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A novel image fusion approach based on compressive sensing

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ABSTRACT

Image fusion can integrate complementary and relevant information of source images captured by multiple sensors into a unitary synthetic image. The compressive sensing-based (CS) fusion approach can greatly reduce the processing speed and guarantee the quality of the fused image by integrating fewer non-zero coefficients. However, there are two main limitations in the conventional CS-based fusion approach. Firstly, directly fusing sensing measurements may bring greater uncertain results with high reconstruction error. Secondly, using single fusion rule may result in the problems of blocking artifacts and poor fidelity. In this paper, a novel image fusion approach based on CS is proposed to solve those problems. The non-subsampled contourlet transform (NSCT) method is utilized to decompose the source images. The dual-layer Pulse Coupled Neural Network (PCNN) model is used to integrate low-pass subbands; while an edge-retention based fusion rule is proposed to fuse high-pass subbands. The sparse coefficients are fused before being measured by Gaussian matrix. The fused image is accurately reconstructed by Compressive Sampling Matched Pursuit algorithm (CoSaMP). Experimental results demonstrate that the fused image contains abundant detailed contents and preserves the saliency structure. These also indicate that our proposed method achieves better visual quality than the current state-of-the-art methods.

1. Introduction

The nature image from individual camera, a real description of scenario, cannot capture all complementary information. An efficient way to solve the problem is image fusion. Image fusion is a process of computer vision that combines all significant and relevant information from source images into a unitary synthetic image, which is more appropriate for human perception without any artifact rings or unknown noise. It is a tremendous growth research field with a large amount of applications in medical imaging [1], remote sensing [2], satellite imaging [3], target tracking [4], feature extraction [5], biometrics [6], intelligent robot [7], machine vision [8] and concealed weapon detection [9].

Thus far, image fusion technique can be divided into two categories: the spatial domain-based approach and multi-scale transform- or coefficient-based methods. In spatial domain, the merged image can be composed by acquiring pixels, blocks or regions, which is strongly dependent on the measurements or the segmentation approaches. In practice, image fusion approach in spatial domain has the limitations of blocking artifacts and undesired side effects. While, multi-scale transform-based fusion approach takes image details and direction coefficients into account. It can achieve high fused image quality. Therefore, it is successfully and widely used in image fusion field [4,6,8,10].

In practical applications, multi-scale decomposition methods are the most popular technique in recent years. The fusion schemes based on wavelet transform are widely used to overcome the limitations of spectral distortion, such as discrete wavelet transform (DWT) and dual tree complex wavelet transform [1,4,11–13]. However, the wavelet transform-based fusion approach in two-dimensional domain is failed to represent the smoothness along the contours and curves. Furthermore, wavelet transform has the property of isotropic functions, i.e., it can only obtain limited directional information. Novel multi-scale analysis approaches are proposed including rideglet transform [14], curvelets transform [15], contourlet transform [16], non-subsampled contourlet transform (NSCT) [17] and shearlets transform [18]. Contourlet transform is widely utilized in the edge preserving image fusion domain because of preventing the edge aliasing [19,20]. Paper also illustrates its lack of shift-invariance property, which can lead to obvious Gibbs phenomenon [20]. The improved method, NSCT, inherits the best properties of contourlet transform and contains the characteristic of shift-invariance [17,21,22]. It can

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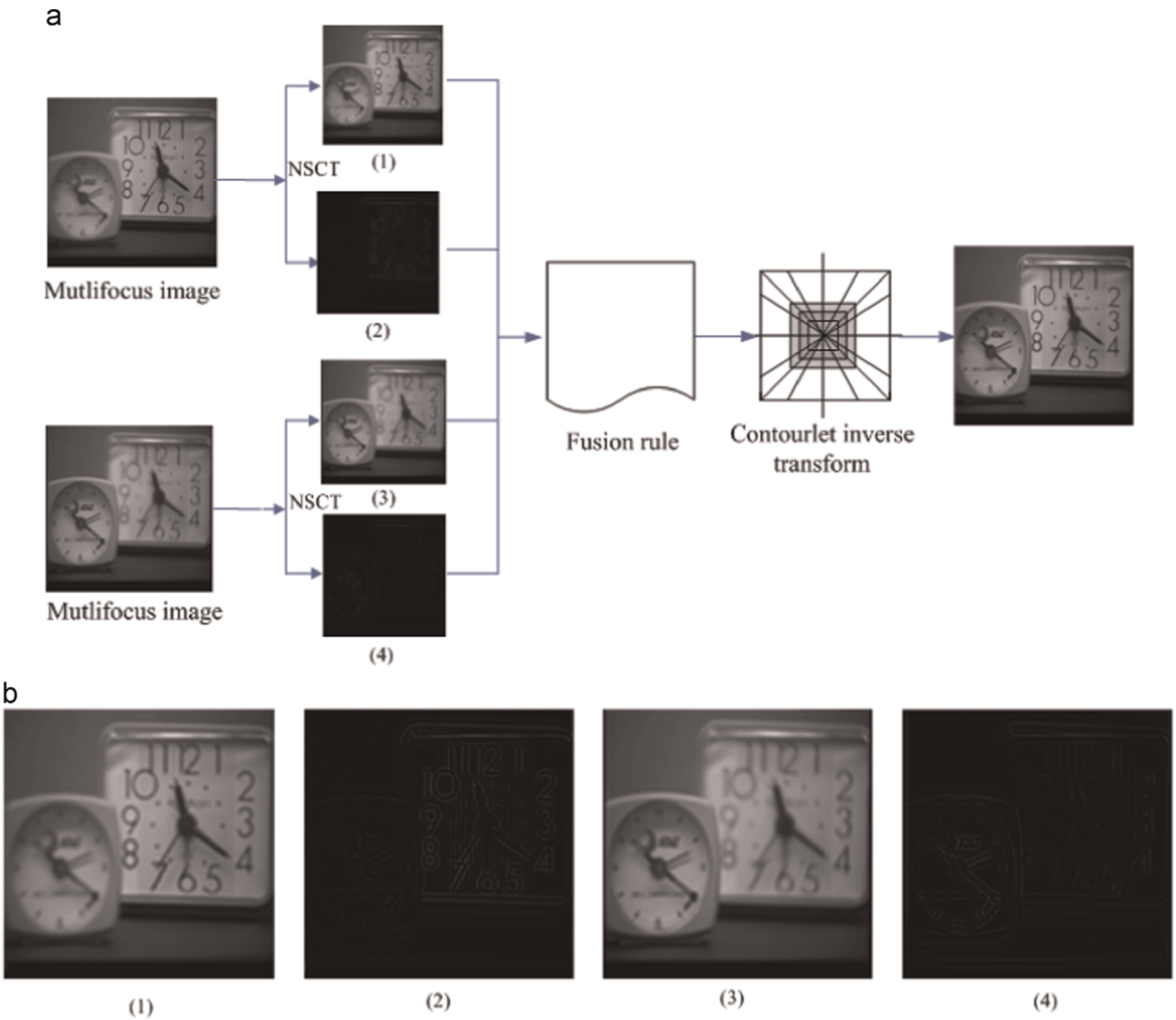

Fig. 1. The generic image fusion framework based on NSCT. (a) The generic image fusion approach and (b) the magnified view of decomposed input image.

obviously reduce the influence of misregistration in image fusion field. The generic image fusion approach based on NSCT is shown in Fig. 1. The general image fusion approach can be shown in Fig. 1 (a). The decomposed images are not clearly because of the limitations of layout in Fig. 1(a). Therefore, the decomposed input images are magnified and shown in Fig. 1(b). This fusion approach uses the constrained threshold of NSCT transform to select a number of sparse coefficients. The fundamental goal is to reduce the computational complexity.

The conventional fusion approach can greatly reduce the computational complexity by only integrating certain non-zero coefficients under NSCT transform. However, how to select the constrained threshold is a key problem. It generally depends on the priori knowledge of the source images. The ill-suited threshold may lead to the problems of poor fidelity and blocking artifacts. By comparison, compressive sensing (CS) theory exploits fewer sparse coefficients (non-zero coefficients) to accurately reconstruct the high-quality image [23–25]. The sparsity of the source images under certain transformation is the only constrained priori information [22–28]. Fortunately, almost all the signals have the property of sparsity in the transformation domain. Furthermore, compressive sensing theory is proved that it can remove the problem of blocking artifacts and enhance the quality of the reconstructed image [25–28]. Many related works have been proposed due to the merits of low computation complexity and high reconstruction quality. Zhou et al. [29] take advantage of the CS theory to cut down the size of the original image proportionally in the encryption process. Its scheme is effective, robust and secure to encrypt and decrypt images. Lang and Zhang [30] apply CS theory into the decryption process to cut down the delivery time and save the occupation of key streams. In the CS-based image fusion domain, Liu [26] proposes a CS-based image fusion scheme to extract much more edge and texture information by directly and merely measure the high frequency sub-bands. Feng et al. [27] give out an infrared and visible image fusion method based on Compressive Sensing. In this CS-based framework, the low and high sub-bands are separately and accurately reconstructed to preserve the correlation among the approximation coefficients and get better fused effect. Thus, the CS-based image fusion scheme is receiving ever-increasing attention and is still intensely ongoing.

Although the above-mentioned algorithms achieve better performance, there are two major limitations in the conventional CS-based fusion approach. Initially, it may generate uncertain measurement results due to the randomness of measurement matrix. The reconstruction error is related with the number of the