Comparison of 3D Set Partitioning Methods in Hyperspectral Image Compression Featuring an Improved 3D-SPIHT†

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Hyperspectral images are generated by collecting hundreds of narrow and contiguously spaced spectral bands of data producing a highly correlated long sequence of images. In this study, we investigate and compare the performance of several three-dimensional embedded wavelet algorithms for compression of hyperspectral images. They are 3D-SPIHT, AT-3D-SPIHT, 3D-SPECK (Three-Dimensional Set Partitioned Embedded block), and JPEG2000. 3D-SPIHT is the three-dimensional extension of the state-of-the-art SPIHT (Set Partitioning In Hierarchical Trees) image compression algorithm. AT-SPIHT uses the same coding algorithm as 3D-SPIHT, but utilizes a more efficient, asymmetric tree structure. 3D-SPECK (Three-Dimensional Set Partitioned Embedded block) is a version of two-dimensional SPECK modified to encode 3D subband blocks. For an image sequence, the 3D-DWT is applied to obtain a wavelet coefficient prism. This prism is partitioned into small code blocks with different sizes, and each subband is treated as a code block. Next, a block splitting algorithm is used on the individual code blocks to test their significance. The block will be split into several smaller sub-blocks recursively according to the significance test.

Several AVIRIS (Airborne Visible InfraRed Imaging Spectrometer) image sequences were used as our test sets to evaluate the compression performance of AT-3D-SPIHT, 3D-SPIHT, 3D-SPECK, and JPEG2000. The rate distortion performances were compared by means of the Peak Signal-to-Noise Ratio (PSNR). AT-3D-SPIHT, 3D-SPIHT, and 3D-SPECK guarantee over 3 dB improvement over 2D SPIHT applied separately to each image at all rates for all sequences. This implies that the hyperspectral image sequences are highly correlated. 3D-SPIHT and 3D-SPECK have similar performances for all sequences. AT-3D-SPIHT outperforms 3D-SPIHT and 3D-SPECK by the approximate range of 0.2 to 0.9 dB PSNR. Since our application is hyperspectral imagery, the visual effect is very important. AT-3D-SPIHT provides high quality reconstructed images even at very low bit rate such as 0.4 bpp.

We also conducted experiments to compare to an enactment of JPEG2000 Part II for multi-component images. For a hyperspectral image sequence, the 3D-DWT transform is applied followed by JPEG2000 coding on separate frames, where different rates are assigned to different frames according to their subband occupancy in order to minimize the mean squared error for a given overall rate. Doing this can assess separately gains from 3D transform and 3D coding. Our results show that for all cases, AT-3D-SPIHT, 3D-SPIHT and 3D-SPECK outperform JPEG2000 by the approximate range of 1 to 2.5 dB PSNR, depending on the image sequence. In other words, the set partitioning algorithms that use 3D coding units are more efficient than JPEG2000, Part II coding for hyperspectral image compression.

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