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Annual Progress Report

Year I: 2006-07

Project Title: **Adaptive Algorithms for Optimal Classification and Compression of Hyperspectral Images**

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Brief Summary of Research Project

The goal of this project is to design and implement efficient algorithms for the real-time compression of hyperspectral images. The uniqueness of this project is that the compression algorithms will be recursively optimized as a function of the performance of classification (or unsupervised clustering) algorithms on the same data. Certain performance metrics will be defined for the classification schemes and some others for the compression algorithms. A combination of these metrics will be used to design a cost function, which in turn will be optimized to update the compression and restoration algorithms. In other words, the performance of the classification algorithms will dictate the real-time adaptation of the digital filters used in the compression schemes. In this new concept, the filters in the compression algorithms, instead of acting independently, form a coupled system with the classification (or clustering) algorithms. This coupled system will be applied to the spectral dimension in this project since compression along the spectral axis is much less researched and understood than compression in the spatial domain. If it works as expected we can also explore a combined spatio-spectral application. In that, using an iterative neural learning algorithm, called the Generalized Relevance Learning Vector Quantization, the classification and feature extraction are welded together with a 2-way feedback loop, and the classification cannot be separated and substituted by a different classifier. Furthermore, it has only been demonstrated to work for low-dimensional data, it shows instabilities for hyperspectral dimensions. In our proposed work, the classification algorithms can be replaced by others if so desired.

Research Progress in Year-I

The first year has been devoted to running numerous systematic evaluations of classification algorithms on compressed and decompressed images. This is a very important step because it will give the necessary insight and measures to develop the appropriate classification metrics and cost functions needed to design efficient compression algorithms. We started with supervised classification as the measure of good classifier performance, because it is simpler and more straightforward than unsupervised clustering. We have used a real hyperspectral image that has been extensively studied and for which much ground truth and trusted training samples exists. We used the best verified spectral samples from that image cube, for complete control, for this initial phase of the development of compression algorithms. Several other real data sets were also used, in addition. The completed tasks included the following. We indicate in parenthesis the location of the activity.

Task 1: (Rice) Created a well controlled spectral sample set from a real hyperspectral image; selected, organized specific data sets, and made available to PI at USU. Produced a benchmark classification for each uncompressed test image.

Task 2: (USU) Produced compressed and decompressed versions of the test images by ADPCM techniques and transform methods under a variety of compression ratios, adaptive quantizers, and adaptive predictive algorithms.

Task 3: (USU) Developed an algorithm that uses ADPCM, a supervised neural network, and a Genetic Algorithm (GA), in order to obtain optimal compression under some given classification metrics. The results are promising and yield efficient compression and classification. However, the computational complexity is quite high. Part of next year will be devoted to reduction of the computational complexity for real-time applications.

Accomplishments

The following publications have resulted from this project with NASA-AISRP credit.

Journal Papers

1. Tamal Bose, M.-Q. Chen, and R. Thamvichai, “Stability of the 2-D Givone-Roesser Model with Periodic Coefficients,” **IEEE Trans. Circuits and Systems**, **Part-I**, 2007 (accepted and in press).

2. M. Radenkovic and Tamal Bose, “A recursive blind adaptive identification algorithm and its almost sure convergence,” **IEEE Trans. Circuits and Systems**, **Part-I**, 2007 (accepted and in press).

Conference Papers

1. Z. Zhang, Tamal Bose, L. Xiao, and R. Thamvichai, “Performance Analysis of the Deficient Length EDS Adaptive Algorithm,” **Proc. of the IEEE Asia Pacific Conference on Circuits and Systems**, pp. 222-225, Dec. 2006.

2. M. Radenkovic and Tamal Bose, “Blind adaptive equalizer for IIR channels with common zeros,” **Proc. of the IEEE International Symposium on Circuits and Systems**, pp. 4195-4198, May 2006.

3. J. Gunther, W. Song, and Tamal Bose, “Stopping and restarting adaptive updates to recursive least-squares lattice adaptive filtering algorithms,” **Proc. of the IEEE Mountain Workshop on Adaptive and Learning Systems**, pp. 1-6, July 2006.

Research Plan for Year-II

Task 1: (Rice) Unsupervised clustering: First, benchmark clustering on uncompressed test images, then on compressed-decompressed images. It involves the evaluation of a number of cluster validity metrics. Again, the same real hyperspectral image will be used, first the best and cleanest spectral samples only, for complete control. This will be followed by using the entire image. Several cluster validity metrics will be selected for inclusion into the optimization schemes.

Task 2: (USU) Develop the mathematical algorithms for optimizing compression algorithms: (a) adaptive filters, (b) predictor models, (c) adaptive quantizers, and (d) transform coders. This effort will require constructing appropriate mathematical cost functions (from the insight gained in Year 1) and deriving several different optimizing approaches as described in the Proposed Methods section.

Task 3: (Rice) Supervised classification of compressed and decompressed images may be repeated as the need arises from Task 2. For example, we may find that the optimization approach could use more guidance from classifications performed at additional compression ratios.

Task 4: (USU) Implement Scheme 1 (see proposal) in conjunction with the developed algorithms in Task 2. The algorithms will have be modified and adjusted based on the results of Task 3. This task will most likely overflow into Year 3.