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Noise suppression and details enhancement for infrared image via novel prior

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HIGHLIGHTS

- Noise suppression and details enhancement algorithm has been raised in this paper.
- Novel prior which is more applicable to infrared image is proposed.
- Structure information of real scene image is protected well and noise is eliminated clearly.
- The targets are more distinct to the background after being processed.

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ABSTRACT

Infrared images always suffer from blurring edges, fewer details and low signal-to-noise ratio. So, sharpening edges and suppressing noise become the urgent techniques in infrared image technology field. However, they are contradictories in most cases. Hence, to depict correctly infrared image features under low signal-to-noise ratio circumstance, a novel prior, which is immune to noise, is presented in this paper. The proposed method scopes noise suppression and details enhancement. In noise suppression, the prior is introduced into Bayesian model to obtain optimal estimation through iteration. In details enhancement, based on the proposed prior, the final image is obtained by the improved unsharp mask algorithm which enhances adaptively details and edges of optimal estimation. The effectiveness and robustness of the proposed method is analyzed by testing the infrared images obtained from different signal-to-noise ratio conditions. Compared with other well-established methods, the proposed method shows a significant performance in terms of noise suppression, actual scene reappearance, enhancing the details and sharpening edges.

1. Introduction

Infrared images take advantage of outstanding stealth, strong penetrability and the day and night operational capacity. So, they are widely used in resource exploration, security surveillance, precision guidance, military remote sensing and many other fields. To satisfy the requirements in the future war, defense research, industrial department and military sectors exploit ceaselessly thermal imaging technology around the world [1,2]. The shortcomings of infrared images, such as strong spatial correlation, low contrast, few details, and the random background noise, which caused by environment interference and the imperfections of thermal imaging system, are urgent to be resolved.

Traditional algorithms can enhance the contrast and details, but distort image edges at the same time [3–6]. In order to address this problem, İlk employs Laplacian edge detection filter and Gauss–Newton algorithm which is applied to adaptive filtering, ensures that the targets edges in images are sharper and that the quality of contrast adjustment has its optimum level with minimum error and maximum peak signal-to-noise ratio [7]. To prevent image from over-enhancement, Zhao introduces the variational infrared image enhancement algorithm based on gradient field equalization with adaptive dual thresholds [8]. Based on adaptive lateral inhibition network, Dai proposes a novel infrared image detail enhancement algorithm, which not only reduces noise by adaptively changing lateral inhibition coefficients according to image scene, but also produces strong contrast between sharp edge and even part [9]. But above-mentioned methods will amplify noise, even drown out useful information. It is critical to suppress infrared noise, in the case of background noise being relatively large in

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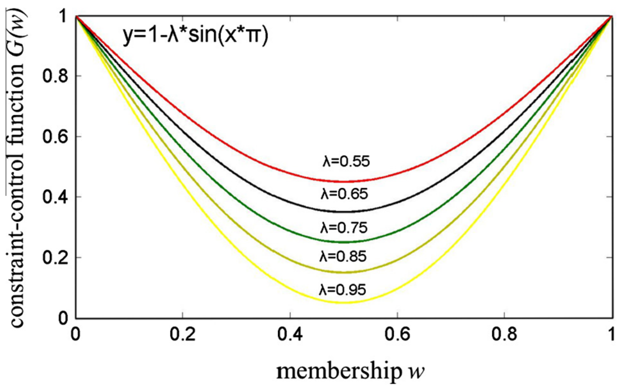

Fig. 1. The relation curves of $G(w) - w$.

infrared image. So, denoising is an essential step to improve the noisy image quality.

Wavelet transform (WT) decomposes the input image with infrared noise into multiple scales, which represents different time–frequency components of the original image. Based on the fact that the number of wavelet coefficients at all the scales is equal to the number of the pixels in the original image, denoising is accomplished by setting soft threshold at each scale, and then the processed wavelet coefficients are transformed back into spatial domain [10]. Curvelet transform, late development of Wavelet transform denoising, is to preserve line structures in original image [11]. For infrared images, however, there is a lack of local structural patterns, which cannot be well represented by using only one fixed wavelet basis. Therefore, both Wavelet transform and Curvelet transform can introduce many visual artifacts and details loss in the denoising output.

To overcome the problem of WT, the recently developed non-local means (NLM) uses a very different philosophy from the above methods in noise removal. It considers that there is strong similarity between different image patches, even though at various locations in natural image. The denoising framework is well established. Each pixel is estimated as the weighted average of all the pixels in the image, and the weights are determined by the similarity between the pixels [12]. Block Matching and 3-D (BM3D) achieves the state-of-the-art denoising performance in terms of both peak signal-to-noise ratio and subjective visual quality. A collaborative image denoising scheme is proposed by patch matching and sparse 3D transform. They search for similar blocks in the image by using block matching and stack them together to form a 3-D array. The so-called BM3D algorithm achieved remarkable denoising results by performing collaborative filtering of the group for each such block and returning the obtained 2-D estimates of all grouped blocks to their original locations [13]. The above two denoising algorithms omit important information that different image regions have different correlation: it can be found that lots of small flat regions were much similar to each other, whereas others may not.

The total variation minimization is introduced by Rudin, Osher and Fatemi, who consider that the total variation of noisy image is significantly larger than non-noise image's. The TV model, preserving the geometrical features of the image, is diffusion filtering method based on constrained convex optimization theory. Gradient is not enough to distinguish edges from noise, so that there are blocking artifacts and lacks of smoothness after denoising.

In light of analyzing the properties of infrared noise, we establish a novel prior model which is more applicable to characterizing the geometrical infrared image features even in the excessively noisy environment. Then the prior model is introduced to maximum a posterior estimation (MAP) model to obtain iteratively denoising image and is employed to improve traditional unsharp mask (UM) algorithm which enhances adaptively edges and details. Eventually the experiment results demonstrate that the proposed method can resolve the contradiction between noise suppression and details enhancement, through testing different signal-to-noise ratio subjects.

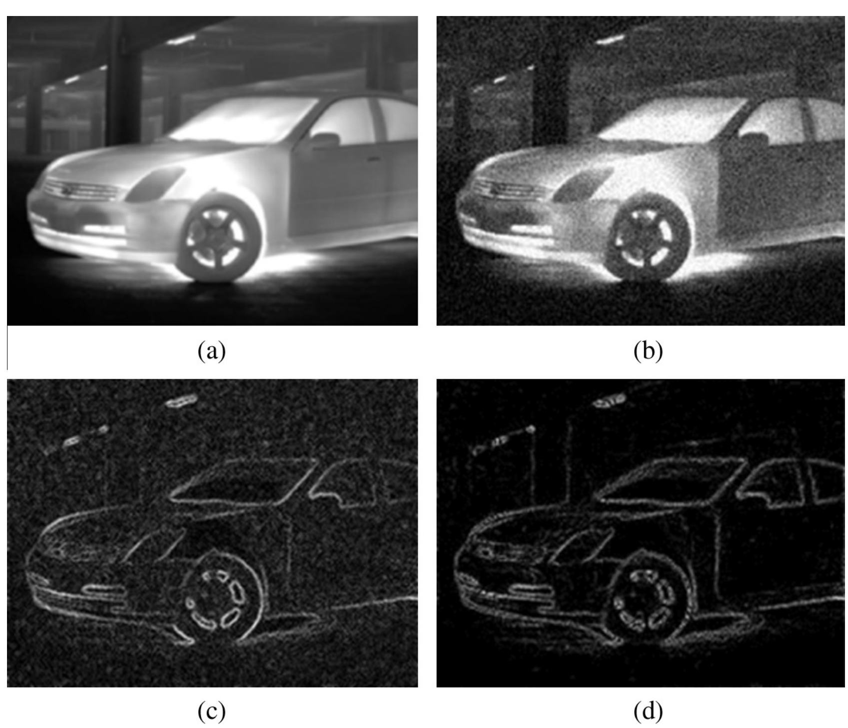

Fig. 2. Comparison of Gibbs prior and novel prior, (a) non-noise infrared image, (b) noisy infrared image, (c) constraint image of (b) under Gibbs prior, and (d) constraint image of (b) under novel prior.