Asian Journal of Chemistry; Vol. 26, No. 13 (2014), 4118-4120

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.17728

Data Compression and Threshold Condition in Two Dimensional Static Modulation of Fourier Transform†

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Published online: 23 June 2014; AJC-15423

The effect of the data compression ratio and threshold condition for the data processing was discussed in the two dimensional Fourier transform technology for static modulation. We investigated the optimized threshold leveling for the improvement of signal to noise ratio and the effective data compression for the fast transmission of collected information. Static modulation to get the interferogram was discussed instead of dynamic modulation in the conventional Fourier transform spectrometers. The data compression and inverse Fourier transformed data were also discussed for fast data processing and transfer.

Keywords: Fourier transform, Data compression, Threshold condition.

INTRODUCTION

Fourier transform spectrometry has been studied for remote sensing earth atmosphere from space[1-3]. Though the theory of Fourier transform spectroscopy is a technology long ago, many researchers have developed the instrumental technology for more precise and faster investigation about many kinds of materials that difficult to access[4-6]. Compared with their dispersive counterparts, there are many advantages of Fourier transform spectrometers. For the same resolving power and similar instrument size, Fourier transform spectrometers can offer more than several ten times higher energy gathering capability. Today it is used in common as an atmospheric sounder for monitoring air pollution and clouds movements[7,8].

Some spaceborne Fourier transform spectrometers have already gone into geostationary orbit and provided many operations of monitoring chemical species covered on continents and oceans[9]. However, there has been a strong request for the simpler instrument, because the instruments had been more complicated for longer wavelength coverage and for much more data to be processed. There has been a limitation of dynamic modulation in the conventional Fourier transform spectrometer. The conventional Fourier transform spectrometer using dynamic parts of optics to get the optical path difference is not proper to load on a low earth orbit satellite owing to the difficulty to allow even the least scanning time to get an interferogram and its loading on a geostationary satellite suffers from low resolution and fixed surveillance area. Therefore, the static modulation is the most important technology for loading on a low earth orbit satellite and working with higher resolution and accuracy for chemical information of the earth surrounding species.

The most important technology is the static modulation method. Though the fundamental concepts of modified Michelson interferometry and Fourier transform have been discussed by other groups[1], various methods to get the optical path difference by spatial structure characterization and algorisms of a remote sensing and static modulated Fourier transform spectrometer are still being studied[4-6]. The static modulated Fourier transform spectrometer has not a moving optic and can get the spectroscopic information at once without at the least scanning time. Three key technologies of static modulation are the stationary interferometer, the inverse Fourier transform algorism and the structural characteristics of optical system. The stationary interferometer is for the optical system to get the interferogram without a moving mirror. The inverse Fourier transform algorism is for remote sensing and the structural characteristics of optical system is for the system design and implementation.

In this study, the effect of threshold condition for the two dimensional Fourier transformed information was analyzed in terms of data compression rate because the static modulation method in Fourier transform spectrometer can allow single data collection unlike the dynamic modulation.

†Presented at 5th International Symposium on Application of Chemical and Analytical Technologies in Nuclear Industries (Nu-ACT 2013), Daejeon, Korea

EXPERIMENTAL

Static modulated Fourier transform spectrometer: Several research groups have proposed some types of static modulated Fourier transform spectrometers[1,3,6]. The essential concept of static modulation based on how optical path difference can be generated without any moving part in the interferometer. The Fourier transformed single beam spectrum can be obtained from the interferogram that generated by interferometer. The conventional Fourier transform spectrometer has a dynamic interferometer to get an interferogram, which has a moving mirror module to generate optical beam path difference. In common, it needs a few seconds to get an optical retardation. Upon Felgett advantage, the optical measurement over wide bands of wavelength in Fourier transform spectroscopy can be observed simultaneously and records it as the interferogram.

The static modulated Fourier transform spectrometer has a modified stationary interferometer, which has many sub-interferometers of different optical path lengths. The sampling frequency in the dynamic modulated interferometer modified to the two dimensional sub-interferometric distribution in the static modulated interferometer. The structure of the stationary interferometer composed of many small sub-interferometers of the different optical path lengths each other. The spacing of neighboring interferences is should be constant as much as the sampling rate of the conventional interferometer. The interferogram of the stationary interferometer is measured by detecting the interference signals arriving the detector array without the scanning optical elements. Therefore, the least number of interference signals is important to get the optimal interferogram from the stationary interferometer.

RESULTS AND DISCUSSION

Threshold condition for the two dimensional Fourier transform: Fourier transform provides the mathematical base for processing the signals without any loss of information. It has been used for the infrared spectrometry, the communication system, the image transformation such as aerial image, synthetic aperture radar (SAR), X-ray inspection image, magnetic resonance image (MRI). Fourier transform is a tool for improvement of the signal to noise ratio with optical filter to cut off the side lobe wavelength.

Data processing time depends on the data size of the image or the two-dimensional signal information. The optimal threshold condition with the least influence to the original information reduces the data size and therefore the processing time. The data compression ratio can be decided by the followings,

$$\frac{M\times N}{(M\times N)-(M'\times N')}$$

where, M × N is the matrix of the original information and M' × N' is the matrix of the compressed data after threshold application.

Fig. 1 is the variation of a 960 × 720 pixels image with the application of threshold condition. (a) is for the original image, (c) is for the 0.02 % and (e) is the 0.08 % threshold condition applied image. (b), (d) and (f) are the Fourier transform of the original, 0.02 % threshold and 0.08 % threshold

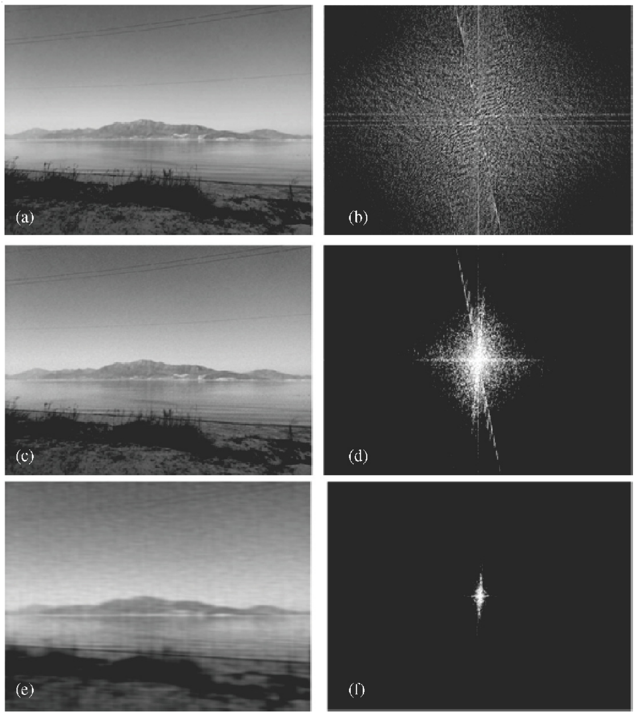
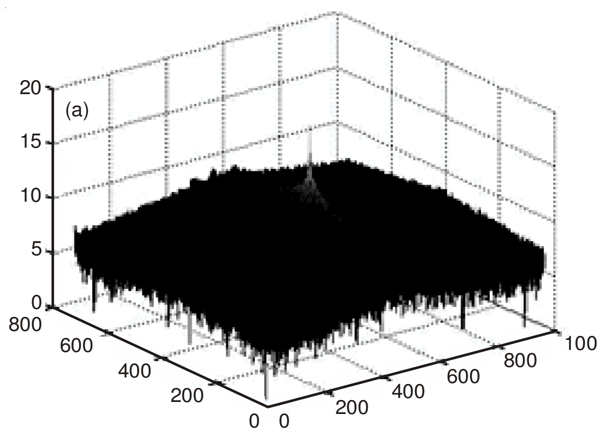


Fig. 1. Variation of the image quality, Fourier transformed information with the data compression ratio. (a) and (b) are for the original image, (c) and (d) are for 0.02 % threshold condition and (e) and (f) are for 0.08 % threshold condition application

condition application, respectively. The center denotes the low frequency and the outside edge is for high frequency region. The data compression rate was 20.1 and 304.4, respectively. Though the Fourier transformed images of (b) and (d) showed a big difference, it is not easy to find an identifiable distinction compared to that of the original image. However, (c) and (e) showed a remarkable blurring compared to the original image of (a). It seemed that the 0.02 % threshold application was the optimal data compression in that case. Compared (b) with (d) and (f), many grey points of (b) changed into blacks in (d) and (f), which means that the low valued points treated as zero under the threshold level application.

Fig. 2 is the Fourier transforms of (a) the original, (b) 0.02 % and (c) 0.08 % threshold condition applied contour descriptions. These three dimensional illustrations are for Fig. 1(a-c), respectively and shows how the threshold condition eliminates the unnecessary data points in two-dimensional data processing.



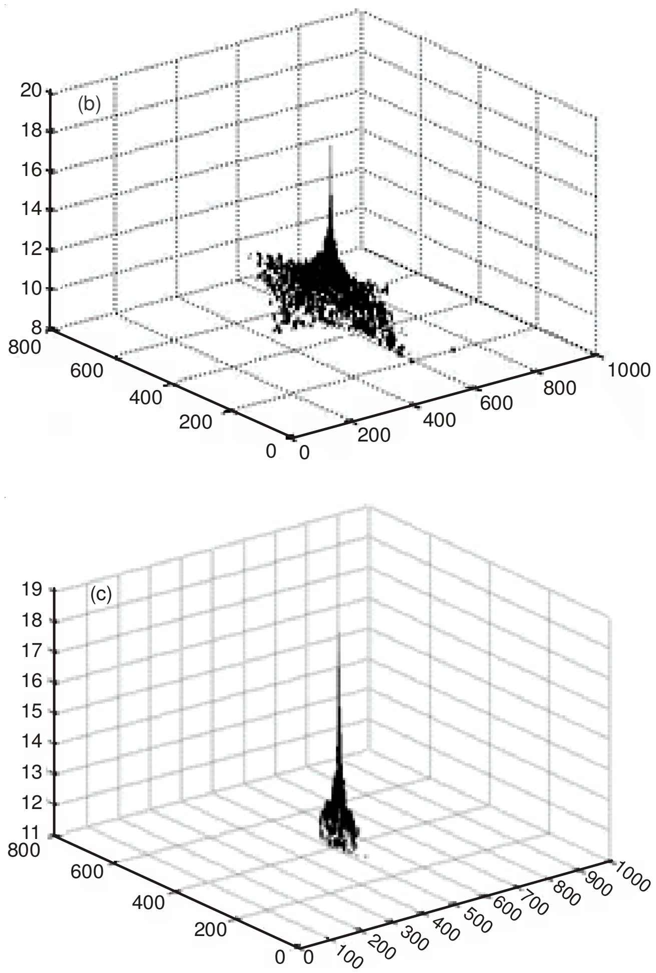


Fig. 2. Contour descriptions of the Fourier transform of (a) the original, (b) 0.02 % and (c) 0.08 % threshold condition applied images

Fig. 3 showed the variation of the data points to be processed in terms of the threshold condition application. In the two-dimensional data processing as in the static modulation of Fourier transform spectrometer, the number of data points decreases exponentially with increasing threshold level.

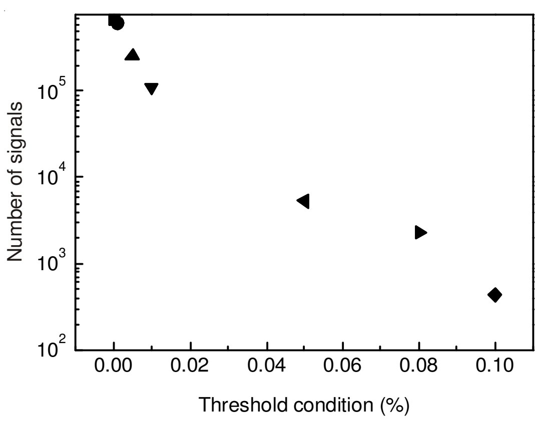


Fig. 3. Number of data points to be processed with threshold condition application

The interferogram acquired from the stationary interferometer has a two-dimensional signal. Fig. 4 showed the 39 × 39 two-dimensional signal distribution. The white points are strong intensity and the blacks are for zero or very low intensity.

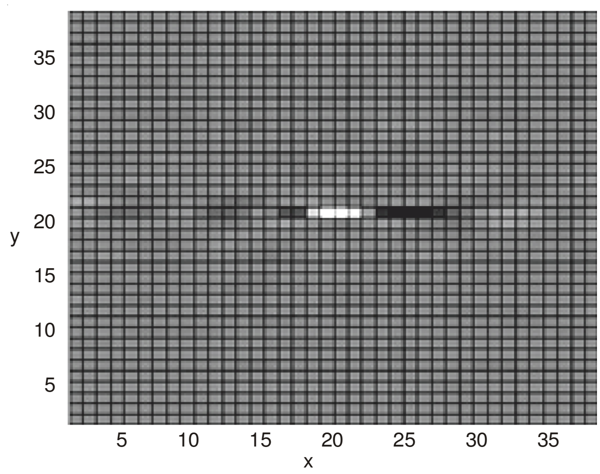


Fig. 4. Interferogram distributed in 39 × 39 two-dimensional detector array

Data compression ratio was discussed in terms of threshold condition in Fourier transform data processing. Data compression is important in the static modulation of a Fourier transform spectrometer, because the number of data signals is limited in the stationary interferometer structure. The application of the optimal threshold condition to the acquired two-dimensional information also improves the signal to noise ratio through the elimination of low background noise. The concept of the stationary interferometer is based on the distributed two-dimensional interferogram with the same number of sampled signals as that of the conventional one-dimensional interferogram. However, the spatial distribution of interferogram on the two-dimensional detector array still has many problems such as diffraction, stability of every component of the common path interferometer, the variation of the responsivity of the detector elements with temperature and resolution. Nonetheless, the static modulated Fourier transform spectrometer has many advantages including the spaceborne possibility.

ACKNOWLEDGEMENTS

This research was supported by Space Technology Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2013M1A3A3A02042369).

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