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An improved fusion algorithm for infrared and visible images based on multi-scale transform

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HIGHLIGHTS

- Morphology-hat transform is used on source images to enhance images contrast.
- Contourlet transform is used to decompose the original image into multi-scale and multi-direction images.
- Different fusion strategies are used on the low-frequency images and high-frequency images to obtain better fused effect.
- Three experiments are performed to compare the proposed method with other current methods.
- Subjective and objective evaluations are given.

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ABSTRACT

In this paper, an improved fusion algorithm for infrared and visible images based on multi-scale transform is proposed. First of all, Morphology-Hat transform is used for an infrared image and a visible image separately. Then two images were decomposed into high-frequency and low-frequency images by contourlet transform (CT). The fusion strategy of high-frequency images is based on mean gradient and the fusion strategy of low-frequency images is based on Principal Component Analysis (PCA). Finally, the final fused image is obtained by using the inverse contourlet transform (ICT). The experiments and results demonstrate that the proposed method can significantly improve image fusion performance, accomplish notable target information and high contrast and preserve rich details information at the same time.

1. Introduction

Image fusion is an effective technology to process multi-sensor image data and has gradually attracted people's attentions. Image fusion technology has been applied to military affairs [1], remote sensing [2–4], medical science [5] and other fields. The infrared and visible sensors are widely used in the fields of military affairs and remote sensing, so many countries have put the emphases of image fusion technologies on infrared and visible images. A visible image contains a lot of high frequency components and can reflect the details of the scene under the certain illumination. But the contrast of the visible image is low when the illumination of the scene is poor. An infrared image can reflect gray scale of the scene. In an infrared image, gray scale is determined by the difference of temperature between the target and background. But an infrared image can not reflect the real details of the scene. Visible or infrared images have respective disadvantages, when they are used alone. For these two complementary images, image fusion technology can effectively integrate and excavate their feature information. So more information can be obtained to fully understand the scene. Image fusion can make the target detection faster and more accurate under the hidden and camouflage situations [6].

In recent years, the image fusion method based on transform domain has become a hot spot in the field of image fusion. Firstly, we can decompose images by multi-scale and multi-resolution transform to obtain each layer image. And then according to some fusion strategies, the images in each layer are fused to obtain the fused images in each layer. At last, the fused images in each layer are reconstructed to obtain the final fused image. Compared with the simple fusion method based on spatial domain, the quality and effect of the fusion image will be improved by this fusion method based on transform domain. Contourlet transform (CT) is proposed based on wavelet transform by DO and Martin Vetterli in 2002 [7,8]. It is a "real" two-dimensional representation for images. Contourlet transform (CT) is also called Pyramidal Directional Filter Bank (PDFB). It has the characteristics of wavelet transform. It also has the characteristics of multi-direction, multi-scale and anisotropy. It is more suitable to describe the geometrical features of images [9,10]. Compared with wavelet transform, sparse

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expression of contourlet transform is better. It can realize the decomposition of arbitrary direction at any scale and is good at describing contours and directional texture information of images.

The traditional multi-scale image fusion methods exist many problems. For example, the descriptions of edges and textures are not clear, the image information is not abundant and so on. So this paper proposes an image fusion method for infrared and visible images based on contourlet transform combined with morphology and PCA. This method can obtain the ideal fusion effect in the infrared and visible images.

2. Principle of the algorithm

This paper proposes a fusion algorithm based on contourlet transform combined with morphology and PCA. First of all, Morphology-Hat transform is used for two images separately. Then the two images were decomposed into high-frequency and low-frequency images by contourlet transform. The image fusion strategy of high-frequency images is based on mean gradient, and the image fusion strategy of low-frequency images is based on PCA. The flow chart of the proposed algorithm is shown in Fig. 1.

2.1. Morphology-hat transform

As is shown in Fig. 1, the two source images will be processed by morphology-hat transform. Image enhancement is a basic problem in image processing and computer vision. Its purpose is marking the contrast of images more obvious. Here we use this technology to process source images in order to enhance the contrast of the final fused images.

Morphology-hat transform is also named as top and bottom hat transform. The important parts of top and bottom hat transform [11] are opening and closing operation. The basic principles of opening and closing operations are as follows: To assume that $f(x,y)$ is the input image, $S(i,j)$ is the structural element. D_f is the domain of function of f and D_S is the domain of function of S, then the dilation operation is defined as $f \oplus S$:

$$(f \oplus S)(i,j) = \max[f(i-x, j-y) - S(x,y) | (i-x), (j-y) \in D_f; (x,y) \in D_S] \quad (1)$$

Erosion operation is defined as $f \Theta S$;

$$(f \Theta S)(i,j) = \min[f(i+x, j+y) - S(x,y) | (i+x), (j+y) \in D_f; (x,y) \in D_S] \quad (2)$$

The process of opening operation is that processing images by erosion operation at first and then dilation operation. The formula of opening operation is as follows:

$$\varphi_s = f \circ S = (f \Theta S) \oplus S \quad (3)$$

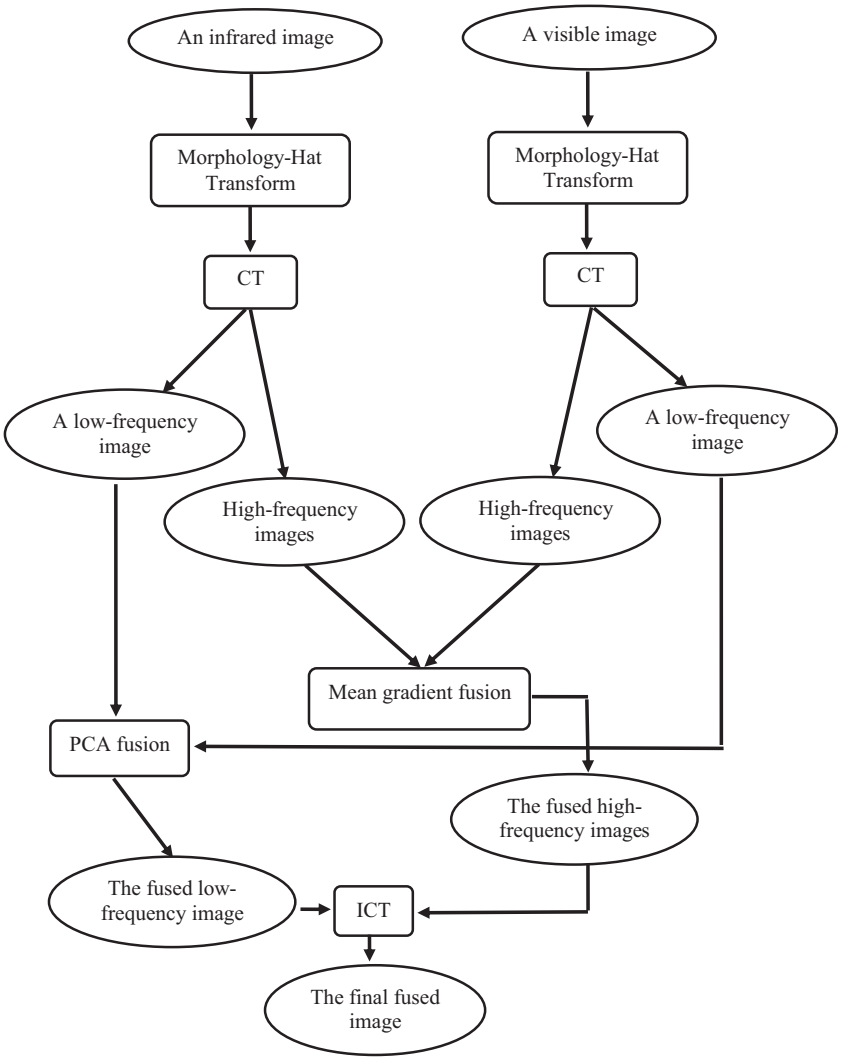

Fig. 1. The flow chart of the proposed algorithm.