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Improved morphological component analysis for interference hyperspectral image decomposition ☆

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ABSTRACT

Due to the special imaging principle, lots of vertical interference stripes exist in the frames of the IHI (interference hyperspectral image) data, which will affect the result of compressed sensing theory or other traditional compression algorithms used on IHI data. In this paper, MCA (morphological component analysis) algorithm is adopted to separate the interference stripes layers and the background layers, and an IMCA (improved MCA) algorithm is proposed according to the characteristics of the IHI data, dictionary learned from the LSMIS (Large Spatially Modulated Interference Spectral Image) data is used to sparsely represent the stripes layers instead of traditional basis, and the condition of iteration convergence is improved. The experimental results prove that the proposed IMCA algorithm can get better results than the traditional MCA, and also can meet the convergence conditions much faster than the traditional MCA.

0. Introduction

Interference hyperspectral imaging is a very powerful technology in the field of remote sensing. This technology can get the spectral and spatial information of the observed targets, which has been widely used in many fields, such as meteorology, military, environmental monitoring and geology. The interference hyperspectral spectrometer has been successfully equipped in the "Chang'E" lunar exploration satellite. Interference hyperspectral imaging has become the research focus in the recent years. IHI (interference hyperspectral image) is three-dimensional data, which is formed with the principle of the LASIS (Large Aperture Static Imaging Spectrometer). IHI has high resolution. Its massive data leads to the difficulty on the storage and transmission. So it is necessary to design efficient compression methods according to the special characteristics of IHI. At present, the compression methods for IHI include predictive algorithms [1–3], vector quantization algorithms [4], transform algorithms [5,6] and data coding algorithms [7,8].

There are lots of interference stripes in each frame of the IHI data, and their positions are fixed. In the compression and reconstruction of the IHI, the interference stripes affect the final result seriously [6]. The inherent characteristics will seriously impact the directly application of many traditional methods, such as the predictive coding and adaptive lifting wavelet transform. The characteristics also cannot meet the precondition of compressed sensing.

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In [3], the structure of IHI data is changed with the corresponding column extracted mode, but the interference stripes still cannot be removed. In [5], tensor theory is adopted in the data compression, but the effect of the interference stripes is not considered. In [6], interference stripes have been removed in the high frequency domain through changing order of the wavelet transform, but in the low frequency domain, the interference stripes still cannot be removed. However, MCA (morphological component analysis) algorithm is adopted in this paper, which can be used to separate the interference stripes from the background, and an IMCA (improved MCA) algorithm is proposed in this paper to better the decomposition result and computational efficiency of the traditional MCA.

The imaging principle and characteristics of IHI will be introduced in the next section. The MCA algorithm will be introduced in Section 2. According to the characteristics of IHI, an improved MCA algorithm with dictionary learned from LSMIS (Large Spatially Modulated Interference Spectral Image) will be proposed in Section 3. Experiments and analysis will be given in Section 4 and the conclusion will be given in Section 5.

1. Characteristics of IHI data

Fig. 1 shows the sketch map of the interference hyperspectral spectrometer. d is the shear amount of split light. f_{FTL} is the focal length of the Fourier lens. O is the point on the detector when the OPD (optical path difference) is zero. The OPD of point P on the detector is:

$$x = d\sin\theta = y\frac{d}{f_{FTL}} \tag{1}$$

According to the theory of Fourier transform, as the range of wavenumber $\Delta f = f_{\max} - f_{\min}$, the interference intensity I is:

$$I(x) = \int_{f_{\min}}^{f_{\max}} B(f)\cos(2\pi fx)df = \int_{f_{\min}}^{f_{\max}} B(f)\cos\left(2\pi fy\frac{d}{f_{FTL}}\right)df \tag{2}$$

$B(f)$ is the spectral intensity of incident light:

$$B(f) = \int_0^{\delta_m} I(x)\cos(2\pi fx)dx = \int_0^{\delta_m} I(x)\cos\left(2\pi fy\frac{d}{f_{FTL}}\right)dx \tag{3}$$

δ_m is the maximum OPD.

Fig. 2 shows the sketch map of three dimensional IHI data produced by LASIS [3,4].

The main characteristics of IHI data are as follows:

First, there are vertical interference stripes in each frame of IHI. Second, the background of IHI has horizontal shift between frames.

In order to get better result when the traditional compression algorithm are applied on the IHI, MCA algorithm is adopted to separate the interference stripes from the background in this paper.

2. Morphological component analysis

Suppose an image signal X contains M different signal layers X_i, $i = 1, 2, \ldots, M$. X is the sum of the M signal layers, i.e., $X = X_1 + X_2 + \ldots + X_M$. The basic thought of MCA [9] is that there is a group of orthogonal basis or dictionary can only sparsely represent the ith layer X_i but cannot sparsely represent other layers.

In this paper, MCA is used to separate the interference stripes from the background. X is one frame of the IHI data containing N pixels, which is composed of two parts, i.e., interference stripes layer X_I and background layer X_B:

$$X = X_I + X_B \tag{4}$$

In MCA algorithm, each layer signal can be sparsely represented by a group of orthogonal basis or dictionary as follows:

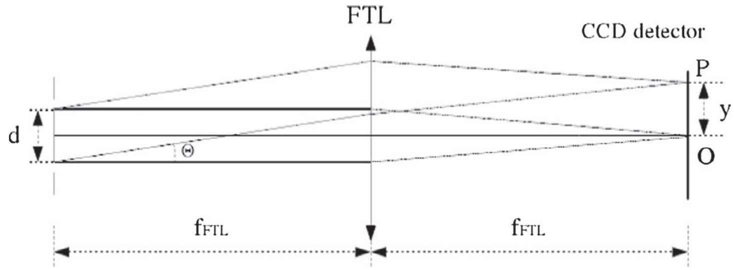

Fig. 1. The sketch map of the interference hyperspectral spectrometer.