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Improved Anscombe transformation and total variation for denoising of lowlight infrared images

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Abstract: The infrared image is corrupted by heavy Poisson noise in lowlight situation, which results in the loss of detail information. To suppress the heavy Poisson noise and keep the distinct edges of images in the lowlight situation, the denoising method based on the improved Anscombe transformation in wavelet domain is proposed. The Anscombe transformation in wavelet domain is improved to control the image distribution from Poisson into Gaussian distribution accurately; then the improved total variation regularization is applied to the wavelet-Anscombe domain for suppressing the heavy noise effectively with the optimal wavelet function. Denoising experiments on artificially degraded and practical lowlight infrared images show that the proposed denoising method can suppress the noise effectively and preserve the detail of images with heavy noise compared with several state-of-the-art methods.

Keywords: lowlight, Anscombe VST, infrared denoising, total variation, wavelet

1. Introduction[1]

Infrared images are generally obtained in lowlight condition such as nighttime, and thus the heavy Poisson noise appears in the infrared image [1-3]. Therefore, the lowlight denoising is an important problem to be solved. Most denoising methods are designed for suppressing the low noise level [4-6], but the heavy noise often exists in the low light condition and leads to low quality of image denoising [7]. Therefore, the suppression of the heavy Poisson noise is a challenge for infrared image denoising.

There are two main types of methods for suppressing the Poisson noise. One is using the statistics of the noise model in the transform domain such as wavelet domain to design an effective Bayes denoising algorithm [8]; the other is using the variance stabilization transform (VST) [9, 10], such as Anscombe transformation, which can map inhomogeneous Poisson process into additive white Gaussian process.

The denoising methods of the first type adjust the independence of Poisson variables via their empirical marginal distributions [11]. Timmermann and Nowak [12] used Bayesian setting to estimate the Haar parent coefficients for suppress the noise. Unser et al. [13] used Bayesian Skellam mean estimator and unbiased estimator of risk to recover the noise-free wavelet coefficients. Rodrigues and Sanches [14] proposed a Bayesian algorithm to remove the Poisson intensity dependent noise. Hirakawa et al. [15] proposed the Skellam distribution of Haar wavelet domain and improved the shrinkage operators for minimizing the risk functions.

The denoising methods of the second type use the Anscombe VST transform to estimate the mean of Poisson for attaining homoscedasticity of noise. This denoising process involves three steps. First, applying the Anscombe VST to standardize the distribution of Poisson noise into Gaussian noise [10]; second, denoising the image with a Gaussian noise filter, such as total variation [16, 17]; finally, applying the inverse Anscombe VST to obtain the desired estimate of noise-free image [18]. Recently many researchers utilize the VST transform in image denoising and other fields. Starck et al. [19] present an extension of the multiscale VST for detecting and characterizing astrophysical sources of high-energy gamma rays. Jin et al. [20] use VST for estimating unknown noise parameters from corrupted images.

In the second step of the VST method, there are many traditional Gaussian denoising methods, such as total variation [21-26], nonlocal denoising [27], BM3D [28], dictionary learning [29], et al. After denoised by these methods, the image applies with the inverse VST for obtaining the final Poisson denoised image.

All the Poisson denoising methods will be effective when the Poisson noise is in low level. If the Poisson noise is heavy, the above methods will not be effective and thus the images restored by above denoising methods will lose detail information. To solve this problem, we propose an improved Anscombe transformation in the wavelet domain with an optimal parameter that can select the proper wavelet basis for suppressing the heavy Poisson noise. We also improve the total variation model in the wavelet-Anscombe domain to suppress the heavy noise. From the experimental results of artificially degraded images and practical lowlight infrared images, the proposed method outperforms state-of-the-art algorithms.

The organization of the paper is as follows. Section II details the proposed method, including the introduction of Poisson noise

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