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13. ABSTRACT *(Maximum 200 words)*

In this report we summarize the results of a two-year research project on new techniques for high-speed recognition of multiple targets.

Devising means of automatically detecting and recognizing multiple targets led us to new insights into automatic and semi-automatic feature selection, parallel computer architectures, training procedures, and robustness in the face of changing data environments. These insights, we believe, contribute to the growth of the technology and mathematics of intelligent machines.

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1. FORWARD

In this report we summarize the results of a two-year research project on new techniques for high-speed recognition of multiple targets.

Devising means of automatically detecting and recognizing multiple targets led us to new insights into automatic and semi-automatic feature selection, parallel computer architectures, training procedures, and robustness in the face of changing data environments. These insights, we believe, contribute to the growth of the technology and mathematics of intelligent machines. The importance of the use of such machines in military weapons was well demonstrated in the Gulf War.

A. STATEMENT OF PROBLEM STUDIES

We devised and tested mathematical techniques for high speed detection and classification of multiple targets. This problem was divided into four subproblems: feature selection, multiclass decisions, high-speed cluster finding, and parallel computer architectures for high-speed image analysis.

B. SUMMARY OF MOST IMPORANT RESULTS

1. Tree Classifiers

We developed an automated method for designing tree classifiers that classify targets with both near-optimal accuracy and high speed. The method exploits the discriminability of Tomek links joining opposed pairs of data points in multidimensional feature space to produce a hierarchically structured piecewise linear decision function. Experiments on real data obtained from ship images and numerical character images suggest that the accuracy of the tree classifier designed by this scheme is comparable to that of the k-NN classifier, while its speeds are much greater.

2. Adaptive Classifiers of Objects in Cinematic Sequences

We developed an algorithm for designing a time-varying classifier that is suitable for classifying multiple objects in cinematic sequences of images. We refer to this algorithm as the mixed-adaptation algorithm. In the mixed-adaptation algorithm an initial classifier is first constructed. The initial classifier is subsequently revised by unsupervised cluster analysis. Cluster analysis and classifier revision take place after the processing of each image frame. Our experiments suggest that the mixed-adaptation algorithm is suitable for overcoming the difficulties created by statistically unrepresentative design data when analyzing scenes containing multiple objects.

3. Multicomputer Architectures for Image Analysis

We devised efficient mapping algorithms for assigning computational tasks to hypercube-connected multiprocessors so as to minimize the task completion time. Two iterative-refinement mapping schemes were tested: (1) subcube pairwise exchange and (2) subcube cyclic exchange. In tests on various problem graphs of a pipelined algorithm, the proposed mapping algorithms reduced the CPU time significantly, while achieving a good quality of mapping.

4. Genetic Algorithms for Large-Scale Feature Selection

We devised and tested genetic algorithms for automatic selection of small numbers of features for pattern classification, starting from a large number of features -- usually over twenty. We showed on both real and modeled error rate functions that our feature selection procedure outperforms all other nonexhaustive methods, in particular sequential search and branch-and-bound. On 30-dimensional real data provided by the U.S. Army Missile Command our genetic algorithm outperformed sequential search.

5. Mixed Adaptation for Robust Classifiers

We showed that mixed adaptation produces robust classifiers. In this technique a supervised training phase exploits statistically scene invariant labeled data to produce an initial classifier. This is followed by an unsupervised training phase that exploits clustering properties of unlabeled data. We devised a probabilistic model supporting the design of the mixed adaptation technique. The robustness of this technique was demonstrated successfully on synthetic and real examples. These examples include the detection of unspecified dotted curves in dotted noise and the detection and classification of vehicles in cinematic sequences of infrared imagery.

6. Mapping Techniques for Exploratory Multidimensional Data Analysis

We devised and constructed in software a versatile collection of mapping methods for computer-aided analysis of multidimensional data. We devised a new mapping technique -- the least squares mapping -- which was included in the constructed software. Least squares mapping combines a squared error criterion with agglomerative clustering. We tested these mapping methods in two experiments: one for cluster analysis and the second for classifier design. The first experiment involved sixteen human subjects and the second involved fourteen. In both of these experiments untrained humans aided by the generalized declustering mapping and our least squares mapping outperformed or equaled automatic clustering and classifier design techniques.

C. PUBLICATIONS AND TECHNICAL REPORTS

1. Publications

1) W. Siedlecki, K. Siedlecka, J. Sklansky, "An Overview of Mapping Techniques for Exploratory Pattern Analysis", Pattern Recognition Vol. 21, No. 5, pp. 411-429, 1988.

2) W. Siedlecki, K. Siedlecka, J. Sklansky, "Experiments on Mapping Techniques for Exploratory Pattern Analysis", Pattern Recognition Vol. 21, No. 5, pp. 431 - 438, 1988.

3) W. Siedlecki, K. Siedlecka, J. Sklansky, "Mapping Techniques for Exploratory Pattern Analysis", Pattern Recognition and Artificial Intelligence, E.S. Gelsema and L. N. Kanal (Editors), Elsevier Science Publishers B. V. (North Holland), 1988.

4) Y. Park, J. Sklansky, "Automated Design of Piecewise Linear Classifiers of Multiple-Class Data", Proceedings of Ninth International Conference on Pattern Recognition, Rome, 1988

5) Y. Moon, N. Bagherzadeh, J. Sklansky, "A macropipelined multicomputer architecture for image analysis", Journal of the Optical Society of American A, 1989

6) W. Seidlecki, J. Sklansky, "On automatic feature selection", International Journal on Pattern Recognition, Vol 2, No. 2, August 1988, pp. 197-220

7) W. Siedlecki, J. Sklansky, "A note on genetic algorithms for large-scale feature selection", Pattern Recognition Letters, 1989, pp. 335-347

8) Y. Park, J. Sklansky, "Automated design of multiple-

class piecewise linear classifiers", Journal of Classification, 1989, pp. 195-222.

9) Y. Park, J. Sklansky, "Automated Design of Linear Tree Classifiers", Pattern Recognition, Vol 23, No. 12, 1990, pp. 1393-1412.

10) D. Gutfinger, R. Nishimura, H. Doi, J. Sklansky, "Robust Curve Detection By Temporal Geodesics", April 1990

11) D. Gutfinger, J. Sklansky "Robust Classifiers by Mixed Adaptation", IEEE Transactions on Pattern Analysis and Machine Intelligence, in press (1991)

2. Technical Reports

1) W. Siedlecki, "Feature Selection for Large Scale Classifiers", 1988 (Ph.D. Dissertation)

2) Y. Moon, "Multicomputer Architectures for Image Analysis", 1990 (Ph.D. Dissertation)

3) Y. Park, "Linear Tree Classifiers", 1990 (Ph.D. Dissertation)

4) D. Gutfinger, "Mixed Adaptation and Robust Classifiers", 1990 (Ph.D. Dissertation)

D. SCIENTIFIC PERSONNEL AND DEGREES AWARDED

J. Sklansky, Principal Investigator
D. Gutfinger, Research Assistant - Ph.D. in 1990
Y. Moon, Research Assistant - Ph.D. in 1990
Y. Park, Research Assistant - Ph.D. in 1990
W. Siedlecki, Research Assistant - Ph.D. in 1988