Investigating the Effect of Bit Depth Rescaling on Spectral Bands Cross-Correlation in Hyperspectral DataCube

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***Abstract*— Hyperspectral data analysis nowadays is one of the most common activities in the scientific community regarding data fusion and processing; most available free data through NASA websites are very helpful for researchers and postgraduate studies; Data has different formats band interleaved by pixel (BIP), Band sequential (BSQ) and Band-Interleaved-by-Line (BIL); also, it differs in bit depth from 12 to 16; as well as processed or raw format, headers included or without header; many researchers have to reformat the data for further use with either standard software like Environment for Visualizing Images software (ENVI), or custom developed software. This paper investigates the effect of rescaling pixel bit depth of hyperspectral data, on the spectral correlation between successive bands of the datacube. On the other hand, all other reformatting processes like band reordering and headers removal will not affect the spirit of the hyperspectral cube itself.**

Keyword - Hyperspectral Datacube; Spectral correlation; Bit depth; Spectral Analysis.

I. INTRODUCTION

Hyperspectral images typically have a high degree of spectral and spatial correlation. Consequently, data compression can significantly reduce hyperspectral data volumes to more manageable size for storage and communication.

Compressing hyperspectral data cube with Component Of The Shelf (COTS) coders has became an interesting area of research. A standard video coder has been used to compress hyperspectral data in many researches. A video is a sequence of still images, a hybrid video coder use the correlation in time by doing block based motion compensated prediction between images. In principle only the differences are transmitted. This method of coding is used on hyperspectral data if we consider one of the three dimensions as the time axis [1].

Hyperspectral data is distinguished by its unique spatial-temporal and spectral correlation for data in three dimensions, manipulating the data may affect one of its exclusive properties.

Investigating the spectral correlation between hyperspectral bands showed that, on one sample, there is a strong spectral correlation between different bands that are up to $40 - 50$ bands away [2].

Bit depth is the number of bits used to represent a pixel; dynamic range is closely related with bit depth which gives more accurate representation of the point being imaged.

For most free available hyperspectral data samples from airborne or space-borne, large bit depth is used (10-16 bit per pixel); on the other hand, many researchers have carried out their research using COTS program for the hyperspectral data; while COTS software available more likely to operate in 8 bits per pixel.

This paper begins with an introduction about the need of bit depth rescaling in hyperspectral data compression using video codec in the first section; while in the second section, bit depth rescaling is defined and explained; section three discusses the cross-correlation and equation to estimate it; fourth section shows how the experiment was carried out and data samples parameters; finally, results are shown and discussed.

II. BIT DEPTH RESCALING

Bit depth is one of the main attributes of any image. The more bits assigned to each pixel, the more possible intensities states the pixel can take. Conventional bit-depth scaling methods such as spatial 2D filtering and dithering algorithms [4] suffer from false contours or dithered pattern artifacts, which significantly deteriorate image quality in display devices.

Based on linear bit depth rescaling [5]; this experiment has been carried out, converting the bit depth from 12-16 bit/ pixel to 8bit/pixel.

Linear rescaling sets a minimum and maximum input value to 0 and 255 respectively and all other values in between are linearly aligned to intermediate output values.

In digital grayscale images one has a finite number of different intensities available, usually between 256 and 4096 levels, depending on the application. The number of uncompressed bits per pixel is the bit depth of the image.

Bit depth 8 allows 256 intensity levels; bit depth 12 allows 4096 intensity levels.

Downscaling of bit depth are investigated by researcher in order to enhance the process of rescaling and minimize the losses [6]; rescaling process makes each pixel intensity down scaled to another value while this should not affect visual sense of the human eye; in the field of hyperspectral imaging rescaling may affect the spectral correlation between

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successive bands negatively, which may consequently result in different behavior when using a compression algorithm depend on inter-band correlation.

III. SPECTRAL CROSS-CORRELATION

A correlation is a number between -1 and +1 that measures the degree of similarity between two variables in our case it is bands or images. A positive value for the correlation implies a positive association (large values of X tend to be associated with large values of Y and small values of X tend to be associated with small values of Y). A negative value for the correlation implies a negative or inverse association (large values of X tend to be associated with small values of Y and vice versa).

Cross-correlation is used usually to describe the relation between two probably similar signals, hyperspectral datacube is distinguished with the significant highly correlated bands; since the same image is taken in different spectral bands; there is a high probability of having many regions within the image that reflects the light with the same intensity.

Measuring the inter band similarity with Cross-correlation using "(1)" indicated how these bands can be predicted, or generated from each other, this concept is used in hyperspectral data compression.

Cross-correlation is estimated using the following formula:

$$cor_{i,j} = cov(x_i,x_j)/\sqrt{(var(x_i)*var(x_j))} \quad (1)$$

where $cor_{i,j}$ is the correlation value between bands i and j; $cov(x_i,x_j)$ is the covariance between bands i and j; $var(x_i)$ and $var(x_j)$ is the variance of the individual bands, i and j, respectively.

The normalization and mean values of the correlation between bands are implemented according to Fast Normalized Cross-Correlation [7].

The proposed algorithm assumes a template of one image then represents the template as sum of rectangular basis function, the correlation is then implemented to each basis function instead of the whole template, and the result is weighted sum of the correlation function of the basic functions.

IV. IMPLEMENTATION

The implementation was carried out by using ENVI [9] for rescaling of hyperspectral data down to 8-bits per pixel; bands Cross-correlation has been estimated using MATLAB [8] program, to generate Cross-correlation curves for both the original data and the downscaled data.

In Figures 1, 2, 3, 4, 5, 6 and 7, x-axis is the bands number starting from 0 till 224, while Y-axis is the Cross-correlation values with maximum of 1 represents identical highly correlated successive bands, while zero indicates no correlation between the two successive bands.

Cross-correlation between bands is estimated for the original data cube; the hyperspectral datacube is then linearly rescaled and the inter-band Cross-correlation is estimated for the new datacube with the same way and same order.

Hyperspectral data used is downloaded from Airborne Visible Infrared Imaging Spectrometer (AVIRIS) website [10]; the hyperspectral data cube has the following characteristics:

The files are in raw format (no header). All data samples are stored as: 2-byte integers, big-endian byte order, band-interleaved-pixel (BIP).

Each file is a 512-line with 224 bands.

- "hawaii_sc01.raw" is 512 lines x 614 samples x 224 bands, instrument bit depth = 12 bits
- "maine_sc10.raw" is 512 lines x 680 samples x 224 bands, instrument bit depth = 12 bits
- "Aviris_sc0" is 512 lines x 680 samples x 224 bands, instrument bit depth = 16 bits.
- "Aviris_sc3" is 512 lines x 680 samples x 224 bands, instrument bit depth = 16 bits.
- "Aviris_sc10" is 512 lines x 680 samples x 224 bands, instrument bit depth = 16 bits.
- "Aviris_sc18" is 512 lines x 680 samples x 224 bands, instrument bit depth = 16 bits.
- "f960705t01" is 512 lines x 680 samples x 224 bands, instrument bit depth = 16 bits.

In all the figures, solid RED line represents the inter-band correlation in the original data; while dotted Blue line is the downscaled data.

V. RESULTS

Seven files downloaded from the AVIRIS website, each figure below indicates the name of each file; in Figures 1, 2, 3 and 4, it can be seen that the highly correlated bands have lost their correlation after the downscaling process.

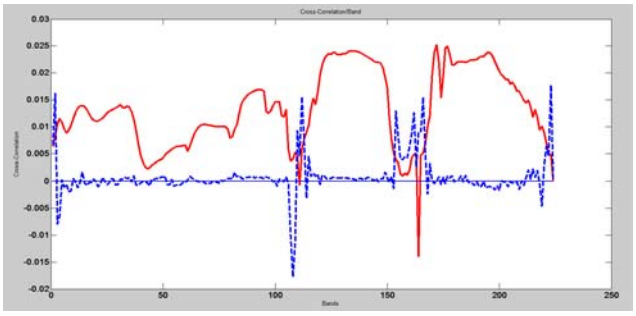

Figure 1, "Aviris_sc0".

In Figure 1, Inter band Cross-correlation has been lost after the process of bit depth rescaling.

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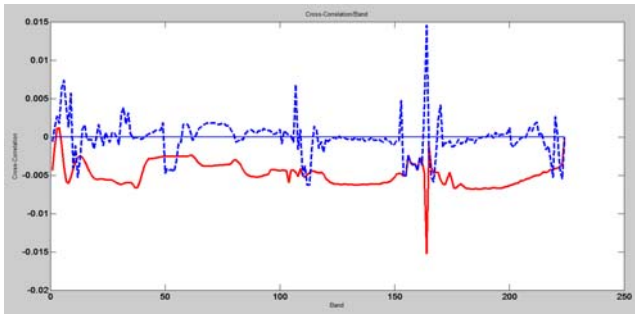

Figure 2, "aviris_sc3".

In Figure 2, Inter band Cross-correlation has been lost after the process of bit depth rescaling.

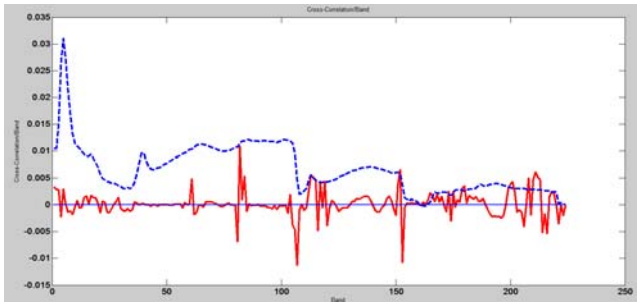

Figure 3, "f960705t01".

In Figure 3, Inter band Cross-correlation has been lost after the process of bit depth rescaling.

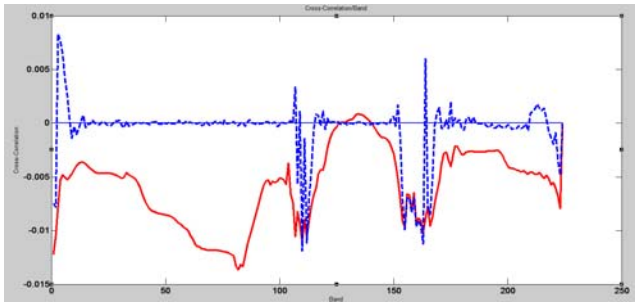

Figure 4, aviris_sc18.

In Figure 4, Inter band Cross-correlation has been lost after the process of bit depth rescaling.

On the other hand, in Figures 5, 6 and 7, bands kept their property in different -uncontinuous- manner.

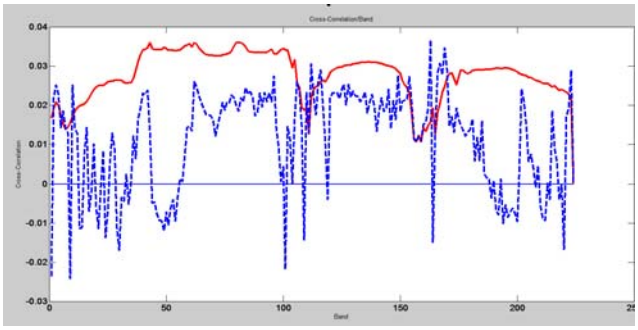

Figure 5, "aviris_sc10".

In Figure 5, Inter band Cross-correlation has been preserved after the process of bit depth rescaling, but in a difference discrete manner.

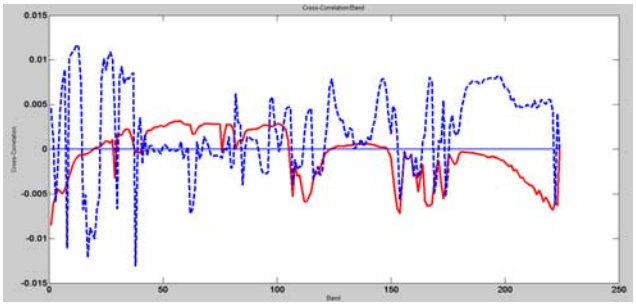

Figure 6, hawaii.

In Figure 6, Inter band Cross-correlation has been preserved after the process of bit depth rescaling, but in a difference discrete manner.

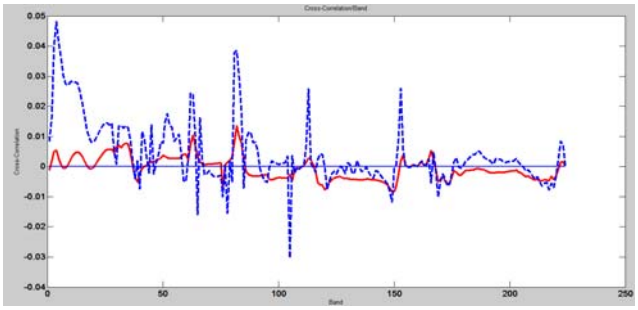

Figure 7, maine_sc10.

In Figure 7, inter band Cross-correlation has been preserved after the process of bit depth rescaling, but in a difference discrete manner.

Losing about 50% of pixel`s value, even in with a linear relative manner, have shown that, this is not a linear process;

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and correlation cannot be kept even if the ratio between values across bands is preserved.

Losing Cross-correlation is significantly observed in the results, which gives a conclusion about the similarity behavior between bands.

A significant point can be noted in almost all curves; that the downscaling process reverses the correlation behavior between bands.

CONCLUSION

The process of bit depth rescaling for hyperspectral data cube takes a significant time of processing, as well as estimating the Cross-correlation between successive bands in the datacube.

Processing one datacube takes about 420-460 second using Matlab 2010 running in Intel core2 due Quad (3 GHz) processor.

Surprisingly, inter-bands Cross-correlation has been lost in the downscaling process; From the graphs, it can be concluded that the process of bit depth rescaling for the hyperspectral datacube significantly affects the cross-correlation between hyperspectral data bands, in most cases the Cross-correlation is missed during the process of linear rescaling.

It is not recommended to downscale the bit depth of hyperspectral data cube if further data fusion or spectral profile analysis is needed.

Many researches that used a COTS decoder [1] have to reconsider this issue and indicated whether this process can affect their results or not.

However; COTS codec should be modified -if it is an open source- to handle data with more intensity ranges, i.e., 10-12-16 bit per pixel.

One important issue explains why the using video codec that depend on successive bands similarities, usually gives a non satisfactory results in compressing hyperspectral data. Losing these similarities-correlation- between bands has a great influence on the performance of the Video codec.

Further studies can be carried out in different types of bit depth rescaling methods such as Gaussian and square root; which may have a significant improvement on inter band Cross-correlation.

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