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Title: Advanced Algorithms for Information Science

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Los Alamos
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Advanced Algorithms for Information Science

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Abstract

This is the final report of a one-year, Laboratory Directed Research and Development (LDRD) project at Los Alamos National Laboratory (LANL). In a modern information-controlled society the importance of fast computational algorithms facilitating data compression and image analysis cannot be overemphasized. Feature extraction and pattern recognition are key to many LANL projects and the same types of dimensionality reduction and compression used in source coding are also applicable to image understanding. We have begun developing wavelet coding which decomposes data into different length-scale and frequency bands. New transform-based source-coding techniques offer potential for achieving better, combined source-channel coding performance by using joint-optimization techniques. We initiated work on a system that compresses the video stream in real time, and which also takes the additional step of analyzing the video stream concurrently. By using object-based compression schemes (where an object is an identifiable feature of the video signal, repeatable in time or space), we believe that the analysis is directly related to the efficiency of the compression.

Background and Research Objectives

Feature recognition has been a classic problem in the field of artificial intelligence. The problem of computers recognizing a person or their actions has not been adequately solved although considerable advance has been made. Some systems can recognize some people much of the time, but the error rate are too high to be implemented in systems that require high security.

Part of the Laboratory's mission is to secure the nation's -- and other nations' -- stockpile of plutonium. Although a 24-hour manned guard is possible, it is very expensive. Further, it does not ensure security at remote sites located in other countries, *e.g.*, Russia. Further, when the storage facility is at remote sites, the bandwidth required to transmit the video information via satellite is extremely large. New data compression techniques must be developed. It was the purpose of this work to investigate new

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developments in the field and to implement these into a portal system that has a sufficiently high success rate that it can be used to track and help secure our plutonium stores. The data compression algorithms will have wide application to other Laboratory programs, *e.g.*, satellite surveillance.

Importance to LANL's Science and Technology Base and National R&D Needs

The focus will be on enhancing our capabilities in those areas of advanced technologies (both the hardware and software) required for future high-priority Los Alamos information science and technology (IS&T) missions. Information science is used in all of the Laboratory's core competencies, and is central to *Theory, Modeling and High Performance Computing*. In a modern, information-controlled society the importance of fast computational algorithms facilitating data compression and image analysis cannot be overemphasized. Feature extraction and pattern recognition are key to many LANL projects, and the same types of dimensionality reduction and compression used in source coding are also applicable to image understanding. Success in this area will enhance the national security and help the Laboratory ensure the surety of the plutonium stockpile.

Scientific Approach and Accomplishments

The importance of fast computational algorithms facilitating data compression and image analysis cannot be overemphasized. For these algorithms to be useful they need to fulfill a variety of criteria. They need to yield high data-compression rates, and still need to be of low computational complexity to allow for a fast implementation. They should be robust with respect to data loss and error (possibly arising from noisy or faulty transmission). And with the increasing availability of multi-processor and parallel systems, they should allow for easy implementation on such systems. It was the purpose of this LDRD project to assess the Laboratory's capabilities and to begin the effort to enhance and exploit them.

We pursued two research areas in connection with video coding: joint source-channel coding and image understanding. Real communication systems involve both compression (source coding) and error correction (channel coding). New transform-based source-coding techniques appear to offer potential for achieving better combined source-channel coding performance in practice by using joint optimization techniques. Feature extraction and pattern recognition are key to many LANL projects, and the same types of dimensionality reduction and compression used in source coding are also applicable to image understanding. Wavelet coding decomposes data into different length-scale and frequency bands, an approach that is useful, e.g., for texture segmentation we also initiated on a system that not only compresses the video stream in real time, but which also takes the additional step of analyzing the video stream concurrently. By using object-based compression schemes (where an object is an identifiable feature of the video signal, repeatable in time or space), we believe that the analysis is directly related to the efficiency of the compression. We are aiming towards hardware implementations, and we are examining hardware systems.

Since we are aiming at high compression rates and possible data transmission implementations, we chose to investigate bi-orthogonal wavelets. For biorthogonal wavelets the transform into wavelet space (the analysis step) and the back transform (the synthesis step) can now use different length filters. By doing this, one shifts the computational load onto one end of the transmission, which for example may be advantageous for playing back compressed movies. Typically biorthogonal wavelets also lead to higher compression ratios. Examples of these transforms have been programmed and tested for speed.

As a further extension one can utilize the fast lifted wavelet transform (FLWT). Building on simple steps, splitting the data and then using the various parts for interpolating and extrapolating between one another, the FLWT can be used to add additional properties to the expansion. Currently, we have implemented the condition that the dual scaling functions have the same number of vanishing moments as the primal scaling functions, leading to higher compression rates. This allows for non-uniform grids and is aimed at easing implementation on multiprocessors and parallel systems.