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Quality-based Spatial/Spectral Image Transformation

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***Abstract*— Remote sensing image plays a very important role for GIS services as one of its important data source. It's very large volume requirement may lead to latency during data transmission. Several alternative solutions are identified as the solution for the issue. This paper is intended to discuss the effect of image compression technique to allow the reduction of the storage and bandwidth requirement at the same time maintaining the quality of the compressed image. An experiment has been performed towards several multispectral images to foresee the effectiveness of the proposed method. The ongoing study shows promising result especially in terms of storage and image quality.**

Keywords- Image processing, Image coding, Image quality.

I. INTRODUCTION

A. Background Study

Compression, as the name implies, deals with techniques for reducing or removing redundancy in the image data [6]. With the large amount of size that the remote sensing image contains, a certain compression is required to remove unnecessary data. This report discusses lossy compression, which is the suitable technique to solve the underlying problem. Lossy compression allowed degradations in the reconstructed image in exchange for a reduced bit rate as compared to lossless compression [13]. Hyperspectral/Multispectral image data consists of a large number of two dimensional images with each different image corresponding to the radiation received by the sensor at a particular wavelength. These images are often referred to as band images or simply bands since they correspond to reflected energy in a particular frequency band [14]. Such image data may be represented as follows:

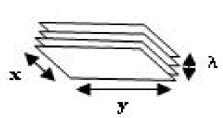

Figure 1 Hyperspectral/Multispectral Image Data

Figure 1 above shows the properties of a multispectral/hyperspectral image, which comprise of its spatial entities (x and y) and spectral entities (λ or its frequency band).

A hybrid approach is proposed for image compression process. The ongoing research puts emphasize on enhancing the GIS service, by reducing the required storage and bandwidth for its transmission. It also gave a fundamental insight on the object of the transformation, and how the transformation would affect the properties of the image data.

B. Rational

Internet GIS is a very promising area to be explored for the use of GIS services at different time and places. There are various possibilities with the usage of internet as the medium for interaction. Remote sensing images can be used to store, analyze and predicts climate change, land usage, urban development, vegetation growth, etc which may help us to enhance the environment's circumstances. Unfortunately, these large data are known to cause bottlenecks or network congestion during transmission [20]. This is considered to be a serious problem and as stated by [4] [5] [19], remote sensing image influence the low performance of data transmission.

Compressing the image on the server side or within the GIS network is considered to be the ideal solution, where the images can be compressed to their smallest usable size; therefore the volume of data transmitted across the network is reduced [10]. The purpose of compressing an image is to reduce the bandwidth required and storage requirement, which in turn increase the usefulness of GIS services. During compression process, certain amount of image redundancy is reduced due to the transformation of the image matrix. Visual distortion in exchange for a fewer bandwidth and storage might considered tolerable to the human eyes [18]. Nevertheless, a certain error metric has been used to determine the image quality and possible usefulness of the reconstructed data in analysis, such as detection and classification.

II. COMPRESSION METHOD

There are two major approaches of compression towards multispectral image. One is a 3D extension of existing 2D compression, where the multispectral image is treated as an image cube as a whole [3]. The ongoing research gives a special attention into spatial/spectral compression.

Noted for its relative simplicity and low memory requirements JPEG lossy compression mode applies the DCT (Discrete Cosine Transform) to independent 8 × 8 blocks of image samples. This allows transformation of the image matrix, used to compress an image [8].

Remote sensing images consists of spatial and spectral element, from which each element has to be treated differently since spectral element contains more valuable information than the spatial element [3]. Hence one must carefully transform/compress the image to avoid any unnecessary loss of significant information. An existing method is identified to adapt the JPEG's DCT approach and applied it in spatial/spectral transformation [15]. Proposed method as described below offers more advantages.

A. *Proposed Method*

Multispectral image happens to have different spatial-frequency in its respective spectral components, where an infrared band may have lower spatial resolution than other visible band of the same multispectral image [7], also spectral correlation of a multispectral cube provides more crucial information than the spatial information [3]. Compression is in essence removing unnecessary information contained within the pixel(s) of an image.

To achieve sufficient storage/bandwidth requirement while attempting to preserve its image quality, lossy spatial/spectral compression considered to be very useful in terms of reducing multispectral image size [3]. Although produces lesser quality images lossy compression considered acceptable if applied with a pre-defined quality preference as the limitation for compression process.

The authors would like to propose a hybrid method in quality-driven spatial/spectral transformation DCT/PCA. DCT as the spatial transform, while PCA (Principal Component Analysis) capable for image compression while preserving significant information [17] is chosen for spectral transform.

Both methods will be discussed thoroughly in the following sections.

B. *Spatial Transform*

Spatial transform is used to reduce the spatial redundancy present inside the image, with the transformation performed towards the vertical (rows) and horizontal (columns) element of the spatial domain. Rabbani and Jones stated that, spatial redundancy is due to the correlation (or dependence) between neighboring pixel values [13]. A widely used 2D DCT (Discrete Cosine Transform) [1] [18] is applied on both selected method as stated in the following.

$$Xk1,k2=\sum_{n1=0}^{N1-1}\sum_{n2=0}^{N2-1} x_{n1,n2}\cos\left[\frac{\pi}{N1}\left(n1+\frac{1}{2}\right)k1\right]\cos\left[\frac{\pi}{N2}\left(n1+\frac{1}{2}\right)k2\right] \quad (1)$$

The 2D DCT is applied to the image file, with 1D DCT towards its rows and another 1D DCT to its columns; hence the 2D DCT is separable in the two dimensions [1], which is illustrated below.

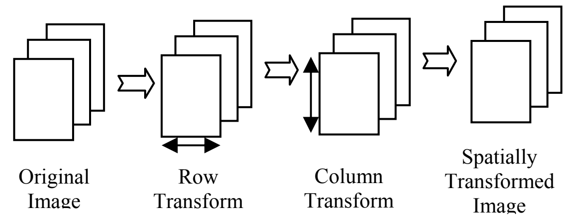

Figure 2 Spatial Transformation Process

C. *Spectral Transform*

Spectral compression or transformation, transform the spectral domain of the image to reduce image size. However, spectral information offers very significant information. Therefore, a certain approach is needed.

Spectral transformation using DCT has proven to be a useful tool in compressing the spectral element of an image [15]. DCT uses the DC coefficients to reduce the redundancy due to correlation between pixels, which is obtained from the 8x8 pixel block transformation [9]. The DCT coefficients, or the $X_{k1,k2}$ defined in (1) here decide the final image by numbers of coefficients are selected according to the percentage of image quality preferred.

PCA, is known as one the several methods that is able to minimize the information loss while compressing the data, hence reduction in storage requirement while slightly losing significant information, may be obtained by using this method [11]. PCA uses its principal components derive from its transformation, either by correlation or covariance of the pixels properties/spectral properties. The covariance for PCA, which is used in this paper, is shown below.

$$\mathrm{cov}(X,Y)=\sum_{i=1}^{n}\frac{(Xi-\overline{X})(Yi-\overline{Y})}{N} \quad (2)$$

The PCA in this report also implemented the user defined percentage of quality preferences of the final reconstructed image. Eigenvalues yields the principal components (PC) significance percentage of the image; within its eigenvector, or $\lambda(X,Y)$ as shown below.

$$\mathrm{cov}(X,Y)=\lambda(X,Y) \quad (3)$$

The idea is to achieve a reconstructed image with less PC's as possible. A program written in Matlab implements this scenario to process several multispectral LANDSAT image courtesy of space imaging LLC.

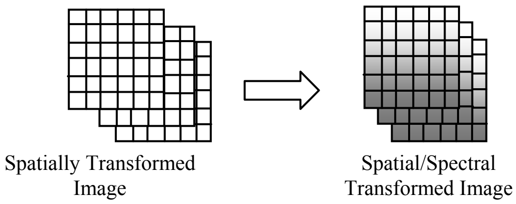

Figure 3 Spectral Transformation

III. RESULT AND ANALYSIS

A series of quality factor-based test has been performed on the selected methods, DCT/DCT and DCT/PCA. Both methods have been widely used and shown credible capabilities towards compressing image data [18] [12] [17].

To verify the performance of the selected compression methods more than one metric evaluation should be used [2]. Selected metric evaluations are MSE (Mean Square Error) and PSNR (Peak Signal-to-Noise-Ratio). As stated by [16] JPEG PSNR quality factor of 0-80 is 30 dB and below.

	Image	DCT MSE	DCT PSNR	Size (Kb)	DCT/DCT Space Savings (%)
90 % Quality	Paris	18.04	36.09	101	15.8
	Rio	7.91	40	83	13.5
	Tokyo	2.73	43.99	68	21
	Little Coriver	25.85	34.3	108	9.3
80 % Quality	Paris	21.89	35.24	99	17.5
	Rio	11.59	38.4	83	13.5
	Tokyo	3.23	43.27	67	22.1
	Little Coriver	34.3	33.05	108	9.3
70 % Quality	Paris	25.03	34.61	98	18.3
	Rio	14.45	37.41	82	14.6
	Tokyo	3.69	42.7	66	23.3
	Little Coriver	41.2	32.2	107	10.1

Table 1 DCT/DCT – Spatial/Spectral Compression Results

	Image	PCA MSE	PCA PSNR	Size (Kb)	DCT/PCA Space Savings (%)
90 % Quality	Paris	18.21	36.1	93	22.5
	Rio	22.15	36.33	60	37.5
	Tokyo	2.53	44.34	65	24.4
	Little Coriver	21.97	34.94	93	21.8
80 % Quality	Paris	22.04	35.27	83	30.9
	Rio	25.89	35.36	47	51
	Tokyo	3.02	43.58	59	31.4
	Little Coriver	29.15	33.72	81	31.9
70 % Quality	Paris	24.85	34.68	75	37.5
	Rio	28.48	34.64	22	77.1
	Tokyo	3.51	42.93	53	38.4
	Little Coriver	33.15	33.08	77	35.3

Table 2 DCT/PCA – Spatial/Spectral Compression Results

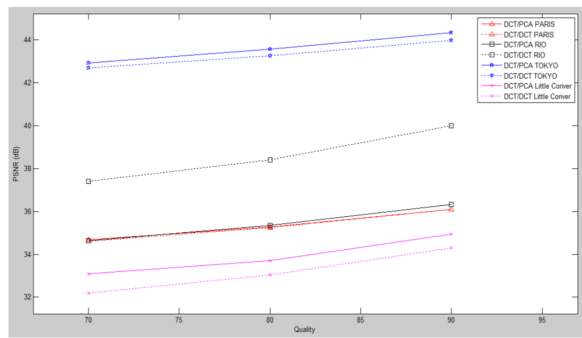

Figure 4 PSNR vs Quality Factor

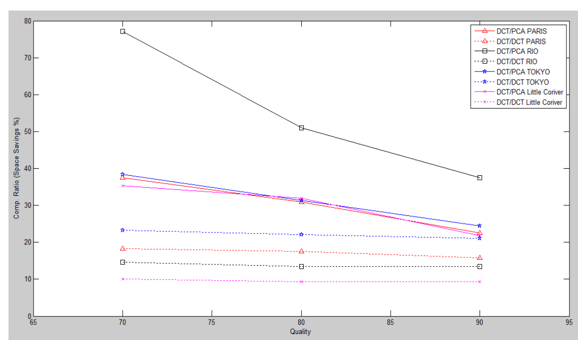

Figure 5 Compression Ratio vs Quality Factor

In Figure 4, the PSNR result shows the majority of DCT/PCA reconstructed image exceeds DCT/DCT. Hybrid DCT/PCA in Figure 5 also shows better results in compression ratio than DCT/DCT in compression ratio based on the percentage of quality preferred.

Additionally, both methods are performing quite well on their respective PSNR performance, in comparison to JPEG PSNR. Therefore, higher quality preference produces bigger storage and bandwidth requirements while lower quality produces lesser storage and bandwidth requirements. The results are deemed accommodating in understanding the need of quality consideration in multispectral image compression.

IV. CONCLUDING REMARKS

Spatial/spectral transformation is considered very suitable in reducing the storage and/or bandwidth requirement for multispectral image. In this research there are two method namely, the DCT/DCT and hybrid DCT/PCA compression

The result leads to a conclusion that, hybrid method DCT/PCA is considered to have a better performance to compress multispectral image than its competitor the DCT/DCT compression. DCT/PCA obtains better PSNR results on the majority of the test images, while outperforming DCT/DCT on the compression ratio percentage on all images.

This report shows the spatial/spectral transformation capability of compressing multispectral image with promising results; however, spatial compression cost the accuracy of spatial domain data. Further research on image processing is intended to identify which method is recommended in multispectral image compression for certain applications.

V. FUTURE WORK

Future work of this project is intended to combine several other image compression methods. With the main purpose is still to take account of the quality preferences of the reconstructed image.

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