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A multi-scale non-uniformity correction method based on wavelet decomposition and guided filtering for uncooled long wave infrared camera

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ABSTRACT

In uncooled long-wave infrared (LWIR) imaging systems, non-uniformity of the amplifier in readout circuit will generate significant noise in captured infrared images. This type of noise, if not eliminated, may manifest as vertical and horizontal strips in the raw image and human observers are particularly sensitive to these types of image artifacts. In this paper we propose an effective non-uniformity correction (NUC) method to remove strip noise without loss of fine image details. This multi-scale destriping method consists of two consecutive steps. Firstly, wavelet-based image decomposition is applied to separate the original input image into three individual scale levels: large, median and small scales. In each scale level, the extracted vertical image component contains strip noise and vertical-orientated image textures. Secondly, a novel multi-scale 1D guided filter is proposed to further separate strip noise from image textures in each individual scale level. More specifically, in the small scale level, we choose a small filtering window for guided filter to eliminate strip noise. On the contrary, a large filtering window is used to better preserve image details from blurring in large scale level. Our proposed algorithm is systematically evaluated using real-captured infrared images and the quantitative comparison results with the state-of-the-art destriping algorithms demonstrate that our proposed method can better remove the strip noise without blurring image fine details.

1. Introduction

Nowadays infrared imaging systems have a wide range of military and civilian applications including night vision, surveillance systems, fire detection, robotics etc. The focal plane array (FPA) is an important component of the uncooled long-wave infrared (LWIR) imaging system. Due to the non-uniform responses of the FPA detectors, raw infrared images usually contain fixed pattern noise (FPN). Moreover, it is observed that FPN is related to the ambient temperature variation and characteristics of detectors will significantly change when the temperature of FPA fluctuates [1,2].

As a typical kind of FPN, strip noise is an unwanted but commonly existing phenomenon in LWIR imaging systems and it is often introduced in the readout circuit of the FPAs. Nowadays, most infrared FPA readout circuits are designed based on the CMOS structure [3]. Different from the CCD structure in which all detectors share a common amplifier, different columns of the infrared CMOS array use different amplifiers. Since the non-uniformity of the amplifiers, strip noise emerges within a column. Human beings are especially sensitive to the resulting strip noise [4]. The strip noise will significantly degrade the quality of the captured IR images and affect subsequent high-level image processing tasks such as image registration, object identification, image fusion. Therefore it is essential to conduct non-uniformity correction (NUC) to remove strip noise on raw IR images.

It is a challenging task to remove the strip noise using traditional calibration based [5] or scene based NUC methods [6,7]. The two-points calibration method employs two temperature-uniform blackbodies at different temperatures to calculate the gain and bias parameters of a linear NUC model. It will interrupt the capturing process and is not suitable for dynamic infrared imaging applications [5]. The limitation of scene-based method is that they usually need plenty of image frames to estimate stable NUC factors. Also, all these scene-based NUC techniques produce ghosting artifacts when scene objects do not move enough [6]. Currently, some researches have been concentrated on improving destriping algorithm by considering the prior knowledge of the characteristics of the noise [8–10].

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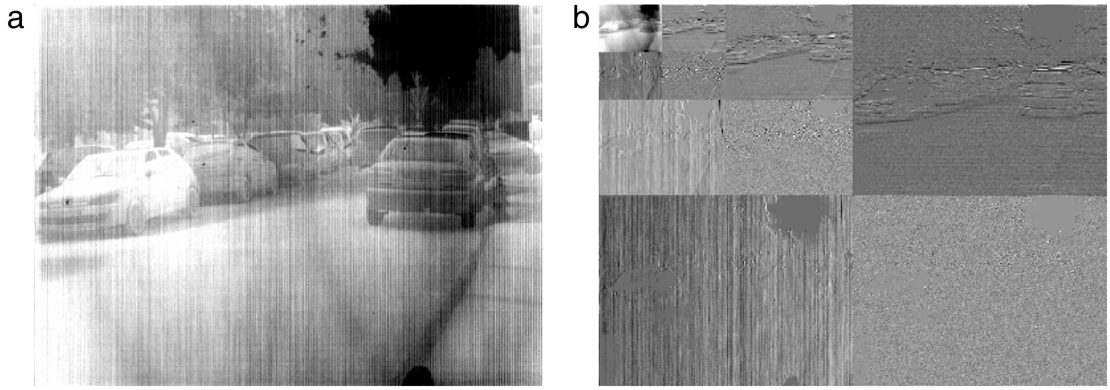

Fig. 1. Three-level wavelet decomposition of a real-captured infrared image. (a) is the original image and (b) is the decomposition result. The images are normalized to 0–1 value range for visualization.

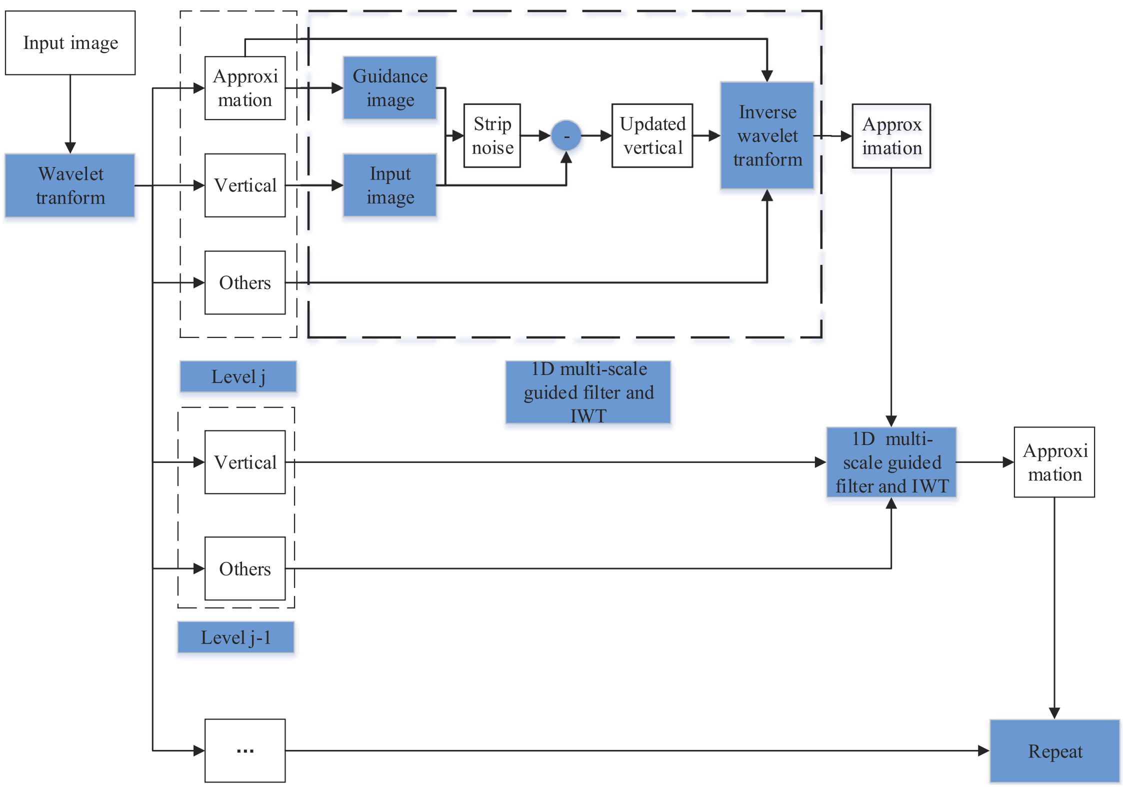

Fig. 2. Workflow of our proposed algorithm.

In this paper, an effective NUC method is proposed to remove strip noise without loss of fine image details. This NUC method consists of two consecutive steps. Firstly, wavelet-based image decomposition is adopted to separate the original image into three scale levels: large, median and small scales. Each scale level contains an approximation component and three other directional components (i.e. horizontal, vertical and diagonal). The extracted vertical components contains strip noise and vertical-orientated image textures; The diagonal-orientated and horizontal-orientated image textures are extracted into corresponding directional components as shown in Fig. 1(b). Then we utilize the 1D guided filter (details are given in Section 3.2) to further separate the strip noise from the image textures within a single column. On the highest level j, our method takes image approximation and vertical component, respectively, as the guidance image and the input image, to carry out the 1D guided filtering. After computing the strip noise on level j, we update the vertical detail and reconstruct the approximation component of the $j-1$ level. The above procedures are repeated until we obtain the image with the same size of the original input image. In the filtering step, we proposed a novel multi-scale 1D guided filter to eliminate the strip noise while preserving the fine details. More specifically, in the small scale level, we choose a small filtering window for guided filter to eliminate strip noise. On the contrary, a large filtering window is used to better preserve image details from blurring in large scale level. Our proposed method can better remove the strip noise without blurring the fine details. The complete workflow of our proposed algorithm for strip non-uniformity correction is illustrated in Fig. 2.

The main contribution of this research is to present a multi-scale filtering strategy for effective strip FPN removal. The small scale vertical component contains a significant amount of strip noise, so we make use of a small size 1D guided filter to better remove the noise accordingly. On the other hand, the large scale vertical component mainly contains structural edges or textures, so we make use of a guided filter of large size to preserve image details. This novel multi-scale filtering