Chapter

Compression of High-Resolution Satellite Images Using Optical Image Processing

Anirban Patra, Arijit Saha, Debasish Chakraborty and Kallol Bhattacharya

Abstract

This chapter presents a novel method for compressing satellite imagery using phase grating to facilitate the optimization of storage space and bandwidth in satellite communication. In this research work, each Satellite image is first modulated with high grating frequency in a fixed orientation. Due to this modulation, three spots (spectrum) have been generated. From these three spots, by applying Inverse Fourier Transform in any one band, we can recover the image. Out of these three spots, one is center spectrum spot and other spots represent two sidebands. Care should be taken during the spot selection is to avoid aliasing effect. At the receiving end, to recover image we use only one spectrum. We have proved that size of the extracted image is less than the original image. In this way, compression of satellite image has been performed. To measure quality of the output images, PSNR value has been calculated and compared this value with previous techniques. As high-resolution satellite image contains a lot of information, therefore to get detail information from extracted image, compression ratio should be as minimum as possible.

Keywords: image compression, grating, Fourier transform, image retrieval, LISS- III sensor

1. Introduction

Compression of images is an important application in the field of satellite image processing as it is suitable for optimization of storage space and sharing over internet with optimum bandwidth utilization. For compression of satellite images, it is performed either directly from the image or from transformed part of the images. As discussed in [1] the compression of satellite images is based on Block Truncation Coding (BTC) technique. It first converts RGB satellite image into HSV planes. After that, each of the H and S planes are encoded using block truncation coding with quad clustering and V plane is encoded with BTC based bi-clustering or tri clustering depending on the edge information present in the plane. This method is better than previous BTC methods compared to visual quality of the output image. [2] discussed the image compression method based on evidence theory and k-Nearest Neighbor (KNN) algorithm. The main drawback is that the information loss is large [2]. To improve the quality of the output image, Fourier Transform and Huffman Coding is used for modification the previous technique. In both method, visual quality of satellite image is poor. [3] discusses the use of integer wavelet regression by increasing temporal correlation, which consequently improves the compression gain. [4] discusses a satellite image compression technique using discrete wavelet transform for noise removal to compress satellite images. [5] has discussed the use only hardware-based solutions in this lossless compression technique of X Sat images. [6] has analyzed the use of Discrete Wavelet Transform in their lossy image compression work and performance of different wavelets for satellite image compression. [7] has used the conventional Discrete Cosine Transform system for lossless image compression. [8] proposes an image compression technique using multiplexing and encryption by optical grating method [9–12].

In this chapter, we proposed a scheme to compress multiple high-resolution satellite images by using phase grating. Each image is modulated by applying high value of spatial frequency and a fixed orientation angles. For each image, multiple bands have been generated due to modulation which are placed in the same spectrum plane (only three bands are clearly visible). The spectrum is encoded and filtered using Gauss filtering. To detect the location of maximum image information, an intensity graph has been plotted in the decrypted plane. All stored images can be securely and efficiently retrieved by applying inverse Regional Fourier Transform operation. This proposed technique is simple and suitable for optimization of storage space and bandwidth in satellite communication.

The chapter is organized as follows:

- Section I describes the location and data used in this chapter
- Section II discusses the proposed compression method
- Section III presents proposed methodology of our research work
- Section IV provides result of our research work and PSNR value of the extracted images
- Section V concludes the paper and discuss why low compression ratio is desired for land cover analysis.

2. Description of location and data used

Images which are used in our research work, collected from Regional Remote Sensing Centre (East). The images are satellite picture of different areas in Kolkata Metropolitan Area.

All satellite images used in this paper are captured by LISS III 23 m sensor. LISS- III sensor is an optical sensor working in four spectral bands (Green, Red, Near Infrared and Short-Wave Infrared). It covers a 141 km- wide swath with a resolution of 23 meters in all spectral bands [13, 14].

3. Proposed methodology

3.1 Frequency and orientation angle selection for phase grating

According to rule of phase grating, value of the grating frequency ($u0$) should be high. Low grating frequency is creating aliasing problem and therefore it would be very difficult to reconstruct the original image. In this chapter, we propose to select

$u0$ = 1400, which is sufficient for filtering. In grating, value of the orientation angle (θ) varies from 0 to 360^0. We have worked with 0 deg orientation angle.

The diffraction gratings used are illustrated in **Figures 1** and **2**.

3.2 Mathematical expression

Let us assume that image, denoted by $f_1(x,y)$, is modulated by two sinusoidal phase gratings along the reference abscissa and of the form $\exp\left[i\left(\frac{m}{2}\right)\sin 2\pi u_1 x\right]$ where u_1 is the spatial frequency and m is the phase contrast. In such a case, the first modulated object may be expressed as:

$$s_1(x,y) = f_1(x,y)\exp\left[i\left(\frac{m}{2}\right)\sin 2\pi u_1 x\right] \quad (1)$$

Invoking the well-known convolution theorem, the Fourier transform of this modulated object is given by,

$$S_1(u,v) = [F_1(u,v) \circledast \left[\sum_{q=-\alpha}^{q=+\alpha} J_q\left(\frac{m}{2}\right)\delta(u - qu_1, v)\right] = \left[\sum_{q=-\alpha}^{q=+\alpha} J_q\left(\frac{m}{2}\right)F_1(u - qu_1, v)\right] \quad (2)$$

where J_q is the qth order Bessel Function of the 1st kind. The diffraction order is represented by the parameter ‘q’.

The diffraction pattern, as given by Eq. (2) is a series of diffraction spots each containing the object spectrum. Considering the zero order and the first two orders of the spectrum, Eq. (2) may be represented by,

$$S_1(u,v) = \left[J_0\left(\frac{m}{2}\right)F_1(u,v) + J_{-1}\left(\frac{m}{2}\right)F_1(u+u_1,v) + J_{+1}\left(\frac{m}{2}\right)F_1(u-u_1,v)\right] \quad (3)$$

3.3 Retrieval of images from spectral band

The reconstruction of images is achieved by decrypting the encrypted plane followed by plotting an intensity graph of the spectrum horizontally. This intensity graph is generated using the intensity values with respect to its location (pixel position). In the intensity graph, peak values indicate the brightest spots, where information of images are maximum. To avoid any human intervention, system automatically finds the intensity level horizontally, vertically and diagonally. In addition, regional Inverse Fourier Transform is applied around the peaks by using a

Figure 1.
Sinusoidal phase grating along x axis.

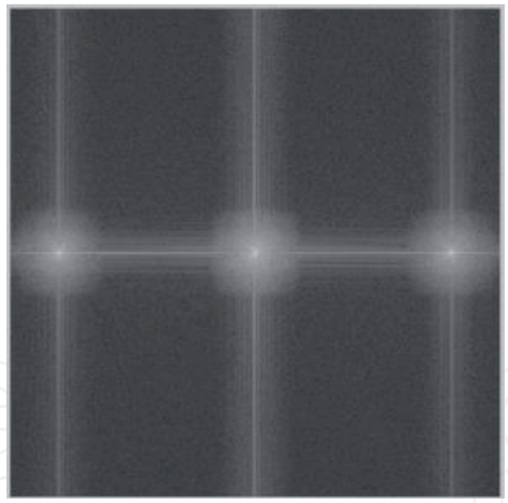

Figure 2.
Spectrum of an image due to modulation.

fixed cut-off frequency. As only one sideband is enough for image reconstruction, hence we select one side-band. This spectrum is filtering using a cut-off value of 120. Proper operating frequency is selected and there is no overlapping during the band selection, so the extracted images are free from aliasing problem. As center band contains the information of all images, therefore filtering is not applied across center band.

3.4 Quality checking of filtered image

PSNR value is calculated using Mean Square Error (MSE) approach:

$$PSNR = \frac{1}{mn}\sum_{y=1}^{m}\sum_{x=1}^{n}\left[f(x,y)-b(x,y)\right]^2 \qquad (4)$$

Where $f(x,y)$ and $b(x,y)$ are original image and retrieved image respectively and m, n denotes size of images.

4. Results and discussions

Satellite Images chosen for testing the algorithm described in Section III are shown in **Figure 3(a)-(c)**. The dimensions of the selected images are 512 x 512.

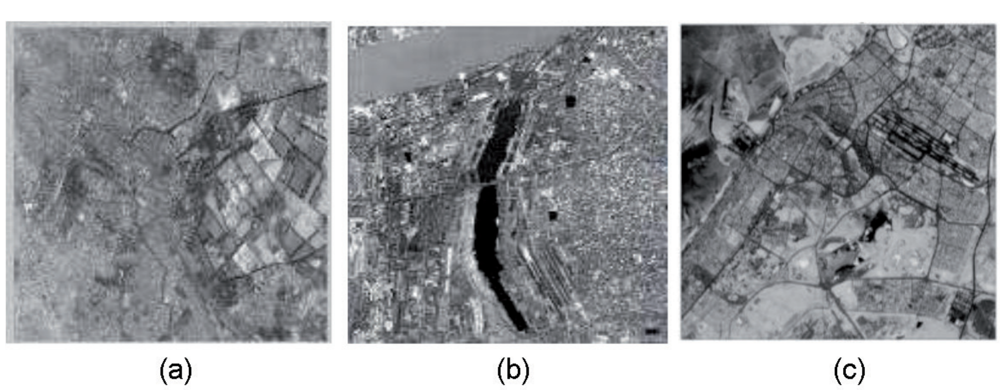

Figure 3.
Three high Resolution Satellite Images.

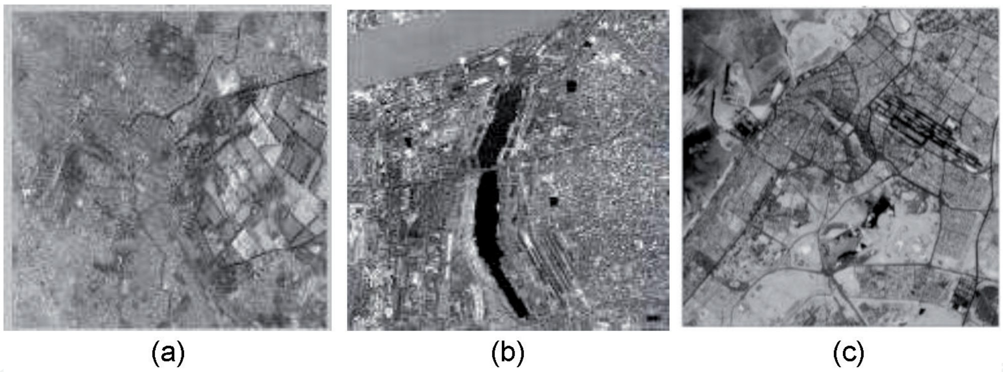

Figure 4.
Three extracted images.

Image	Original image size (kB)	Compression ratio (compressed image/original image)	PSNR
$f_1(x, y)$	242	0.84	32.5
$f_2(x, y)$	240	0.81	31.73
$f_3\ (x, y)$	254	0.86	31.6

Table 1.
Summary of PSNR calculation.

During zonal filtering operation, images $f_1(x, y)$, $f_2(x, y)$ and $f_3\ (x, y)$ have been extracted by Regional Inverse Fourier Transform taking upper spectrum from horizontal direction. Extracted images are shown in **Figure 4(a)-(c)**, respectively. A summary of the PSNR calculation is presented in **Table 1**.

5. Conclusion

In this chapter, phase grating technique has been proposed for compressing the high- resolution satellite images in frequency domain. The original image is retrieved by applying Inverse Fourier Transform from the respective spectrum of the image. As presented here, since we have taken only few coefficients from the spectrum, the size of the output image is less than the main original image. It should be mentioned that in high resolution satellite image, compression should be as minimum as possible. The main reason for the requirement of low compression ratio is mainly due to large geographical area representation (as these images contain a lot of information). High compression ratio is not suitable for accurate land cover analysis. To maintain the same dimension with original image and to avoid aliasing effect, spectral area is carefully selected. Compared with earlier methods, visual quality of the selected satellite images is very good as it is captured by optical LISS-III sensor. Our proposed technique is simple and suitable for optimization of storage space and bandwidth in satellite communication.

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