JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Sand-Dust Image Enhancement and Infrared Strip-Noise Removal Using Anisotropic Guided Filter

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Abstract : The guided filter and its later variations have been widely used in various image processing and computer vision applications, owing to its minimal complexity and good edge-preservation features. Despite this success, the guided filter's various variations are unable to handle increasingly aggressive filtering strengths, resulting in the appearance of "detail halos." At the same time, when the input and guide images ae same guided filter exhibit structural inconsistencies, these existing filters function poorly. the guided filter acting as a variable-strength locally isotropic filter on the image. The use of unweighted averaging in the final steps of guided filter variants such as the adaptive guided filter, weighted guided image filter, and gradient-domain guided image filter causes this behavior, according to our analysis. The Anisotropic Guided Filter (AnisGF) is a novel filter that uses weighted averaging to achieve maximum diffusion while maintaining strong edges in the image. The proposed weights are optimized based on local neighborhood variances to produce anisotropic filtering while maintaining the original guided filter's low computing cost. The proposed method of detail halos and the management of inconsistent structures found in previous guided filter variations, according to synthetic experiments. Furthermore, experiments with sand-dust image enhancement and strip-noise removal also show how the technique improves image quality.

IndexTerms - **Detail halos, Edge preservation, Isotropic guided filter, Adaptive guided filter, Weighted guided filter.**

I. Introduction

Sand and dust particles in the atmosphere can significantly degrade the quality of images captured in arid and desert regions. These particles scatter light, leading to reduced contrast, color distortion, and loss of image details. Moreover, images acquired using infrared (IR) sensors often suffer from striping noise, which can be caused by various factors such as sensor imperfections, electronic interference, or uneven illumination. Enhancing the quality of sand and dust-laden images and effectively removing striping noise from IR images are crucial tasks for many applications, including remote sensing, surveillance, and environmental monitoring. Traditional image enhancement and denoising methods may not be effective enough to handle these specific challenges, as they often fail to preserve important image details while reducing noise and enhancing contrast. In recent years, guided filter-based techniques have shown promising results in various image processing tasks, including image enhancement and denoising. The anisotropic guided filter, in particular, has been recognized for its ability to preserve edge information while effectively reducing noise and enhancing image quality. Anisotropic filters adapt their filtering strength and directionality based on local image structures, making them well-suited for handling complex image features like sand and dust particles or striping noise in IR images. Infrared photographs show typical strip noise. It's tough to reduce noise from infrared pictures with poor texture without sacrificing delicate image details. In this article, we present a single-image-based method for accurately removing strip-type noise from infrared images without causing blurring. A 1-D row guided filter is employed first to accomplish edge-preserving horizontal image smoothing. Thermal imaging, night vision, video surveillance, astronomy, fire detection, and robotics are just a few of the military and civilian applications where infrared imaging technology is useful. Strip noise may be accurately distinguished from high-frequency signals induced by visual texture using this innovative local linear noise behavioral model. Solving such decomposition problems with a modified 1D column guided filter is effective. The illustrated de-striping approach may be easily implemented in FGPA to improve the quality of infrared camera photos.

II. Literature Survey

Kaiming He, Jian Sun, and Xiaoou Tang [1], The Guided Image Filtering as a problem is Addressing noise reduction and detail preservation in images. The guided filter is introduced as a versatile tool for various image processing tasks, offering effective noise reduction while preserving important image features.

R. M. H. Nguyen and M.S. Brown [2], Devised a new rapid and effective method for minimizing Lo gradients. Their strategy is founded on insights and descends. Gion fusion, which converges faster than other approaches and approximates the optimal Lo norm better. Furthermore, this approach can be used on both 2D and 3D mesh topologies. Many examples [100] indicate the effectiveness of their strategy.

L. Xu, C. Lu, Y. Xu, and J. Jia [3], The presented a new image processing method in [99], which is very successful for sharpening significant edges by enhancing the steepness of the transition and removing a reasonable level of low amplitude structures. A global control optimization strategy that leverages Lo gradient minimization is used to achieve the seemingly counterintuitive effect. Non-zero gradients occur around considerable structure in a barren style of control. Unlike other edge conservative smoothing algorithms, their method is based on globally important edges rather than local functions. It is particularly useful for edges extraction, clip art JPEG artefact distance, and non-photorealistic effect development as a basic tool.

D. Krishnan and R. Fergus [4], The offer a multi-order deconvolution strategy that is orders of magnitude quicker than existing Hyper-Laplace prioritization techniques. They employed alternating minimization technique in which one of the two phases is non-convex, pixel-separable problem. A lookup table can solve this sub-problem per pixel (LUT). Finding the roots of a cubic or quartic polynomial for two stated values of a, 1/2 and 2/3, can also yield an analytical solution. Their method (which uses LUTs or mathematical formulas) may unfold a 1 Megapixel image in under -3 seconds, but it is unlikely to attain comparable quality to existing methods like iterative rebalancing squares (IRLS), which takes 20 minutes. Furthermore, their solution is fairly broad and may be easily adapted to other image processing

Y.Kim et al. [5], proposed a green decomposition technique for global EPS that minimizes the L2 data target function and regularization terms in linear time. Unlike earlier decomposition-based methods, which require the solution of a massive linear system, their method solves an identical restricted optimization issue, yielding a chain of 1-D sub-problems. For weighted-least squares and -L1 smoothing issues, this enables the use of a quick linear time solver. To provide speedy convergence, an alternating path technique of multipliers set of rules is used. Their method is totally parallelizable, and its execution time is comparable to that of recent EPS techniques.

S. Paris and F. Durand [6], proposed a fresh signal-processing evaluation of the bilateral filter, which complements recent work that looked at it as a PDE or a strong information estimator. Importantly, this sign-processing perspective allows us to apply down-sampling in space and depth to develop a unique bilateral filtering acceleration. This provides a consistent expression of accuracy in terms of bandwidth and sampling. The filter in a higher-dimensional space in which the signal intensity is introduced to the original domain dimensions is the key to their evaluation. On this augmented space as the bilateral filtering acceleration.

E Liu, Jenny Yuen, and Antonio Torralba [7], SIFT Flow Dense Correspondence across Scenes and Its Applications Dense correspondence estimation between image. Introduces the SIFT Flow algorithm for estimating dense correspondences between images, which could be useful for aligning and enhancing sand dust images.

III. EXISTING SYSTEM

Guided filtering [8]: The guided filter removes noise in the input image while preserving clear edges. Specifically, a "flat patch" or a "high variance patch" can be specified by the parameter of the guided filter. Inconsistent Structures in the Guided Filter: The guided filter's poor performance when dealing with inconsistent structures is another downside (For example, when the input and guide patches are structured differently). Weighted Guided Image Filter: This section proposes an edge-aware weighting, which is then merged into the GIF to generate the WGIF.

IV. PROPOSED SYSTEM

Both limitations share the lack of anisotropy in the formulation of current guided filters. The problem of detail haloing, which we mentioned before, reveals that these filters are only weakly anisotropic. While the averaging step accurately adjusts the level of diffusion to preserve strong edges, low-pass filtering these values completely eliminates these measures. When is low, this process preserves detail at an edge due to weak diffusion, whereas when is large, it erodes the edge due to excessive diffusion.

Existing guided filters don't follow the gradient restrictions of the guide picture when dealing with inconsistent structures because they lack anisotropy. The WLS and WL1 global filters employ a penalty term based on the gradients of the guide image. By preventing the filter from bridging large gradients in the guiding picture, this penalty causes an anisotropic effect. The covariance of the input and guide patches affects the diffusion effect in guided filters. When structures are inconsistent, the covariances are modest, resulting in a small i values, which permit strong diffusion while ignoring the gradient restrictions in the guide patch. Anisotropic integration, similar to detail halos, can be used to eliminate this.

This, like detail halos, can be avoided by including anisotropy in the filter formulation, particularly one derived from the structure of the guiding picture. The regularization of a i has little to no effect on the degree of anisotropy in each of these situations due to the final averaging step used in each. This suggests that normal guided filter versions like AGF, WGIF, and GGIF have the same concerns. We can improve anisotropy by regularizing the averaging step rather than regularizing a i. As a result, we recommend using a weighted average strategy:

$$\tilde{s}_i = \sum_{j \in N(i)} \omega_{ij} s_j \qquad (1)$$

$$\tilde{t}_i = \sum_{j \in N(i)} \omega_{ij} t_j \qquad (2)$$

where ω_{ij} is the weight given to a pixel in a neighbourhood at j that surrounds the central pixel at i. The goal of these weights is to maximise diffusion while keeping the guide image's edge boundaries strong.

$$\underset{\omega_i}{\operatorname{argmin}}\, s_i^2 + \mu \sum_{j \in N(i)} \left\| \omega_{ij} \nabla_j \right\|_2^2 \qquad (3)$$

Where ω_{ij} is a vector containing the weights of all surrounding neighbourhoods centred on pixel I in the guide picture, and j is a vector containing the gradients of the neighbourhood at pixel j in the guide image.

This isn't the first time a weighted averaging method has been used to tweak the guided filter. The demosaicing technique employs a residual variance-based weighted averaging algorithm. Because its function was to communicate detail between colour channels in an image, it was designed to minimize the transformation error of the guided patch to the input patch. Due to the residual variance requirements, any structural differences between the two patches are discarded in favour of a transformation that attempts to rebuild the input patch as closely as possible while avoiding diffusion effects. The proposed system block diagram is shown in figure 1.

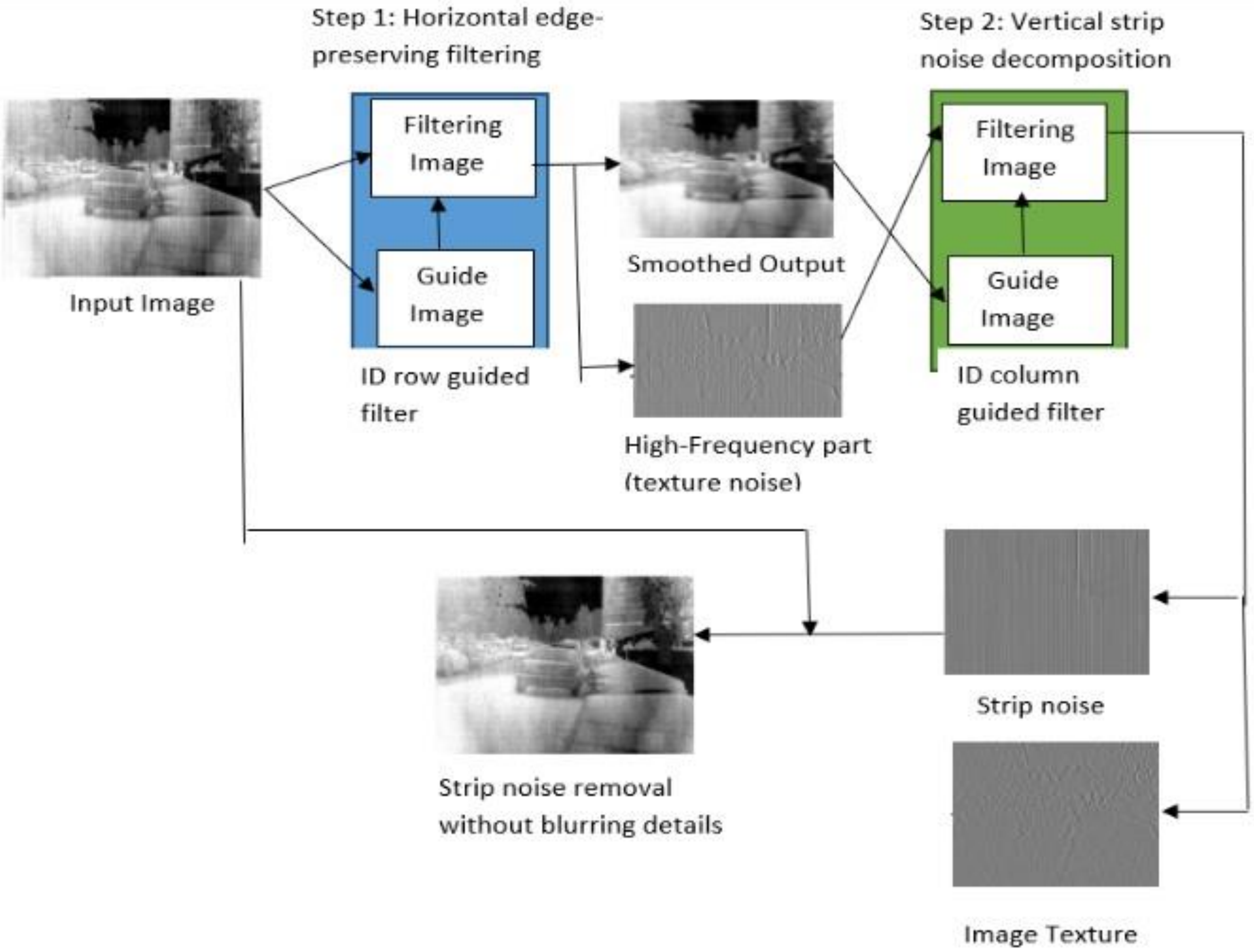

Fig 1: Block diagram of the proposed system

V. RESULTS AND DISCUSSION

Experiment results in figure 2 show that the output image strongly adheres to the input image's gradient structure. The anisotropic guided filter is smoothing-oriented which has complexity of O(n). The algorithm accurately removes strip-type noise present in infrared images without causing blurring effects. Firstly, a 1D row guided filter is applied to perform edge-preserving image smoothing in the horizontal direction. The extracted high-frequency image part contains both strip noise and significant amount of image details. Through a thermal calibration experiment. Based on the derived strip noise behavioral model, strip noise components are accurately decomposed from the extracted high-frequency signals by applying 1D column guided filter. Finally, the estimated noise terms are subtracted from raw infrared images to remove strips without blurring image details.

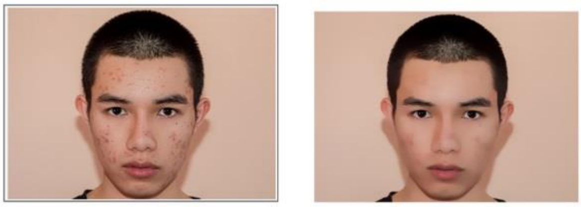

Fig 2: Input and Output image of proposed system

VI. CONCLUSION

This study developed a novel filter that builds on the guided filter's foundation while addressing many of its drawbacks. AnisGF can simply be considered of as a generalised guided filter. This can be parameterized to reproduce the behaviour exactly of the latter. This characteristic suggests that new filter may be used in the numerous applications that already avail, while adding anisotropy into the guided filter's performance as an additional capacity This anisotropic behaviour could be ubiquitous. This anisotropic behaviour may be more desirable in some applications such as enhancement, noise reduction and segmentation. As identified in this work, the AnisGF still presents some limitations, particularly with density dependence which can be addressed by extending the filter to multiple scales.

VII. FUTURE SCOP

The Gaussian Spatial weighing can replace the regularization term. With the use of Adaptive Regularization term, instead of dependence on local variance we can allow for the reuse of already computed values. Further advancement in the algorithm can be introduced by Deep Convolution Neural Network.

VIII. ACKNOWLEDGMENT

We are grateful to our guide Associate Prof. Mr. D. MUNEENDRA for this continuous support and guidance. Through his guidance, We were able to successfully complete our project. Our sincere thanks go to our Head of the Department of Electronics and Communication Engineering at Siddharth Institute of Engineering and Technology, for her support and time.

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