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**13. SUPPLEMENTARY NOTES**

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**14. ABSTRACT**
The objectives of this project were, simply put, to develop advanced statistical pattern recognition methodologies for the Tufts University artificial nose (and other sensors of interest -- notably, hyperspectral imagers). This effort had significant positive impact on the Tufts University artificial nose. In particular, I claim that the paper: C.E. Priebe, ''Olfactory Classification via Interpoint Distance Analysis,'' *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. No. 4, pp. 404-413, April 2001. is among the most important papers ever published on statistical pattern recognition for artificial olfactory sensor systems. Additional publications detail advancements made which positively impact the Tufts nose (and are applicable to many other sensor systems). Furthermore, this effort produced workable initial versions of a methodology for jointly optimizing classification with sensing and processing, in terms of adaptive dimensionality reduction. This latter concept is relevant to a wide variety of adaptive sensors, and will be pursued in the future.

**15. SUBJECT TERMS**
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August 17, 2001

Wendy M. Veon
AFOSR/PKC
801 North Randolph Street
Room 732
Arlington, VA 22203-1977

SUBJECT: Final Reports for AFOSR Grant No. F496209910213 - Under the direction of Dr. Carey Priebe

Dear Ms. Veon:

Enclosed please find the following final reports for the subject award:

____ Financial Status Report (SF 269)

____ Report of Inventions and Subcontracts (DD Form 882)

_X_ Final Technical Report

If you have any questions or concerns regarding these reports or need anything further, please do not hesitate to contact me at gene@jhu.edu or (410) 516-6762.

Sincerely,

Gene Rutherford
Sponsored Projects Specialist

cc: E74-2031

# Final Technical Report
# Due 30 June 2001

## Advanced Data Analysis Methods for Analyte Recognition from Optical Sensor Arrays

Air Force Office of Scientific Research /
DARPA Applied and Computational Mathematics Program

DOD F49620-99-1-0213
04/01/99--03/31/01

PI: Carey E. Priebe
<cep@jhu.edu>
Department of Mathematical Sciences
Whiting School of Engineering
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Baltimore, MD 21218-2682

**Objectives**:
The objectives of this project were, simply put, to develop advanced statistical pattern recognition methodologies for the Tufts University artificial nose (and other sensors of interest -- notably, hyperspectral imagers).

**Notable accomplishments:**
This effort had significant positive impact on the Tufts University artificial nose. In particular, I claim that the paper: C.E. Priebe, "Olfactory Classification via Interpoint Distance Analysis," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. No. 4, pp. 404-413, April 2001. is among the most important papers ever published on statistical pattern recognition for artificial olfactory sensor systems. Additional publications detail advancements made which positively impact the Tufts nose (and are applicable to many other sensor systems). Furthermore, this effort produced workable initial versions of a methodology for jointly optimizing classification with sensing and processing, in terms of adaptive dimensionality reduction. This latter concept is relevant to a wide variety of adaptive sensors, and will be pursued in the future.

**Future transition plans:**

The Tufts University Artificial Nose effort uses many of the advancements developed in this effort.

The ONR Information, Electronics, and Surveillance program (Jim Buss) is interested in our methodology for jointly optimizing classification with sensing and processing, based on a prototype developed for the HyMap Airborne Hyperspectral Scanner.

A proposal titled "The Adaptive Data Cube for Integrated Sensing and Processing" has been submitted to DARPA/DSO BAA00-36. This proposal will continue the current effort, with significant redirection toward developing dimensionality reduction methodologies which jointly optimize classification procedures with tunable paramaters available in adaptive sensing and processing.

**Refereed Journal Publications related to the artificial nose:**

C.E. Priebe, "Olfactory Classification via Interpoint Distance Analysis," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. No. 4, pp. 404-413, April 2001.

J. Xie and C.E. Priebe, "A Weighted Generalization of the Mann--Whitney--Wilcoxon Statistic," *Journal of Statistical Planning and Inference*, to appear. (Available as Technical Report No. 593, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix A).

J. Xie and C.E. Priebe, "Generalizing the Mann--Whitney--Wilcoxon Statistic," *Journal of Nonparametric Statistics*, Vol. 12, pp. 661--682, 2000.

C.E. Priebe and L.J. Cowen, "A Generalized Wilcoxon--Mann--Whitney Statistic," *Communications in Statistics: Theory and Methods*, Vol. 28, No. 12, pp. 2871--2878, 1999.

**Conference Publications related to the artificial nose:**

C.E. Priebe, D.J. Marchette and J.L. Solka, "On the Selection of Distance for a High-Dimensional Classification Problem," *Proceedings of the Statistical Computing Section, American Statistical Association.*

C.E. Priebe and D.J. Marchette, "Characterizing the Dimensionality of a Classification Problem," *Computing Science and Statistics*, to appear.

D.J. Marchette and C.E. Priebe, "Adaptive Nonlinear Dimensionality Reduction," *Proceedings of the SPIE*, Vol. 4055, pp. 140-146, 2000.

C.E. Priebe, J.-S. Pang and T. Olson, "Optimizing Sensor Fusion for Classification Performance," *Proceedings of the International Conference on Imaging Science, Systems, and Technology: CISST '99*, pp. 397-403, 1999.

*Related publications, previous to 1999:*

L.J. Cowen and C.E. Priebe, "Randomized Nonlinear Projections Uncover High--Dimensional Structure," *Advances in Applied Mathematics*, Vol. 9, pp. 319--331, 1997.

A.H. Cannon, L.J. Cowen, and C.E. Priebe, "Approximate Distance Classification," *Computing Science and Statistics*, Vol. 30, pp. 544-549, 1998

C.E. Priebe and L.J. Cowen, "Approximate Distance Clustering," *Computing Science and Statistics*, pp. 337-346, 1997.

**Related manuscripts submitted for publication:**

D.J. Marchette and C.E. Priebe, "Characterizing the Scale Dimension of a high dimensional classification problem." Submitted for publication. (Available as Technical Report No. 614, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix B)

D.J. Marchette, J.G. DeVinney, and C.E.Priebe, "Vector Quantization and Classification Through the Dominating Set of a Digraph." Submitted for publication. (Available as Technical Report No. 613, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix C).

A.H. Cannon, L.F. James, and C.E. Priebe, "Approximating the Posterior via the Nearest Neighbor Regression." Submitted for publication. (Available as Technical Report No. 612, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix D).

C.E. Priebe, J.G. DeVinney, and D.J. Marchette, "On the Distribution of the Domination Number for Random Class Cover Catch Digraphs." Submitted for publication. (Available as Technical Report No. 611, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix E)

T. Olson, J.S. Pang, and C.E. Priebe, "A Likelihood--MPEC Approach to Target Classification." Submitted for publication. (Available as Technical Report No. 590, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD 21218-2682. See Appendix F)

T.A. Dickinson, S.R. Johnson, H. Engelhaardt McClelland, G.A. Bakken, P.C. Jurs, J. White, J.S. Kauer, C.E. Priebe, and D.R. Walt, "Solvent Identification Using Multiwavelength Data from an Optical Sensor Array." Submitted for publication.

S.E. Stitzel, L.J. Cowen, K.J. Albert, D.R. Walt, "Array-to-Array Transfer of an Artificial Nose Classifier." Submitted for publication.

**Related papers will appear in the following upcoming conferences:**

Nonparametrics in Large, Multidimensional Data Mining: January 12-13, 2001, Dallas, Texas.

Data Vizualization Workshop: May 21-25, 2001, Fairfax, Virginia.

3rd IAPR -TC-15 Workshop on Graph-based Representations in Pattern Recognition: May 23-25, 2001, Ischia, Italy. JHU DMS TR #613 (submitted for publication)

33rd Symposium on the Interface: Computing Science and Statistics: June 13-16, 2001, Orange County, California. Invited paper.

**Recent and upcoming invitations for related work:**

Invited to present: "The Adaptive Data Cube: An Experiment in Hyperspectral Pattern Recognition" at the 33rd Symposium on the Interface: Computing Science and Statistics, Orange County, CA, June 2001.

Invited to present: "Investigating an Artificial Nose" at Maryland Chapter of the American Statistical Association Annual Banquet, Columbia, MD, June 2000.

Invited to present: "Statistical Pattern Recognition for an Artificial Nose" at the 1999 WSE Anniversary Symposium, Baltimore, MD, November 1999.

Invited to present: "Optimizing Classification Performance" at the 1999 Joint Statistical Meetings, Baltimore, MD, August 1999.

Invited to present: "Optimizing Sensor Fusion" at the 1999 International Conference on Imaging Science, Las Vegas, NV, June 1999.

Meetings:

DARPA ACMP PI Meeting, San Francisco, CA, July 1999.

DARPA ACMP PI Meeting, Arlington, VA, April 2000.

DARPA Integrated Sensing and Processing Workshop, Boulder, CO, August 2000.

ONR Signal-Image Processing Workshop, Arlington, VA, February 2001.

DARPA Dimensionality Reduction Workshop, Washington, DC, March 12-13, 2001.

DARPA ACMP PI Meeting, Arlington, VA, April 4-6, 2001.

**Doctoral students:**

Two graduated doctoral students focusing on methodologies which we apply to the artificial nose and hyperspectral dimension reduction issues:

Jingdong Xie, Ph.D. (1999)
Dissertation Title: Generalizing the Mann--Whitney--Wilcoxon Statistic
Defended: April 1999
Jingdong Xie is now at MedImmune, Inc.: XieJ@MedImmune.com

Adam Cannon, Ph.D. (2001)
Dissertation Title: Approximate Distance Methods in Classification
Defended: May 2000
Adam Cannon is now at Columbia University: cannon@cs.columbia.edu

Three current doctoral students focusing on methodologies which we apply to the artificial nose and hyperspectral dimension reduction issues:

Jason DeVinney

Heng Zhang

Elvan Ceyhan