourlet transform and achieve the shift-invariance. This desired trait in image processing is absent in contourlet transform due to downsamplers and upsamplers presented in the LPFB and DFB. Therefore, when NSCT is introduced to image fusion, more information of the source image can be retained in the fused image. More importantly, it possesses the shift-invariance. During the fusion processing, the pseudo-Gibbs phenomena and the impacts of mis-registration on the fused images can be reduced effectively. Moreover, the sizes of different subbands and the source images are identical. So it is easy to find the relationship among different subbands, which is advantageous for designing fusion rules [14]. So, as a useful multiscale decomposition and reconstruction tool, the NSCT can be used as the MST in our proposed method.

The overview schematic diagram of the proposed MST fusion method is shown in Fig. 1. For 1-level NSCT decomposition, each of the source images is decomposed into one lowpass subband and a series of highpass subbands in different directions and scales. Then, some fusion rules are employed to fuse the lowpass subband coefficients and the highpass subbands coefficients. Finally, apply the inverse NSCT to the fused coefficients and then the fused image $F$ is obtained. Apart from the NSCT discussed in the above section, the fusion rules for different subbands are other important things in the presented method. In the following subsections, we will focus on the design of the fusion rules for different subbands.

3. SELECTION PRINCIPLES

3.1. Selection Principle for Lowpass Subbands Coefficients

The coefficients in the lowpass subband of the coarsest scale represent the approximation component of the source image. So the ‘average’ scheme can be adopted for the lowpass subband coefficients. However, this will reduce the fused image contrast and lose some useful information of the source images. To improve the quality of the fused image, a focus mea-