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Error correction based on micro-scanning preprocessing for an optical micro-scanning thermal microscope imaging system

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HIGHLIGHTS

- A thermal microscope imaging system based on an uncooled infrared detector.
- A thermal microscope imaging system with an optical micro-scanning instrument.
- The technique for error correction proposed in this paper.
- We can obtain standard 2×2 micro-scanning high spatial resolution oversample image.

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ABSTRACT

In recent years, various thermal microscope imaging systems have been developed to meet the demands of micro-thermal analysis for large-scale integrated circuits, biomedical, science, and research fields. However, conventional thermal microscope imaging systems, which use cooled infrared detectors are heavy and expensive. In order to solve this problem, we developed a thermal microscope imaging system based on an uncooled infrared detector. However, the spatial resolution of the thermal microscope imaging system based on an uncooled infrared detector is low. With optical micro-scanning technology, the spatial resolution of the thermal microscope imaging system can be increased without increasing the detector dimension or reducing the detector unit size. In order to improve its spatial resolution, a micro-scanning system based on optical plate rotation was developed, and an optical microscanning thermal microscope imaging system was obtained after the integrated design. Due to environmental factors, mechanical vibration, alignment error and other factors, there is micro-scanning error in the designed micro-scanning thermal microscope imaging system. The four low-resolution images collected by micro-scanning thermal microscope imaging system are not standard down-sampled images. The quality of the image interpolated directly by four collected images is reduced and the performance of the micro-scanning system isn't fully exploited. Therefore, based on the proposed second-order oversampling reconstruction micro-scanning error correction algorithm and the new edge directed interpolation algorithm, a new micro-scanning error correction technique is proposed. Simulations and experiments show that the proposed technique can effectively reduce optical micro-scanning error, improve the systems spatial resolution and optimize the effect of the imaging system. It can be applied to other electro-optical imaging systems to improve their spatial resolution.

1. Introduction

Thermal microscope imaging system can not only observe the details of the object, but also observe the details of temperature changes. So it plays an important role in the field of thermal microscope analysis. In recent years there have been many thermal microscope imaging products [1–4]. We have developed a thermal microscope imaging system based on an uncooled focal plane detectors [5,6]. In order to improve its spatial resolution, a micro-scanning system based on optical plate rotation was developed [7–9], and an optical micro-scanning thermal microscope imaging system was obtained after the integrated design [10,11]. The imaging system is shown in Fig. 1. When the system collects the image, the micro-scanning zero [12] is taken as the starting point. By rotating the tilted plate in the optical path at intervals of $90^\circ, 2 \times 2$ micro-scanning images $\boldsymbol{A}(i, j)$, $\boldsymbol{B}(i, j)$, $\boldsymbol{C}(i, j)$ and $\boldsymbol{D}(i, j)$, $(i = 1, 2 \ldots, M; j = 1, 2 \ldots, N)$ are collected. Then the

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Fig. 1. Optical micro-scanning thermal microscope imaging system.

low-resolution images are directly interpolated and reconstructed in the order of image collection, and a high resolution image is obtained in which the spatial resolution in the horizontal and vertical directions is increased by 4 times.

However, due to environmental factors, mechanical vibration, alignment error and other factors, the four low-resolution images obtained by micro-scanning thermal microscope imaging system are not standard down-sampled images. That is, the micro-displacement between the low-resolution images is not the micro-displacement of the half-pixel pitch in the standard 2×2 micro-scanning mode. The quality of the reconstructed image is reduced and the performance of the micro-scanning system isn't fully exploited. Therefore, the technique to reduce the system micro-scanning error and improve the system performance should be studied. Early based on the second-order Taylor series expansion, we proposed a second-order oversampling reconstruction (SOR) technique [13] for micro-scanning error correction. This technique can make the non-standard 2×2 micro-scanning images similar to the standard 2×2 micro-scanning images, which can reduce the micro-scanning error. In this paper, we apply this technique to micro-scanning image preprocessing, and propose a new micro-scanning error correction technique which is combined with new edge directed interpolation (NEDI) [14–16] algorithm.

The paper is organized as follows. In Section 2, we describe NEDI algorithm, the error correction technique, down-sampling model and the error correction principle. In Sections 3 and 4, we show the results obtained from simulated and experimental images. In Section 5, we summarize the paper and list the advantages of our technique.

2. Error correction technique

2.1. New edge directed interpolation

New edge directed interpolation (NEDI) is a typical image edge interpolation algorithm. It combines bilinear interpolation with adaptive interpolation. The algorithm processing flow chart is shown in Fig. 2. Firstly, edge detection is carried out on the low-resolution image, which is divided into two regions (the edge region and the flat region) by the threshold control method. For the edge region, adaptive interpolation is used and for the flat region, bilinear interpolation is used. As s result, a high resolution image can be obtained.

2.2. Error correction technique

Firstly, the micro-scanning zero is taken as the starting point in the optical micro-scanning thermal microscope imaging system, and 4 images are collected according to the standard 2×2 micro-scanning mode. Because there is error in the micro-

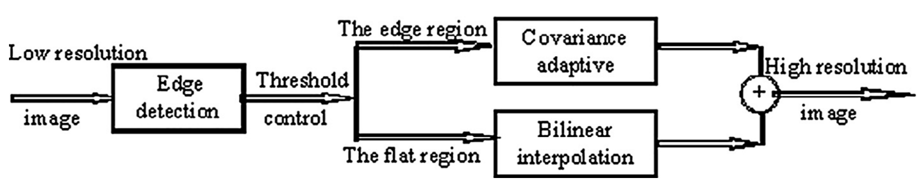

Fig. 2. NEDI algorithm processing flow.

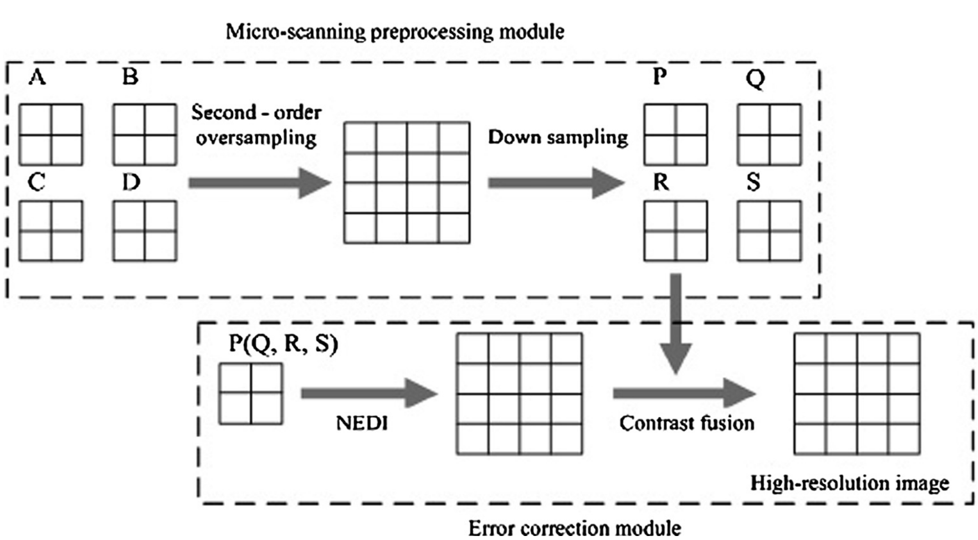

Fig. 3. Micro-scanning error correction based on micro-scanning preprocessing.