Infrared Physics & Technology 76 (2016) 661–666

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

Regular article

High-resolution over-sampling reconstruction algorithm for a microscanning thermal microscope imaging system

Meijing Gao [a], Jingyuan Wang [a,*], Wei Xu [a], Congrong Guan [b]

[a] The Key Laboratory for Special Fiber and Fiber Sensor of Hebei Province, School of Information Science and Engineering, Yanshan University, Qinhuangdao, Hebei 066004, China
[b] School of Optoelectronics, North China University of Technology, Beijing 100041, China

HIGHLIGHTS

- A thermal microscope imaging system based on an uncooled infrared detector.
- A thermal microscope imaging system with an optical micro-scanning instrument.
- The algorithm based on the principle of the Second-order Taylor series expansion.
- We can obtain standard 2×2 micro-scanning high spatial resolution oversample image.
- The algorithm was simple, fast and had low computational complexity.

ARTICLE INFO

Article history:
Received 6 September 2015
Revised 26 April 2016
Accepted 26 April 2016
Available online 27 April 2016

Keywords:
Imaging processing
Thermal microscope imaging
Microscanning
Oversampling
Image reconstruction
Spatial resolution

ABSTRACT

Due to environmental factors, mechanical vibration, alignment error and other factors, the micro-displacement of four collected images deviates from the standard 2×2 micro-scanning images in our optical micro-scanning thermal microscope imaging system. This influences the quality of the reconstructed image and the spatial resolution of the imaging system cannot be improved. To solve this problem and reduce the optical micro-scanning errors, we propose an image reconstruction method based on the principle of the Second-order Taylor series expansion. The algorithm can obtain standard 2×2 microsanning under-sampling images from four non-standard 2×2 microsanning under-sampling images and then can obtain high spatial oversample resolution image. Simulations and experiments show that the proposed technique can reduce the optical micro-scanning errors and improve the systems spatial resolution. The algorithm has low computational complexity, and it is simple and fast. Furthermore this technique can be applied to other electro-optical imaging systems to improve their resolutions.

1. Introduction

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 [1–3]. 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 [4,5]. As a result of the discrete sampling of the focal plane detector region and spatial integration over the detector unit, thermal microscope imaging generally belongs to the category of undersampled imaging and even approaches the optical diffraction limit. With optical micro-scanning technology, the spatial resolution of the thermal microscope imaging system can be increased without increasing the detector dimensions or reducing the size of the detector unit [6,7]. During the micro-scanning imaging process, multiple sampling is carried out on the same scene. The focal plane array is displaced in equal steps, with a step size of $1/N$ (where N is an integer). Then the final micro-scanning reconstructed image pixel number is N^2 times that of the original image. Using micro-scanning, the information can be obtained over more of the scene, and the system spatial resolution can be greatly improved [8]. In Ref. [4], we used micro-scanning technology based on rotating an optical plate to realize a thermal microscope system with an optical micro-scanning instrument (Fig. 1). However, the relationship between the positions of the micro-scanning instrument and detector will be changed after every alignment, and there is a deviation between the initial scanning point and the standard zero point. As a result, the designed micro-scanning instrument can not improve the spatial resolution, but it

* Corresponding author.
E-mail address: 383591269@qq.com (J. Wang).

http://dx.doi.org/10.1016/j.infrared.2016.04.034
1350-4495/

Fig. 1. Imaging system.

sometimes degrades the resolution. Therefore, we proposed a zero-calibration technique using image registration and geometric theory. Results show that the proposed technique can improve the thermal microscope imaging quality [9–11]. But due to environmental factors, mechanical vibration, alignment error and other factors, the micro displacement of collected four images deviated from the standard 2×2 microscanning, and the micro-displacement position is not a standard upright square (Fig. 2), so that the direct reconstruction can not obtain the ideal high-resolution images and influenced the reconstruction image quality. Therefore, an error correction algorithm for the micro-scanning instrument needs to be studied. In this paper, we demonstrate an error calibration technique. The algorithm can reduce the micro-scanning error and obtain standard 2×2 micro-scanning high spatial resolution oversample image by using the four non-standard 2×2 micro-scanning under-sampling images. The paper is organized as follows. In Section 2, we provide a description of the designed thermal microscope imaging system. In Section 3, we describe the over-sampling reconstruction algorithm(error-calibration method). In Section 4, we show results obtained from simulated and experimental images. In Section 5, we summarize the paper and list the advantages of our technique.

2. System composition

The optical micro-scanning thermal microscope imaging system is composed of an uncooled infrared detector, a rotating-optical-plate micro-scanning instrument, an infrared microscope, a mechanical structure component, and a computer [12] (see Fig. 1). The rotating-optical-plate micro-scanning instrument consists of components including an infrared optical plate (that is, an optical plate that transmits infrared light), a mount for the optical plate, an electronically controlled rotating platform and the corresponding controller. The object on the platform is imaged by the infrared focal plane array through the infrared objective lens and the micro-scanning device. Then thermal microscope images are collected on the computer. With a 2×2 model four-point mechanical micro-scanning scheme, the micro-scanning instrument is placed in front of the focal plane array and controlled by the computer, as shown in Fig. 3.

The optical plate is oriented at an angle with respect to the optical axis. A mechanical device rotates it around the optical axis of the system. We collected four images at intervals of 90° from the micro-scanning zero. Then four low-resolution images of the same scene were collected. Each image had the same displacement, which is one-half of the photosensitive pixel size of the [4]. The standard 2×2 micro-scanning location is shown as the continuous line in Fig. 4. The labels 1, 2, 3, and 4 represent four standard locations respectively, and they are located in the four quadrants of 45°, 135°, 225°, and 315°; thus they form a standard upright square. The four low-resolution images captured at the standard locations are sub-sampled, and we can use them to reconstruct a high-resolution image. Thereby the spatial resolution of the system is improved. However the micro displacement of collected four

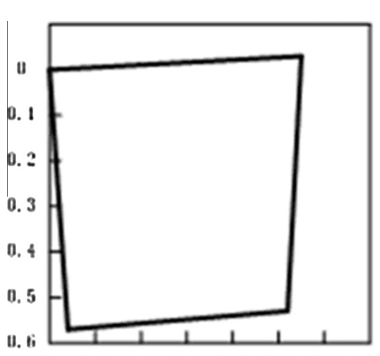

Fig. 2. The micro displacement position of 2×2 microscanning imaging of system.

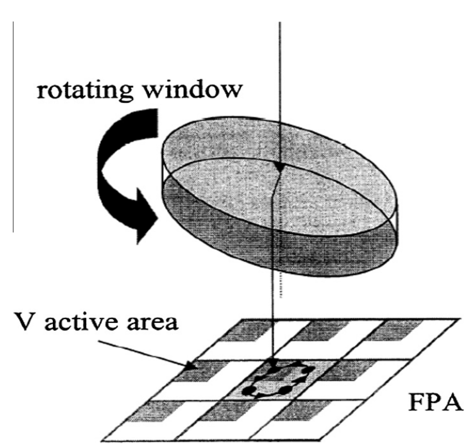

Fig. 3. Schematic of the micro-scanning technique.