SEMIANNUAL RESEARCH PROGRESS SUMMARY

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EARTH OBSERVATIONAL RESEARCH USING MULTISTAGE EOS-LIKE DATA

Principal Investigators

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INTRODUCTION

Work under this grant is directed at preparation for the EOS era and, in particular, high spectral resolution data such as that from the imaging spectrometers HIRIS and MODIS. The objectives of the work are (a) to prepare suitable means for analyzing data from high spectral resolution sensors and (b) to advance the fundamental understanding of the manner in which soils and vegetative materials reflect high spectral resolution optical wavelengths. The work thus involves basic Earth science research and information system technique understanding and development in a mutually supportive way.

Some key factors influencing remote sensing information extraction in the new context of imaging spectrometry are (a) there will be a very much larger number of spectral bands available than in the past, (b) this should lead to the possibility of discriminating between a larger number of more detailed ground classes, (c) there is, in remote sensing, inherently a paucity in the size of training sets available by which to quantitatively define classes to be discriminated between, and (d) there is also an inherent impreciseness in the knowledge of values of some of the analysis parameters (e.g. class prior probabilities, class statistics, loss functions, etc.).

Research Directions and Previous Results

In the face of these factors, work during this multi-year effort has been divided into the following thrust areas[1]:

- **Feature Design or Selection.** Create a calculation procedure which would allow one to determine the best mission-specific spectral feature set for discriminating between a given set of Earth surface materials, given the location, time of season, and raw high resolution spectral samples to be available from a given sensor. The feature set may be realized either in terms of a linear combination of the original sensor bands or by selecting an optimal subset of them. [2,4,6,8,20,21,31]

- **Analysis Algorithm Design.** Determine a set of analysis algorithms which are well matched to the EOS era high dimensional data to be available and a list of classes presumably larger in number and more detailed in character than have traditionally been possible to use. Hierarchical analysis schemes were selected for study as an effective means for dealing optimally with large numbers and/or quite detailed classes; other methods under study relate to fundamentals of inference and decision-making in the face of imprecise or partial knowledge. [1,7,10,12,13,14,15,17,23,28,29,30,32,33,34,35,36,37, 38,39,40,41]

- **System Simulation.** Create a capability to simulate an entire remote sensing system, including the ground scene, atmosphere, sensor system, and analysis procedure, so that it is possible to study the interrelated effects of various system parameter settings and noise sources across the entire

[1] Numbers in brackets refer to papers and reports listed in the Bibliography of Previous Results below.

system, including the functioning of the algorithms produced by the above research efforts. Here the definition of noise is taken to be any deleterious effect that occurs in such systems. The motivation for this study, which is more basic in character, stems from the fact that as the information to be derived from such systems becomes more detailed, the interrelated effects between various system parameter selections and degrading influences within such systems will need to become more fully understood if the full potential of such systems is to be realized. The simulator should also be useful for simulating data sets and analysis situations which are not yet available, but which will be in the future. [3,9,11,16,18,22]

- **Earth Science Studies.** Develop the fundamental understanding of the variations of physical and chemical properties of soils and vegetation and their influence on high spectral resolution optical wavelengths. Effects of a human dominated landscape on soils and vegetation are a major emphasis. These studies provide a means for first-level testing of the new information extraction technology which results from the other research areas. [5,19,21,24,25,26, 27].

- **Analysis System Implementation.** Create a data analysis system implementation which has the power and flexibility needed in the future research environment, but which is economical to acquire and use and has greater emphasis on ease of use than has been the case in past implementations.

This latter area of work is motivated by the observation from previous land-oriented satellite programs that it is important, especially for analysis algorithms that are new and at all complex or require significant study in order for users to adopt them and realize there full potential, that there be a convenient means available for Earth scientists to try the algorithms on their own problem. Here, "convenient" means that the implementation hardware must be inexpensive or readily available and the software must be easy to learn and use, even for the occasional user. This work has been begun by building a software system on a personal computer workstation which contains a system of algorithms suitable for the analysis of multispectral data sets.

BIBLIOGRAPHY OF PREVIOUS RESULTS

Following is a bibliography of papers, reports, theses, published abstracts, and presentations produced previously by work supported at least in part by this grant.

[1] Benediktsson, Jon Atli and Philip H. Swain, "Methods for Multisource Data Analysis in Remote Sensing," (M.S. Thesis), Technical Report TR-EE 87-26, Purdue University, May-87, 65pp

[2] Chen, C.C. Thomas and D.A. Landgrebe, "Spectral Feature Design for Data Compression in High Dimensional Multispectral Data," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Ann Arbor, MI, May-87, pp. 685-690

[3] Kerekes, J.P. and D.A. Landgrebe, "A Noise Taxonomy for Remote Sensing Systems," Proceedings of International Geoscience and Remote Sensing Symposium, Ann Arbor, Michigan, May-87

[4] Ghassemian, Hassan and David Landgrebe, "An Unsupervised Feature Extraction Method for High Dimensional Image Data Compaction," Proceedings of the IEEE Systems, Man, and Cybernetics Conference, George Mason University, also appeared in IEEE Control System Magazine, Vol. 8, no. 3, June 1988, pp. 42-48, Oct-87, pp. 540-544

[5] Wu, You, "Quantitative Assessment of Landsat TM Data for Detailed Soil Mapping," Master of Science Thesis, Agronomy Department, Purdue University, W.Lafayette, IN., May-88

[6] Chen, Chih-Chien Thomas and David A. Landgrebe, "Spectral Feature Design in High Dimensional Multispectral Data," (Ph.D. Thesis), Technical Report TR-EE 88-35, Purdue University, School of Electrical Engineering, West Lafayette, IN, Aug-88, 140pp.

[7] Ghassemian, Hassan and David Landgrebe, "On-Line Object Feature Extraction for Multispectral Scene Representation," (Ph.D. Dissertation), Technical Report TR-EE 88-34, Purdue University, Aug-88, 153 pp

[8] Chen, C.C.T. and D.A. Landgrebe, "A Spectral Feature Design System for High Dimensional Multispectral Data," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Edinburgh, Scotland, Sep-88, pp. 891-894

[9] Kerekes, J.P. and D.A. Landgrebe, "Simulation of Optical Remote Sensing Systems for Earth Resource Analysis," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Edinburgh, Scotland, Sep-88, pp. 1211-1214

[10] Lin, Qian and Jan Allebach, "Improving Cover Type Identification in Speckled SAR Images by Prefiltering and Sequential Classification," Proceedings of 26th Annual Allerton Conference on Communication, Control, and Computing, Monticello, Illinois, Vol. II, Sep-88, pp. 609-618

[11] Kerekes, J.P. and D.A. Landgrebe, "HIRIS Performance Study," Technical Report TR-EE 89-23, Purdue University, Apr-89, 38pp

[12] Hakil Kim and P.H. Swain, "Combining Multispectral and Ancillary Data in Remote Sensing Using Interval-Valued Probabilities," World Conference on Information Processing and Communication, Seoul Korea, Jun-89

[13] Kim, H. and P.H. Swain, "Combining Multispectral and Ancillary Data in Remote Sensing Using Interval-Valued Probabilities," Proceedings of World Conference on Information Processing/ Communication, Seoul, Korea, Jun-89, pp. 1-6

[14] Benediktsson, J.A. and P.H. Swain, "A Method of Statistical Multisource Classification with a Mechanism to Weight the Influence of the Data Sources," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Vancouver, Canada, Jul-89, pp. 517-520

[15] Benediktsson, J.A., P.H. Swain and O.K Ersoy, "Neural Network Approaches Versus Statistical Methods in Classification of Multisource Remote Sensing Data," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Vancouver, Canada, Jul-89, pp. 489-492

[16] Kerekes, J.P. and D.A. Landgrebe, "Remote Sensing System Research Using A System Simulation," Proceeding of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS'89), Vancouver, B.C., Jul-89

[17] Kim, Hakil and Philip H. Swain, "Multisource Data Analysis in Remote Sensing and Geographic Information Systems Based on Shafer's Theory of Evidence," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Vancouver, Canada, Jul-89, pp. 829-832

[18] Kerekes, J.P. and D.A. Landgrebe, "Modeling, Simulation, and Analysis of Optical Remote Sensing Systems," (Ph.D. Thesis), Technical Report TR-EE 89-49, Purdue University, Aug-89, 182pp

[19] Fernandez, R. Norberto, Diego F. Lozano-Garcia and Chris J. Johannsen, "Development of Micro-Computer Based Georeferenced Information Systems - Case Studies from Argentina and Mexico," Interciencia, Vol. 14, No. 5, Sep-89, pp. 247-253

[20] Chen, Chih-Chien Thomas and David A. Landgrebe, "A Spectral Feature Design System for the HIRIS/MODIS Era," IEEE Transactions on Geoscience and Remote Sensing, Vol. 27, No. 6, Nov-89, pp. 681-686

[21] Henderson, Tracey L., A. Szilagyi, M. F. Baumgardner, C-C. T. Chen & D. Landgrebe, "Spectral Band Selection for Classification of Soil Organic Matter Content," Soil Science Society of America Journal, Vol. 53, no. 6, Nov-89, pp. 1778-1784

[22] Kerekes, John P. and David A. Landgrebe, "Simulation of Optical Remote Sensing Systems," IEEE Transactions on Geoscience and Remote Sensing, Vol. 27, No. 6, Nov-89, pp. 762-771

[23] Safavian, S. Rasoul and David A. Landgrebe, "Use of Robust Estimators in Parametric Classifiers," 1989 IEEE International Conference on Systems, Man, and Cybernetics, Cambridge, MA, Vol. 1, Nov-89, pp 356-7

[24] Johannsen, C.J., "Remote Sensing and GIS Applications: Mapping Land Use Changes as Influenced by Land Resources," Geological Society of America Abstracts Vol. 21: Abstract 029594, 1989

[25] Johannsen, C.J. R.N. Fernandez, D.F. Lozano-Garcia, "Use of Remotely Sensed Data for Studying the 1988 Drought," Soil and Water Conservation Society Annual Meeting Abstracts, 1989, p 22ff

[26] Lozano-Garcia, D.F., R.N. Fernandez, P.J. Wyss, C.J. Johannsen, "Assessment of the 1988 Drought in Indiana," American Society of Agronomy Abstracts, 1989, p 18ff

[27] Henderson, T.L., M.F. Baumgardner, D.C. Coster, D.P. Franzmeier, and D.E. Stott, "Use of High-Dimensional Spectral Data to Evaluate Organic Matter-Reflectance Relationships in Soils," (M.S. Thesis/Agronomy), LARS Technical Report 013090, Laboratory for Applications of Remote Sensing, Purdue University, Jan-90, 153pp

[28] Benediktsson, J.A., P.H. Swain, O.K. Ersoy and D. Hong, "Classification of Very High Dimensional Data Using Neural Networks," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90, pp. 1269-1272

[29] Jeon, Byeungwoo and David A. Landgrebe, "A New Supervised Absolute Classifier," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C, May-90, pp. 2363-2366

[30] Kim, B. and D.A. Landgrebe, "Hierarchical Classification in High Dimensional, Numerous Class Cases," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90, pp. 2359-2362

[31] Kim, B. and D.A. Landgrebe, "Prediction of Optimal Number of Features," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90, pp. 2393-2396

[32] Lee, Chulhee and David A. Landgrebe, "A Fast Multistage Gaussian Maximum Likelihood Classifier," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90, pp. 349-352

[33] Lin, Qian and Jan Allebach, "Displaying Multispectral Images on Video Terminals in RGB Color," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90

[34] Safavian, S. Rasoul and David A. Landgrebe, "Predictive Density Approach to Parametric Classification," Proceedings of the IEEE International Geoscience and Remote Sensing Symposium, Washington, D.C., May-90, pp. 2367-2370

[35] Kim, H. and P.H. Swain, "A Method for Classification of Multisource Data Using Interval-Valued Probabilities and Its Application to HIRIS Data," Proceedings of Workshop on Multisource Data Integration in Remote Sensing of the International Association for Pattern Recognition, Technical Committee 7, College Park, MD, Jun-90

[36] Kim, B., and D.A. Landgrebe, "Hierarchical Classification in High Dimensional, Numerous Class Cases," (Ph.D. Dissertation), Technical Report TR-EE 90-47, Purdue University, Jun-90, 109 pp

[37] Benediktsson, Jon A., Philip H. Swain and Okan K. Ersoy, "Neural Network Approaches Versus Statistical Methods in Classification of Multisource Remote Sensing Data," IEEE Transactions on Geoscience and Remote Sensing, Vol. 28, No. 4, Jul-90, pp. 540-552

[38] Kim, Hakil and Philip H. Swain, "A Method of Classification for Multisource Data in Remote Sensing Based on Interval-Valued Probabilities," (Ph.D. Dissertation), Technical Report TR-EE 90-48, Purdue University, Jul-90, 119pp

[39] Lin, Qian and Jan P. Allebach, "Combating Speckle in SAR Images: Vector Filtering and Sequential Classification Based on a Multiplicative Noise Model," IEEE Transactions on Geoscience and Remote Sensing, Vol. 28, No. 4, Jul-90, pp. 647-653

[40] Safavian, S. Rasoul and D. Landgrebe, "Topics in Inference and Decision-Making with Partial Knowledge," Technical Report TR-EE 90-53, Purdue University, Sep-90, 45 pp

[41] Safavian, S. Rasoul and D. Landgrebe, "A Survey of Decision Tree Classifier Methodology," Technical Report TR-EE 90-54, Purdue University, Sep-90, 44 pp

Results Appearing During the Current Reporting Period

A bibliography of papers, theses, and reports appearing during the current reporting period is given below. These results correspond to the above-listed thrust areas in the following fashion:

- **Feature Design or Selection.** [47,49]
- **Analysis Algorithm Design.** [42,43,48,50]
- **System Simulation.** [44,45]
- **Earth Science Studies.** [46]

References [47] and [49] describe a new method of feature selection which is expected to perform well in high data dimensionality situations. The two papers describe a non-parametric and a parametric version of the approach, respectively.

References [42] and [48] describe a new approach to use of spatial and temporal variations as an adjunct to spectral ones. Reference [43] is a PhD thesis on the study and comparison of statistically based and neural network analysis methods. Reference [50] is a documentation of a survey of approaches to decision tree classifiers which was conducted as an earlier part of this research effort.

References [44] describes results obtained in using the simulator created earlier for various HIRIS data gathering situations. Reference [45] describes an analytical version of the simulator which, while not providing as complete a simulation of a real scene and system, requires much less computational resources.

Reference [46] reports that statistical analysis of AVHRR data indicate that land-cover types, soil texture, and soil water-holding capacity have an important effect on vegetation biomass changes.

In addition to these results, substantial progress was made in the **System Implementation** research area. A number of new capabilities were added to the system during this reporting period, and it underwent substantial testing and debugging. As indicated above, by the end of this reporting period, a completed first draft of the system was nearly ready for release to those requesting it.

Bibliography of Results from the Current Period

[42] Jeon, Byeungwoo and David A. Landgrebe, "Spatio-Temporal Contextural Classification of Remotely Sensed Multispectral Data," Proceedings of the 1990 IEEE International Conference on Systems, Man, and Cybernetics, Los Angeles, CA, Nov-90.

[43] Benediktsson, J.A., and P.H. Swain, "Statistical Methods and Neural Network Approaches for Classification of Data from Multiple Sources," (Ph.D. Dissertation), Technical Report TR-EE 90-64, Purdue University, Dec-90, 235 pp.

[44] Kerekes, J.P. and D.A. Landgrebe, "Parameter Tradeoffs for Imaging Spectroscopy Systems," IEEE Transactions on Geoscience and Remote Sensing, Vol. 29, No. 1, Jan-91, pp 57-65.

[45] Kerekes, J.P. and D.A. Landgrebe, "An Analytical Model of Earth Observational Remote Sensing Systems," IEEE Transactions on Systems, Man, and Cybernetics, Vol. 21, No. 1, Jan-91, pp 125-133.

[46] Lozano-Garcia, D. Fabian, R. Norberto Fernandez and Chris J. Johannsen, "Assessment of Regional Biomass-Soil Relationships Using Vegetation Indexes," IEEE Transactions on Geoscience and Remote Sensing, Vol. 29, No. 2, Mar-91, pp. 331-339.

[47] Lee, Chulhee and David A. Landgrebe, "Decision Boundary Feature Selection for Non-Parametric Classifiers," SPSE 44th Annual Conference, St. Paul, MN, May-91.

[48] Jeon, Byeungwoo and David A. Landgrebe, "Spatio-Temporal Contextual Classification based on Markov Random Field Model," 1991 International Geoscience and Remote Sensing Symposium, Espoo, Finland, Jun-91.

[49] Lee, Chulhee and David A. Landgrebe, "Feature Selection Based On Decision Boundaries," 1991 International Geoscience and Remote Sensing Symposium, Espoo, Finland, Jun-91.

[50] Safavian, S. Rasoul and David A. Landgrebe, "A Survey of Decision Tree Classifier Methodology," IEEE Transactions on Systems, Man, and Cybernetics, to appear.