EVALUATION OF JP3D FOR LOSSY AND LOSSLESS COMPRESSION OF HYPERSPECTRAL IMAGERY

Jing Zhang[*†], James E. Fowler[†‡], Nicolas H. Younan[†], and Guizhong Liu[*]
[*]School of Electronics and Information Engineering, Xi'an Jiaotong University, Xi'an, China
[†]Department of Electrical and Computer Engineering, Geosystems Research Institute,
Mississippi State University, USA
[‡]corresponding author, fowler@ece.msstate.edu

The JPEG2000 standard has been widely used for the compression of hyperspectral imagery for both lossy as well as lossless representation. Strictly speaking, as defined by Parts 1 and 2 of the standard [1, 2], JPEG2000 is a 2D image coder designed for the coding of 2D still images. That said, Part 2 provides indirect support for the coding of 3D volumetric imagery such as hyperspectral data in that 1D transforms can be applied across image components such that, when coupled with a 2D spatial wavelet transform, a 3D transform decomposition is effectuated. Additionally, post-compression rate-distortion (PCRD) optimization is applied across all codeblocks in all components to effectively allocate rate across the entire image volume. However, the fundamental embedded-block-coding process in Part-2 compliant coders takes place on 2D codeblocks defined within 2D image components, as was prescribed in the original 2D EBCOT coder [3].

In an effort to provide a true 3D implementation of JPEG2000 for volumetric imagery, Part 10 of the JPEG2000 standard [4–6] has been recently established. Part 10, or "JP3D" as it is commonly known, is, in essence, a straightforward extension of Parts 1 and 2 to realize coding for volumetric data—JP3D provides the same functionality for 3D datasets as Parts 1 and 2 do for 2D data. That is, in addition to permitting true 3D dyadic wavelet transforms, JP3D coding is based on embedded block coding using 3D codeblocks.

Thus far, the JP3D standard has been used for the compression of mainly 3D medical imagery (e.g., [7, 8]). However, given that hyperspectral imagery also takes a volumetric form, it is natural to consider JP3D for hyperspectral compression. The objective of the proposed paper is thus to evaluate JP3D for the compression of hyperspectral imagery. In the full paper, we will explore issues of 3D transforms and 3D codeblock coding as pertaining to JP3D for hyperspectral imagery and will investigate both lossy and lossless compression. For JP3D, we employ the widely-used transform structure of a 1D Karhunen-Loève transform (KLT) applied spectrally followed by 2D spatial discrete wavelet transform (DWT), with reversible, integer-valued transforms employed for lossless compression. For embedded block coding, we evaluate the 2D arithmetic-coding contexts from JPEG2000 Part 1 that are required to be used in JP3D; we also consider an experimental 3D context model that is included with the current JP3D Verification Model implementation but is outside of JP3D-standard compliance.

In the full paper, we will experimentally evaluate the performance of JP3D against the usual use of JPEG2000 for hyperspectral imagery, i.e., a Part-2 implementation with a spectral KLT (e.g., [9]) which we denote here as "JP2K P2." For JP3D, we consider both the standard 2D and experimental 3D context models (denoted "JP3D+2EB" and "JP3D+3EB," respectively). Preliminary results are shown for lossless and lossy coding in Figs. 1(a) and (b), respectively. These results reveal that, for the popular AVIRIS radiance images, JP3D provides lossless coding performance very similar to that of JPEG2000 Part 2, with the experimental 3D context models providing a very slight coding gain. However, for lossy compression, JP3D is unable to match the rate-distortion performance of JPEG2000 Part 2, either with or without the 3D context models.

Whereas JPEG2000 in its Part-1 and Part-2 incarnation is essentially a 2D image coder, JP3D is designed to provide true 3D coding. However, JP3D is clearly oriented toward data that is isotropic in all directions. That is, JP3D was created with medical imagery specifically in mind; however, 3D medical datasets are typically isotropic in that all directions represent spatial dimensions. Hyperspectral imagery, with one dimension being spectral, is fundamentally different—apparently, JP3D is less effective for such anisotropic datasets, at least in its current form. In may be possible that arithmetic-coding context models specifically designed for the anisotropic nature of hyperspectral imagery could improve JP3D performance on such data; however, to the best of our knowledge, no such context models currently exist. As a final note, we observe that,

This work was conducted while J. Zhang was visiting the Geosystems Research Institute at Mississippi State University as a joint Ph.D. candidate funded by China Scholarship Council under the State Scholarship Fund.

Bitrate (bpppb)			
Dataset	JP2K P2	JP3D+2EB	JP3D+3EB
Cuprite	4.92	4.89	4.96
Jasper Ridge	4.86	4.83	4.90
Lunar Lake	5.00	4.97	5.00
Moffett	4.96	4.93	5.00
Average	4.94	4.90	4.97

(a)

SNR (dB)			
Dataset	JP2K P2	JP3D+2EB	JP3D+3EB
Cuprite	54.13	53.31	53.28
Jasper Ridge	50.33	49.69	49.67
Lunar Lake	55.21	54.62	54.59
Moffett	50.92	50.42	50.38

(b)

Figure 1: (a) Lossless compression, (b) lossy compression. Performance at lossless compression is evaluated in the form of a bitrate in bits per pixel per band (bpppb) calculated as the size of the compressed file divided by the number of pixels. The performance of lossy compression is evaluated in the form of a signal to noise ratio (SNR) at a fixed bitrate of 1.0 bpppb.; we measure SNR as the log ratio of signal variance to mean squared error.

although the contributions of this paper are negative in the sense that lossy JP3D does not appear competitive with the usual JPEG2000 Part-2 implementation for hyperspectral imagery, this observation nonetheless represents a valuable contribution to the community given the prominence of the JPEG2000 standard.

1. REFERENCES

[1] *Information Technology—JPEG 2000 Image Coding System—Part 1: Core Coding System*, ISO/IEC 15444-1, 2000.

[2] *Information Technology—JPEG 2000 Image Coding System—Part 2: Extensions*, ISO/IEC 15444-2, 2004.

[3] D. Taubman, "High performance scalable image compression with EBCOT," *IEEE Transactions on Image Processing*, vol. 9, no. 7, pp. 1158–1170, July 2000.

[4] *Information Technology—JPEG 2000 Image Coding System—Part 10: Extensions for Three-Dimensional Data*, ISO/IEC 15444-10, 2004.

[5] P. Schelkens, A. Munteanu, A. Tzannes, and C. Brislawn, "JPEG2000 Part 10 – Volumetric data encoding," in *Proceedings of the IEEE International Symposium on Circuits and Systems*, Kos, Greece, May 2006, pp. 3874–3877.

[6] T. Bruylants, A. Munteanu, A. Alecu, R. Deklerck, and P. Schelkens, "Volumetric image compression with JPEG2000," SPIE Newsroom, June 2007.

[7] T. Bruylants, A. Alecu, T. Kimpe, R. Deklerck, A. Munteanu, and P. Schelkens, "An optimized 3D context model for JPEG2000 Part 10," in *Medical Imaging 2007: Image Processing*, J. P. W. Pluim and J. M. Reinhardt, Eds. San Diego, CA: Proc. SPIE 6512, February 2007, p. 65124K.

[8] T. Kimpe, T. Bruylants, Y. Sneyders, R. Deklerck, and P. Schelkens, "Compression of medical volumetric datasets: Physical and psychovisual performance comparison of the emerging JP3D standard and JPEG2000," in *Medical Imaging 2007: Image Processing*, J. P. W. Pluim and J. M. Reinhardt, Eds. San Diego, CA: Proc. SPIE 6512, February 2007, p. 65124L.

[9] Q. Du and J. E. Fowler, "Hyperspectral image compression using JPEG2000 and principal component analysis," *IEEE Geoscience and Remote Sensing Letters*, vol. 4, no. 2, pp. 201–205, April 2007.