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13. ABSTRACT (Maximum 200 words)

The PI visited NSWC Dahlgren, VA, for six weeks in May-June 2002 and collaborated with scientists in the G33 TEAMS facility, and with Marilyn Rudzinsky of T44 Technology and Photonic Systems Branch. During this visit the PI also presented six educational seminars to NSWC scientists on various aspects of signal processing.

Several items from the grant proposal were completed, including (1) wavelet-based algorithms for interpolation of 1-d signals and 2-d images; (2) Discrete Wavelet Transform domain based algorithms for filtering of image data; (3) wavelet-based smoothing of image sequence data originally obtained for the CRITTIR (Clutter Rejection Involving Temporal Techniques in the Infra-Red) project.

The P.I. visited the University of Stellenbosch, South Africa to collaborate with colleagues Prof. B.M. Herbst and Prof. J. du Preez on the use of wavelet image processing in conjunction with pattern recognition techniques. The University of Stellenbosch has offered the PI partial funding to support a sabbatical visit in Fall 2003, the primary purpose of which is to enable the PI to develop and enhance his expertise in Pattern Recognition.

During the first year, the grant supported publication of 3 refereed papers, presentation of 9 seminars and an intensive two-day course on wavelet theory. The grant supported the work of two students who functioned as research assistants.

14. SUBJECT TERMS
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I. Summary

This report covers the first year of the grant (December 1, 2001 to November 30, 2002).

The P.I. visited the Naval Surface Warfare Center in Dahlgren, VA, for six weeks in May-June to continue his established collaboration with NSWC personnel. For this visit, the P.I. worked with the members of the G33 TEAMS facility, and also collaborated with research scientist Marilyn Rudzinsky. The collaboration with NSWC personnel has been particularly productive, both in regard to the work on this project and also to work in other areas of interest to the Navy. A further benefit to NSWC is that the P.I. presented a series of six instructional seminars on various aspects of signal processing to NSWC scientists; full details are given below.

The P.I. spent five weeks during the summer months in South Africa, working at the University of Stellenbosch. His valuable collaborations with researchers at Stellenbosch were extended, and resulted in plans for the P.I. to spend a six to eight month period of sabbatical leave in Stellenbosch in late 1993 to improve his expertise in the area of Pattern Recognition.

During the first year of the project, the grant has supported the work of two students who performed software development and theoretical derivations. During this period, three refereed papers have been published.

II. List of Research Accomplishments:

The following work was completed during the past year (where appropriate, task numbers from the proposal are included in square brackets):

1. The P.I. visited the Naval Surface Warfare Center in Dahlgren, VA, for six weeks in May and June 2002 to continue his established collaboration with NSWC personnel.
2. MATLAB software was developed for interpolation of 1-dimensional signals and 2-dimensional images, via the inverse Discrete Wavelet Transform. [Task 1(i), 1(ii)].
3. MATLAB software was developed to implement lowpass, bandpass, and highpass filtering in the Discrete Wavelet Transform domain. [Task 3(i)].

4. In collaboration with Marilyn Rudzinsky (T44) at the Naval Surface Warfare Center, work is in progress on wavelet-based smoothing of image sequence data originally obtained for the CRITTIR (Clutter Rejection Involving Temporal Techniques in the Infra-Red) project. The data is obtained from a high-frame-rate, high resolution infrared camera, and consists of scenes in which there is considerable interference from the glitter of sunlight on the surface of water. Figure 1 shows a sample pixel from an image sequence, before and after application of wavelet-based smoothing. [Task 4(i)].
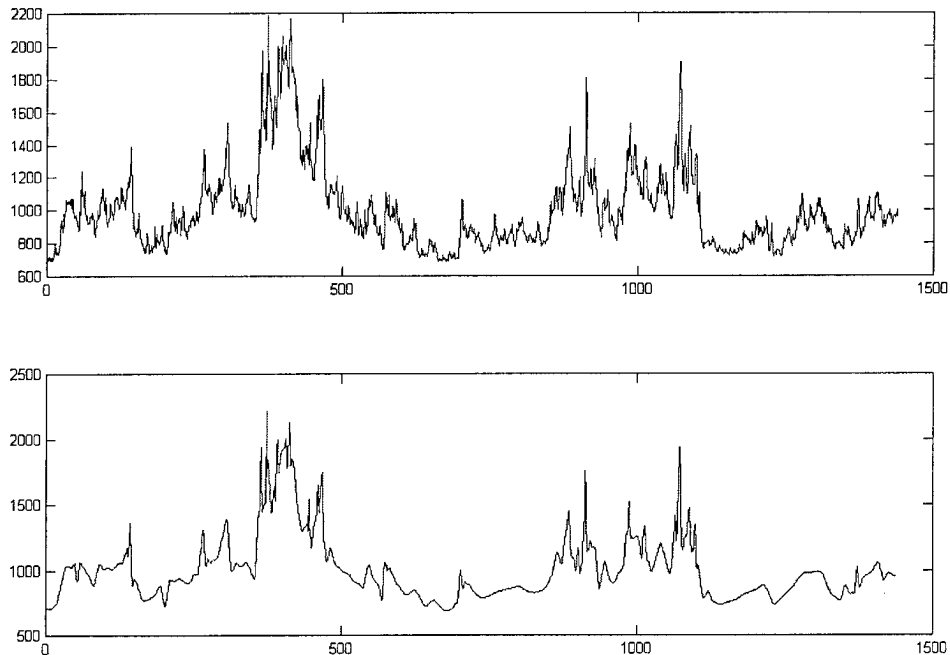

Figure 1. Sample pixel from CRITTIR image sequence showing original time series (top) and time series de-noised by wavelet-based smoothing (bottom).

5. The P.I. visited the University of Stellenbosch, South Africa for a total of eleven weeks in December 2001 - January 2002, and July - August 2002. Work was done in collaboration with the following researchers at this university:

- Dr. Johan du Preez, Professor of Signal Processing in the Department of Electrical Engineering.

- Dr. Ben Herbst, Professor of Applied Mathematics.

Drs. Herbst and du Preez are experts in the area of pattern recognition. This expertise provides a complement to the P.I.'s knowledge of wavelet theory and signal processing, in applying this to problems involving target recognition.

This visit resulted in the initiation of Masters projects at Stellenbosch, in wavelet signal processing, and in independent component analysis

6. The University of Stellenbosch has formally offered the P.I. a temporary Professorship in the Department of Applied Mathematics for the Fall 2003 semester, with partial financial support. Primarily, this will allow the P.I. to develop his

expertise in the area of Pattern Recognition. Expertise in Pattern Recognition is likely to be of benefit to both the P.I. and to ONR, as the Probability and Statistics Program changes its emphasis towards Computational Decision Making.

7. The P.I. continued his established collaboration with Dr. Y.P. Kakad, Professor of Electrical and Computer Engineering at UNC-Charlotte. Dr. Kakad provides expertise concerning the hardware implementation of algorithms developed by the P.I. The collaboration has over the years been fruitful, resulting in several publications.

8. In collaboration with Dr. Y.P. Kakad (see above), a project is under way to apply Independent Component analysis to the signals from light-weight MEMS-based optical gyroscopes in order to increase their accuracy. Precision gyroscopes are important in inertial guidance systems for missiles and aircraft.

9. Presentation of two-day intensive course entitled "Wavelets and Filter Banks" (August 5 and 6), Department of Electrical Engineering, University of Stellenbosch, South Africa. Attendees included university faculty, graduate students, and engineers and scientists from industry who came from various parts of the country to attend.

10. The P.I. presented a series of 6 tutorial seminars on various aspects of signal processing at NSWC in June 2002. These were widely attended by NSWC research scientists, who gave very positive feedback on their usefulness. The titles of the seminars were "Independent Component Analysis", "The Chirp Z-Transform", "The Moving Fast Fourier Transform", "JPEG Image Compression Algorithm", "Introduction to Simulated Annealing", and "Image Compression Using Wavelets".

III. Students:

The following students performed work on this project during the period covered by this report:
1. **Parinita Rane**, M.S. (Computer Science) student. Ms. Rane assisted with the derivation of fast transform algorithms.
2. **Brian Johnson**, B.S.E.T. student. Mr. Johnson assisted with software development. When he graduates in May 2003, he intends to register for M.S.E.E., with his project under the direction of the P.I.

IV. Publications:

The P.I. published the following refereed papers during the year covered by this progress report. Each paper contains a statement of acknowledgement of support from ONR.

1. B.G. Sherlock and Y.P. Kakad, "MATLAB Programs for Generating Orthonormal Wavelets", *WSEAS Conference*, Greece, 2002.
2. B.G. Sherlock and Y.P. Kakad, "Transform Domain Technique for Windowing the DCT and DST", *Journal of the Franklin Institute*, Vol. 339, 2002, pp. 111-120.

3. B.W. Frazier, R.K. Tyson, Y.P. Kakad and B.G. Sherlock, "Robust Control of an Adaptive Optics System Using H_∞ Method", *18th Annual Conference on CAD/CAM, Robotics and Factories of the Future (CARS&FOF'2002),* Porto, Portugal, 2002.

Note: *Journal of Engineering Manufacture* has invited the P.I. to modify paper (3) above, for publication in this journal.

V. Presentations:

1. Two-day intensive course entitled "Wavelets and Filter Banks" (August 5 and 6, 2002), Department of Electrical Engineering, University of Stellenbosch, South Africa. Attendees included university faculty, graduate students, and engineers and scientists from industry who came from various parts of the country to attend.
2. Seminar entitled "Fingerprint Image Enhancement", given at the Department of Applied Mathematics, University of Stellenbosch, South Africa, August 4.
3. Seminar entitled "Independent Component Analysis", given at the Naval Surface Warfare Center, Dahlgren, VA, June 10, 2002.
4. Seminar entitled "The Moving Fast Fourier Transform Algorithm", given at the Naval Surface Warfare Center, Dahlgren, VA, June 12, 2002.
5. Seminar entitled "The Chirp Z-Transform", given at the Naval Surface Warfare Center, Dahlgren, VA, June 19, 2002.
6. Seminar entitled "JPEG Image Compression", given at the Naval Surface Warfare Center, Dahlgren, VA, June 21, 2002.
7. Seminar entitled "Introduction to Simulated Annealing", given at the Naval Surface Warfare Center, Dahlgren, VA, June 25, 2002.
8. Seminar entitled "Image Compression Using Wavelets", given at the Naval Surface Warfare Center, Dahlgren, VA, June 27, 2002.
9. Seminar entitled "Image Compression Using Wavelets", given at the Department of Applied Mathematics, University of Stellenbosch, South Africa, July 25, 2002.
10. Seminar entitled "Independent Component Analysis", given at the Department of Applied Mathematics, University of Stellenbosch, South Africa, August 1, 2002.