Optics Communications 297 (2013) 12–19

Contents lists available at SciVerse ScienceDirect

Optics Communications

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

Image fusion of tempo-spatially modulated polarization interference imaging spectrometer

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ARTICLE INFO

Article history:
Received 1 June 2012
Received in revised form
10 January 2013
Accepted 27 January 2013
Available online 9 February 2013

Keywords:
Spectrometer
Fusion
Filter

ABSTRACT

The space-based tempo-spatially modulated polarization interferometer imaging spectrometer (TSMPIIS) scans over an observed area, and acquires the image-spectrum data cubic consisting of a series of the CCD images taken at different times. Every pixel on the CCD image records interferographs with different optical path differences, corresponding to the incident angles changing from maximum, via zero, and finally to negative maximum. To improve the spatial resolution of the color comprised image acquired by TSMPIIS, the panchromatic (PAN) image of high spatial resolution is fused with the color composite image of high spectrum resolution to produce the fused image of both high spatial and spectrum resolution. Based on the characteristics of the TSMPIIS image data, the FFT (fast Fourier transform)-enhanced IHS (intensity-hue-saturation) transform method is used and compared with IHS and WT (wave transform) methods. The experimental results show that the FFT-enhanced IHS method can establish very good trade-off between spatial and spectral quality of the fused image and largely improve the spatial resolution of the color composite image. The fusion method significantly enhances the instrument performance at very low cost.

1. Introduction

A typical temporally modulated interference imaging spectrometer (TMIIS) is based on the scanning Michelson interferometer [1,2]. It usually requires precise scanning mechanisms and highly stable designs, which imply high cost and substantial bulk. The drawbacks of TMIIS encourage the development of static systems called as spatially modulated interference imaging spectrometer (SMIIS) [3–6]. Most of SMIIS is based on the lateral shearing interference such as the Sagnac interferometer. Due to serious restriction of its pre-aperture with narrow slit, the optical throughput of SMIIS usually is low, and the collected data are correlated with low signal-to-noise ratio. So around 2000 s the novel tempo-spatially modulated polarization interferometer imaging spectrometer (TSMPIIS) is introduced. Without any internal moving parts and pre-aperture, the spectra and panchromatic (PAN) images of targets can be simultaneously acquired. With many attractive advantages such as compactness, robustness, common-path, excellent resolution, and high throughput, the validity of TSMPIIS has been demonstrated [7–10].

In order to better identify a target by its color features, the acquired spectral information is used to re-construct the color composite (CC) image. However, the CC image has low spatial resolution due to the existence of high- frequency noises that come from a variety of sources including the system noises and the process of the re-sampling [11]. For taking full advantage of TSMPIIS, we use the strategy of image fusion. The PAN image of high spatial resolution is fused with the CC image of high spectral resolution. This greatly improves the spatial resolution of the CC image and produces the color image of high spatial and spectral resolutions [12]. Three different fusion methods are discussed and compared. It turns out that the FFT(fast Fourier transform)-enhanced IHS (intensity-hue-saturation) method can effectively suppress high-frequency noises and allow a very flexible fusion to obtain a better fused image.

2. Image data acquisition

The TSMPIIS is generally loaded on satellite or aircraft. When it scans over the whole area of an observed object, every pixel on the CCD records interferographs with different optical path differences, corresponding to the incident angles changing from maximum, via zero, and finally to negative maximum. Thereby,

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http://dx.doi.org/10.1016/j.optcom.2013.01.041

the image-spectrum data cubic consists of a series of the CCD images taken at different times. This is the basic work model of TSMPIIS, which is named as tempo-spatially modulated model (TSM) [10,13].

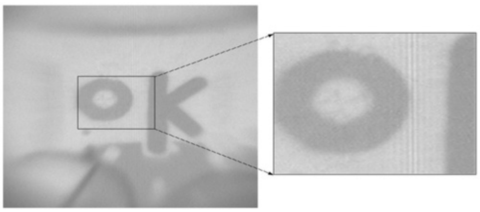

Fig. 1. One frame of the CCD images consisting of the interferograms (vertical strips) and the image (OK) taken by TSMPIIS.

Fig. 1 is one frame of typical interference-images recorded on the CCD at a particular instant by TSMPIIS. It contains the target image and interference patterns. Fig. 2 shows several representative interference-image frames taken at different times. Fig. 2(a) is the interference-image when the target coming into the TSMPIIS FOV (field of view). Fig. 2(b–o) are the target plot's several images of at different position in the field of view of TSMPIIS. Fig. 2(p) is the image when the target leaving out of the FOV of TSMPIIS.

Fig. 3 is the panchromatic image re-constructed that can be achieved by collecting the CCD columns of zero optical path difference (OPD) of each image taken at different time. In other word, the Fig. 3 is the figure of zero FOV. Thus, there is no any interference fringe in Fig. 3. In contrast, the interference data for a given point of the object can be acquired by sampling the same CCD row of the images according to certain orders [10,13]. The spectra for the point can be obtained from the interference

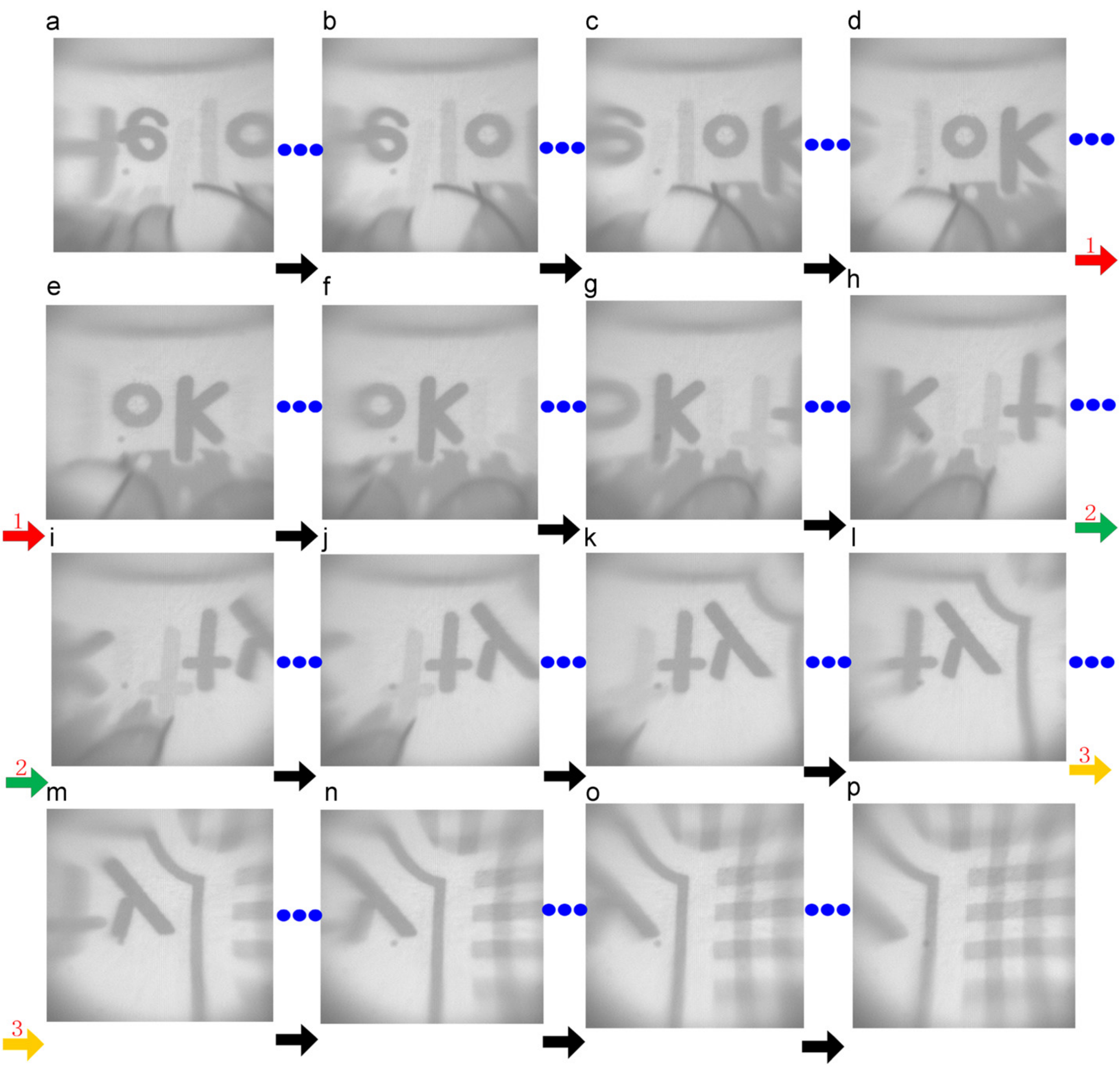

Fig. 2. Parts of an image series (513 frames) taken by TSMPIIS with TSM sampling model at different times under polychromatic light. Arrows denote the direction of the scan. Blue points denote some images in the process of the scan. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)