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Compression of Satellite Images using Sinusoidal Amplitude Grating

Anirban Patra[1]*, Debasish Chakraborty[2], Arijit Saha[3], Kallol Bhattacharya[4]
[1]Assistant Professor; Dept. of ECE, JIS College of Engineering, Kalyani, West Bengal;
[2]Sr. Scientist; RRSC- East, ISRO, Kolkata, West Bengal
[3]Associate Professor; Dept. of ECE, BPPIMT, Kolkata, West Bengal
[4]Professor; Dept. of Applied Optics, University of Calcutta, Kolkata, West Bengal

Abstract: 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. This study presentsa novel method for compressing satellite imagery using sinusoidalamplitude grating. The Satellite image is first modulated with high frequency amplitude grating in a fixed orientation. Therefore, the satellite image is converted into optical frequency domain. Due to this modulation, three spots (spectrum bands) 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. However, to a get a reasonably good output, we have to selectspotcarefully to avoid aliasing effect. All the information of the selected image is basically distributed among three spots of the spectrum. Therefore by selecting any one spot from the spectrum, we can retrieve the main image. As we have taken only few coefficients from spectrum, size of the output image is less than the main image. In this way, we have used this technique for image compression. To measure quality of the output images, PSNR value hasbeen calculated and compared this value with PSNR values of previous techniques.

Keywords: Image Compression, Grating, Fourier Transform, Image Retrieval, LISS- III Sensor.

I. Introduction

Different techniqueshave been used for compression of satellite images either directly from the image or from transformed part of the images. Balakrishnanet. al. [2018] compressed the satellite images based on block truncation coding. It first convertRGB 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.[1]Sahnoun and Benabadji[2014] used of image compression method based on evidence theory and k-Nearest Neighbor (KNN) algorithm. However main drawback of this lossy system was that information loss was too much[2] To improve the quality of the output image , Fourier Transform and Huffman Coding was used for modification the previous technique . In both method, visual quality of theoriginal satellite image was poor.[3]Mamun and Hossain [2017] used integer wavelet regression by increasing temporal correlation, which consequently improves the compression gain. [4]Sahnoun and Benabadji[2015] discussed a satellite image compression technique using discrete wavelet transform for noise removal to compress satellite images. [5] Susilo*et al*[2003] have used only hardware based solutions in this lossless compression technique of X Sat images. [6] Memane and Ruikar [2014] used Discrete Wavelet Transform in their lossy image compression work and performance of different wavelets for satellite image compression have been analyzed.[7] Hacihaliloglu and Kartal[2003] have used conventional Discrete Cosine Transform system for lossless image compression. [8]

In our proposed method, selected satellite image is first modulated by sinusoidal amplitude grating with high spatial frequency having fixed orientation along x-axis, i.e, $\theta = 0°$.Due to modulation along x- axis, three bright spots are generated horizontally on the spectrum plane at different spatial positions. The two extreme spots are actually due to the two side bands produced. From the spectrum plane, filtering any one spot from the spectrum, the original imageis extracted by regional inverse Fourier transform. We have selected the upper side band for filtering purpose.

Though various techniques were used earlier, but the visual quality of their selected satellite images were not satisfactory. Whereas in our method, we have used good quality satellite images captured by LISS-III sensor. The methodology has been discussed in section 3, follwoed by results in section 4 and conclusion has been drawn in section 5.

2. Study area (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 23m 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. [9,10]

3. Methodology

3.1 Frequencyand Orientation Angle selection for grating :
According to rule of sinusoidal amplitude grating, value of the grating frequency (u_0) should be high. Low grating frequency is creates aliasing problem and therefore it would be very difficult to reconstruct the original image. In our research paper we have selected $u_0 = 1200$ which is sufficient for filtering. In grating, value of the orientation angle (θ) varies from 0 to 360^0 . We have worked with 0 orientation angle.
The diffraction gratings used are illustrated in Fig.1

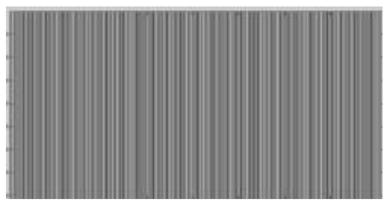

Fig. 1. Grating with orientation $\theta = 0°$

3.2Spectrum Band Generation :
$f_1(x,y)$is the original image and u_0 is the spatial frequency for sinusoidal amplitude gratings. The image $f_1(x,y)$is modulated by the sinusoidal grating $G_1(x)$with orientation $\theta = 0°$; where $G_1(x) = \frac{1}{2}\ (1 + cos2\pi u_0 x)$
After modulation, we have

$$f_1(x,y).G_1(x) = \frac{1}{2} f_1(x,y)(1 + cos2\pi u_0 x) \quad (1)$$

After convolution, we have

$$S(x,y) = f_1(x,y).G_1\,(x) \quad (2)$$

We can write

$$S(x,y) = \frac{1}{2} f_1(x,y).(1 + cos2\pi u_0 x) \quad (3)$$

If the Fourier transform of $S(x,y)$ is$S(u,v)$, then

$$S(u,v) = \ \frac{1}{2}[F_1(u,v)] + \ \frac{1}{4}[F_1(u - u_0,v)] + \ \frac{1}{4}[F_1(u + u_0,v)] \quad (4)$$

Three spectrum bands are generated due to modulation. Mathematically they are represented as $[F_1(u,v)]$, $[F_1(u -$ $u0,vand\ F1u+u0,v$

Out of three terms in the above expression, first term contributes to the central bright patch of the Fourier plane, which is shown in each picture of Fig2(a-c).

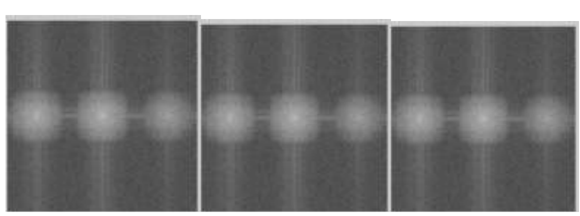

Fig 2(a) Fig 2(b) Fig 2(c)

Fig 2 : Spectrum of Images due to Grating

3.3.Filtering from Spectral Band

As we have maintained a high frequency for optical grating, therefore there are enough gaps between bands i.e. no aliasing effect is there. This is helpful for zonal filtering of image. For filtering purpose, anyone band from two sidebands can be selected. In this paper, we have selected upper sideband for filtering purpose. Inverse Fourier Transform is applied to upper spectrum band (whose Fourier Transform is represented by $[F_1(u+u_0,v)]$.

3.4. Quality checking of filtered image

To check quality of the output images, we have calculated PSNR value of the filtered images.
PSNR value is calculated by

$$MSE = \frac{1}{mn}\sum_{y=1}^{m}\sum_{x=1}^{n}[f(x,y) - g(x,y)]^2 \quad (5)$$

where MSE = Mean Square Error ;$g(x,y)$= Extracted image ; m , n denotes dimension of images

$$PSNR = 20log10\frac{255}{\sqrt{MSE}} \quad (6)$$

Same methodology is applied to other satellite images $f_2(x,y)$ *and* $f_3(x,y)$respectively.

4. Results and Discussions:

Satellite Images which are chosen isshown in Fig 3 (a-c).Dimension of our selected images are 512 x 512.

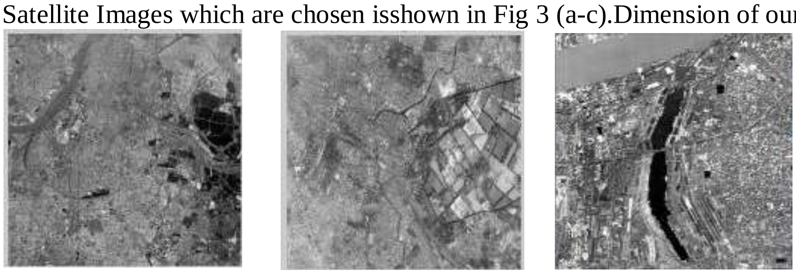

Fig 3(a) Fig 3(b) Fig 3(c)

Fig.3 (a-c) Selected Satellite Images

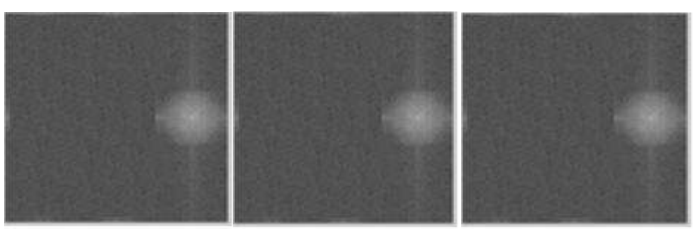

Fig 4(a) Fig 4(b) Fig 4(c)

Fig.4 (a-c) Upper Spectrum of Transformed Images

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 imagesare shown in *Fig 5(a-c)*

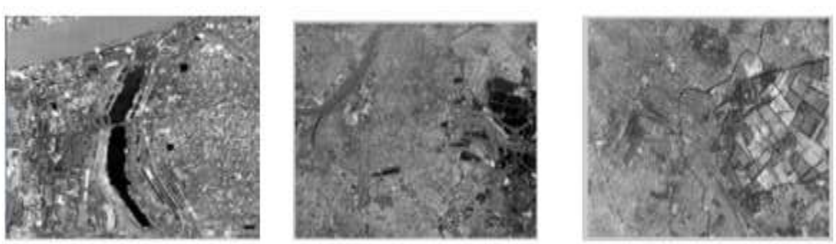

Fig 5(a) Fig 5(b) Fig 5(c)

Fig.5 (a –c) Extracted Satellite Images

Table 1

Image	Original ImageSize (kB)	Compression Ratio(Compressed Image/ Original Image)	PSNR
$f_1(x,y)$	236	0.89	33.4
$f_2(x,y)$	242	0.9	32.8
$f_3(x,y)$	240	0.89	32.5

Table 2

Method	PSNR
DCT and Wavelet Based Image Compression In Satellite Images [Reference 8]	26.23 29.44

Conclusion

Sinusoidal gratinghas been proposed in this study to compress the satellite image in frequency domain. The original object is retrieved by Inverse Fourier Transform from the respective spectrum of the image. As we have taken only few coefficients from the spectrum, size of the output image is less than the main image. 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 theselected satellite images is very good as it is captured by optical LISS-III sensor.Our proposed technique is simple and it showed that the visual quality of the extracted image is better than some previous methods. Moreover this technique has potential multiplex more images by varying the spatial frequency which will be discussed in future communication.

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