Lossless Compression of Hyperspectral Imagery via Lookup Tables and Classified Linear Spectral Prediction

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A challenge of satellite hyperspectral imaging is data compression for dissemination to users and for transmission to ground station from the orbiting platform. Data compression basically consists of decorrelation of the correlated information source, followed by entropy coding of the outcome residues. To meet the quality issues of hyperspectral image analysis, differential pulse code modulation (DPCM) is usually employed for lossless/near-lossless compression, i.e., the decompressed data have a user-defined maximum absolute error, being zero in the lossless case. DPCM basically consists of a prediction followed by entropy coding of quantized differences between original and predicted values. A unit quantization step size allows reversible compression as a limit case.

In a recently published paper [1], Mielikainen introduced a very simple spectral prediction given by the value taken on the current band by the last pixel, previously encountered along the scan line, having the same value as the current pixel on the previous band. Such a prediction, which can be effectively implemented by means of a dynamically updated lookup table (LUT), outperforms most of state-of-the-art methods on a large test set of AVIRIS data, (16-bit radiance format).

The rationale of prediction based on lookup tables has been later extended by Huang and Sriraja in [2] by exploiting two LUTs on the previous band and choosing one among the two values, based on the similarity to a reference prediction, which takes into account of different gains across bands. This strategy yields significant coding benefits (3-4%) at a moderate extra cost.

In this paper, we present a generalization of [2], in which the set of LUTs, two or more, say M, on each band are allowed to span more than one previous band, say N bands, and the decision among one of the NM possible prediction values is based on the closeness of the value contained in the LUT to an advanced prediction, spanning N previous bands as well, provided by a top-performing scheme recently developed by the authors [3] and featuring a classified spectral prediction.

Experimental results carried out on the same AVIRIS dataset as in [1,2,3] show improvements of about 15% over [1], of 10% over [2] and of 13% over [3]. The computational complexity is about 10% higher than that of [3], but several times higher than that of [1] and [2]. However, most of computing time is due to the advanced reference prediction [3],which is responsible for about 5% of the bit rate decrement. The remaining decrement over [1] and [2] depends on the use of multiple LUTs on more than one previous band.

A thorough analysis of the characteristics of all LUT-based algorithms reveals that this strategy takes advantage uniquely of the sparseness of radiance histograms in each band. Actually, LUT-based prediction is equivalent to a dynamic remapping of radiance values, such that the remapped histograms have no holes [4] and spectral correlation, on which compression performances rely, is preserved. Preliminary results of compression of raw, i.e., uncalibrated, 12-bit data produced by an on-board instrument reveal that no advantage whatsoever is given by LUTs and that [3] yields the lowest bit rates on such data. Therefore, it seems that the LUT strategy, though simple and attractive, is not recommended for on-board lossless compression. Furthermore, the nature of LUT prediction make it unsuitable for near-lossless compression. It is expected that the advantages of LUTs vanish as the amount of error increases.

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[3] B. Aiazzi, L. Alparone, S. Baronti, C. Lastri, "Crisp and fuzzy adaptive spectral predictions for lossless and near-lossless compression of hyperspectral imagery", *IEEE Geosci. Remote Sensing Lett.,* Vol. 4, No. 4, pp. 532-536, Oct. 2007.

[4] A.J. Pinho " An online preprocessing technique for improving the lossless compression of images with sparse histograms ", *IEEE Signal Processing Lett.,* Vol. 9, No. 1, pp. 5-7, Jan. 2002.