Infrared and visible image fusion based on robust principal component analysis and compressed sensing

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Abstract

Current infrared and visible image fusion methods do not achieve adequate information extraction, i.e., they cannot extract the target information from infrared images while retaining the background information from visible images. Moreover, most of them have high complexity and are time-consuming. This paper proposes an efficient image fusion framework for infrared and visible images on the basis of robust principal component analysis (RPCA) and compressed sensing (CS). The novel framework consists of three phases. First, RPCA decomposition is applied to the infrared and visible images to obtain their sparse and low-rank components, which represent the salient features and background information of the images, respectively. Second, the sparse and low-rank coefficients are fused by different strategies. On the one hand, the measurements of the sparse coefficients are obtained by the random Gaussian matrix, and they are then fused by the standard deviation (SD) based fusion rule. Next, the fused sparse component is obtained by reconstructing the result of the fused measurement using the fast continuous linearized augmented Lagrangian algorithm (FCLALM). On the other hand, the low-rank coefficients are fused using the max-absolute rule. Subsequently, the fused image is superposed by the fused sparse and low-rank components. For comparison, several popular fusion algorithms are tested experimentally. By comparing the fused results subjectively and objectively, we find that the proposed framework can extract the infrared targets while retaining the background information in the visible images. Thus, it exhibits state-of-the-art performance in terms of both fusion effects and timeliness.

Keywords: Image fusion, Sparse matrix, Robust principal component analysis, Compressed sensing

1. Introduction

Multi-source images have been recognized as essential tools by the image processing community. They are widely used in many fields, such as remote sensing [1], medical imaging [2, 3], and watermarking [4]. The fusion of infrared and visible images plays a significant role in military applications, such as surveillance and target tracking. Visible images with high sharpness and spatial resolution can provide information on the geometry and texture details of the scene, and they are advantageous for overall recognition [5]. However, under poor lighting conditions or when the target is similar to the background, the information obtained from visible images is insufficient. By contrast, infrared images are based on the temperatures of objects. Objects that are warmer or colder than the background can be easily identified. On the other hand, infrared images are unable to describe objects in sufficient detail [5]. Thus, infrared and visible images offer complementary advantages. Therefore, there is an urgent need for developing effective methods for the fusion of infrared and visible images.

Current image fusion techniques mainly focus on the multi-scale transform (MST). Conventional MST-based fusion algorithms include pyramid-based algorithms, wavelet-based algorithms and multi-scale geometric analysis (MGA)-based algorithms. Relatively new methods, such as sparse representation (SR) [6], nonsubsampled contourlet transform (NSCT) [7], and nonsubsampled shearlet transform (NSST) [8]. Following several years of research, such image fusion methods have achieved considerable success.

Classical MST methods, such as LP, DWT, and CVT, show excellent performance in spatial and spectral quality compared to other spatial methods. However, because they are defined in the frequency domain, their sampling feature is not obvious in the spatial domain and they do not have translation invariance [9]. The SR-based fusion algorithm can make the fusion process more robust to noise and misregistration, but it exhibits poor instantaneity [10]. NSCT- and NSST-based image fusion methods have become increasingly popular in recent years. They have shift-invariance and good direction selection; thus, they can fully capture contours and additional details of images. However, their performance in terms of the fusion effect and operation time is heavily dependent on the fusion rule that is selected to process the decomposition coefficient [11, 12]. Moreover, few of the above-mentioned methods takes the characteristics of infrared images into account.

Some recent studies have investigated the characteristics of infrared images from the viewpoint of image fusion. T.Wan et al. [13] proposed a image fusion scheme for combining two or multiple images with different focus points to generate an all-in-focus image. Fu et al. [14] proposed a method for fusing infrared and visible images on the basis of RPCA and NSCT, where RPCA is used to obtain the corresponding sparse matrices, which are then used to guide the fusion rule of