OPTIMAL FILTER BANKS IN HYPERSPECTRAL IMAGE PROCESSING

Input

Analysis

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Motivation

Filter banks (FB's) are widely used in signal and image processing. Many pattern recognition and feature exploitation tasks on hyperspectral remote sensing images are robust with respect to lossy compression. Optimal filter banks can be applied prior to compression to decorrelate the input for more efficient encoding.

We present a background to optimality of filter banks and their application to feature extractions from hyperspectral images lossy compressed and reconstructed with JPEG-2000 Standard.

Optimality concepts

Optimality over a certain class of filter banks is in general understood in the sense of maximizing the *coding gain (CG)* defined as the ratio of the arithmetic and geomtric means of the output subband variances.

Another approach to optimality is in the Principal Component (PC) sense. A PCFB minimizes the reconstruction error when subbands with lower variances are dropped. A PCFB also maximizes the coding gain.

Necessary and Sufficient Conditions for Optimality

A filter bank is optimal in the coding gain sense if and only if the subband signals are uncorrelated random processes and the subband power spectral densities are majorized:

$$S_0(e^{i\omega}) \geq S_1(e^{i\omega}) \geq ... \geq S_{M-1}(e^{i\omega}), \forall \omega \in [0, 2\pi)$$

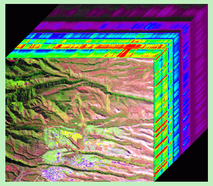
where M is the number of channels of the FB.

On Existence of PCFB's

PCFB's exist for the class of memoryless filters (transform coders) and these are the Karhunen-Loève transforms (KLT). For the class of Infinite Impulse Response (IIR) filter banks PCFB's also exist but they are ideal, that is unrealizable step functions.

For the Finite Impulse Response (FIR) class, a PCFB is not guaranteed to exist except in the case of two channel orthonormal filter banks.

Processing



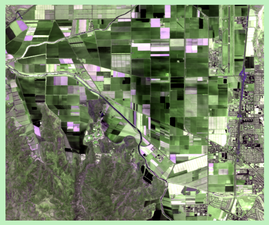
Los Alamos AVIRIS hyperspectral cube

Hyperspectral Imagery:

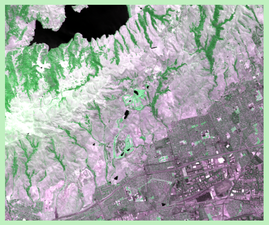
- AVIRIS (Airborne Visible InfraRed Imaging Spectrometer)
- Calibrated images of 224 spectral bands each of 614x512 pixels

Data Processing:

- Compression/reconstruction with JPEG-2000 Standard and various component decorrelations, including the PCFB (Karhunen-Loève Transform) and wavelet transforms.



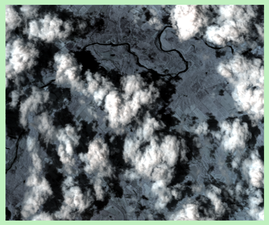
Camarillo scene



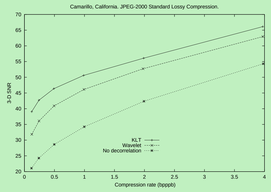
Moffet Field

- Classifications and Transforms
  - ∗ Supervised: Spectral Angle Mapper, Binary Encoding, Minimum Distance.
  - ∗ Unsupervised K-means clustering classification.
  - ∗ Hybrid classification with GENetic Imagery Exploitation (GENIE).
  - ∗ Normalized Difference Vegetation Index Transform (NDVI).

- Performance reported as percentage of correctly classified points or fitness rate.
- Fidelity of reconstructed images is reported as 3-D SNR computed over the whole hyperspectral image cube.

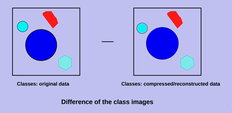


Cloud scene

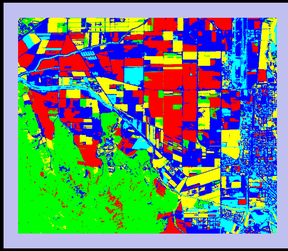


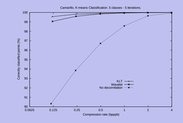
∗ Comparison of performance for JPEG-2000 on Camarillo scene.

Synthesis

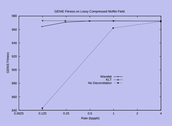


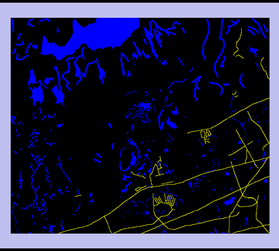
The measure of correctly classified pixels is the percentage of pixels whose class is the same from both original data and compressed/ reconstructed data.



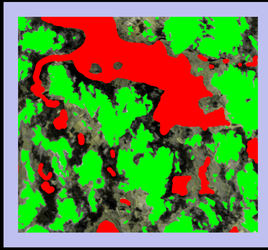


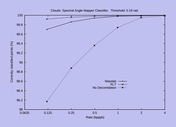
K-means thematic map and its qualitative results.





A GENIE fitness rate plot based on the training classes: yellow for roads and blue for non-roads.





Spectral Angle Mapper performance with the training classes: green for clouds and red for non-clouds.

Conclusions and Future Research

Component decorrelation significantly improves the classification of compressed/reconstructed data. To get 99.9% of the pixels classified correctly with KLT decorrelation a budget of 0.25 to 0.5 bpppb is sufficient.

All the classification tasks employed are robust with respect to lossy compression of the decorrelated source images.

Future work is aimed at expanding the theory and design techniques for FIR filter banks that maximize coding gain in applications involving decorrelation and encoding of hyperspectral images.

Output

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