Software

ICER-3D Hyperspectral Image Compression Software

Software has been developed to implement the ICER-3D algorithm. ICER-3D effects progressive, three-dimensional (3D), wavelet-based compression of hyperspectral images. If a compressed data stream is truncated, the progressive nature of the algorithm enables reconstruction of hyperspectral data at fidelity commensurate with the given data volume.

The ICER-3D software is capable of providing either lossless or lossy compression, and incorporates an error-containment scheme to limit the effects of data loss during transmission. The compression algorithm, which was derived from the ICER image compression algorithm, includes wavelet-transform, context-modeling, and entropy coding subalgorithms.

The 3D wavelet decomposition structure used by ICER-3D exploits correlations in all three dimensions of sets of hyperspectral image data, while facilitating elimination of spectral ringing artifacts, using a technique summarized in "Improving 3D Wavelet-Based Compression of Spectral Images" (NPO-41381), *NASA Tech Briefs*, Vol. 33, No. 3 (March 2009), page 7a.

Correlation is further exploited by a context-modeling subalgorithm, which exploits spectral dependencies in the wavelet-transformed hyperspectral data, using an algorithm that is summarized in "Context Modeler for Wavelet Compression of Hyperspectral Images" (NPO-43239), which follows this article.

An important feature of ICER-3D is a scheme for limiting the adverse effects of loss of data during transmission. In this scheme, as in the similar scheme used by ICER, the spatial-frequency domain is partitioned into rectangular error-containment regions. In ICER-3D, the partitions extend through all the wavelength bands. The data in each partition are compressed independently of those in the other partitions, so that loss or corruption of data from any partition does not affect the other partitions. Furthermore, because compression is progressive within each partition, when data are lost, any data from that partition received prior to the loss can be used to reconstruct that partition at lower fidelity.

By virtue of the compression improvement it achieves relative to previous means of onboard data compression, this software enables (1) increased return of hyperspectral scientific data in the presence of limits on the rates of transmission of data from spacecraft to Earth via radio communication links and/or (2) reduction in spacecraft radio-communication power and/or cost through reduction in the amounts of data required to be downlinked and stored onboard prior to downlink. The software is also suitable for compressing hyperspectral images for ground storage or archival purposes.

This program was written by Hua Xie, Aaron Kiely, Matthew Klimesh, and Nazeeh Aranki of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43238.

Context Modeler for Wavelet Compression of Spectral Hyperspectral Images

A context-modeling subalgorithm has been developed as part of an algorithm that effects three-dimensional (3D) wavelet-based compression of hyperspectral image data. The context-modeling subalgorithm, hereafter denoted the context modeler, provides estimates of probability distributions of wavelet-transformed data being encoded. These estimates are utilized by an entropy coding subalgorithm that is another major component of the compression algorithm. The estimates make it possible to compress the image data more effectively than would otherwise be possible.

The following background discussion is prerequisite to a meaningful summary of the context modeler. This discussion is presented relative to "ICER-3D," which is the name attached to a particular compression algorithm and the software that implements it. The ICER-3D software is summarized briefly in the preceding article, "ICER-3D Hyperspectral Image Compression Software" (NPO-43238). Some aspects of this algorithm were previously described, in a slightly more general con-

text than the ICER-3D software, in "Improving 3D Wavelet-Based Compression of Hyperspectral Images" (NPO-41381), *NASA Tech Briefs*, Vol. 33, No. 3 (March 2009), page 7a. In turn, ICER-3D is a product of generalization of ICER, another previously reported algorithm and computer program that can perform both lossless and lossy wavelet-based compression and decompression of gray-scale-image data.

In ICER-3D, hyperspectral image data are decomposed using a 3D discrete wavelet transform (DWT). Following wavelet decomposition, mean values are subtracted from spatial planes of spatially low-pass subbands prior to encoding. The resulting data are converted to sign-magnitude form and compressed. In ICER-3D, compression is progressive, in that compressed information is ordered so that as more of the compressed data stream is received, successive reconstructions of the hyperspectral image data are of successively higher overall fidelity.

Before encoding each bit, the probability that the bit is a zero is estimated. The probability-of-zero estimate relies only on previously encoded information. The bit and its probability-of-zero estimate are sent to the entropy coding subalgorithm (hereafter denoted the entropy encoder), which effects the desired compression of the sequence of bits that it receives. Better probability-of-zero estimates allow the entropy coder to achieve better data compression. It is the job of the context modeler to produce these probability-of-zero estimates. This concludes the background discussion.

In the context modeling subalgorithm, a bit of a DWT coefficient to be encoded is first classified into one of 19 contexts based on the values of previously encoded bits. Each context amounts to a class for which separate probability-of-zero statistics are gathered. ICER-3D employs a one-dimensional spectral-context model involving context definitions that rely on two neighbors in the spectral direction but no neighbors in the same spatial plane. For comparison, ICER uses a two-dimensional context model relying on eight spatial-frequency-domain neighbors.

During the encoding process, DWT coefficients are assigned to categories in preparation for assigning them to contexts. There are four categories, numbered 0 – 3. The category of a coefficient

is initially 0 and remains 0 so as long as the magnitude bits encoded for the coefficient are all zeros. After the first "1" bit from the coefficient is encoded, the category of the coefficient becomes 1. When the next magnitude bit of the coefficient is encoded, its category becomes 2. When one more magnitude bit from the coefficient is encoded, its category becomes 3 and remains 3 permanently. The context of a bit is determined from the category of the DWT coefficient that contains the bit and the category and signs of the two neighboring coefficients in the spectral dimension.

Compared to the 2D context model used by ICER, the ICER-3D context modeler provides noticeable improvement in compression of sign bits and bits in category 0, and slight improvement for the other categories of bits that are compressed.