Report on 2002 Workshop on Challenges in Pattern Recognition

Prepared by: Alfred O. Hero (workshop chair)

The workshop on Challenges in Pattern Recognition was held as planned in Ann Arbor on Mar 15-18, 2002. The list of participants, talk titles and schedule of talks is included in this report as Appendix A. There were 5 technical sessions consisting of 30-minute presentations by each of the academic participants. These were alternated with one to two hour discussion sessions which were focused on the future of pattern recognition, covering both theory and applications. A list of discussion topics, prepared before the meeting by A. Hero, is included in Appendix B. Minutes of the 4 discussion sessions, taken by R. Nowak, A. Nobel, and A. Jain are included in Appendix C. In the following I will highlight what I believe are the most important conclusions which came out of this workshop.

1. Present state of pattern recognition

The field of pattern recognition has evolved over the past three or four decades into a broad based activity which has had a measurable impact on applications. Some of the most significant practical impact has occurred in the past decade in handwriting recognition, image indexing, target recognition, and speech. The use of kernel-based methods, also known as vector support machines and PAC learning, has allowed attainment of previously unachievable levels of classification performance in these applications. The field has also been energized by recent advances in statistical shape modeling, active contours, pattern theory which have had or are having a measurable impact on shape classification and biometrics. Clustering has also seen a resurgence, enabled by powerful Bayesian analysis, resampling and divide-and-conquer strategies, and new hierarchical and partitioning clustering methods. Such clustering methods are capable of discriminating between much more complex patterns than ever before. As illustrated by many of the technical presentations at the workshop, there are a wealth of new and important applications areas to which pattern recognition has only recently been applied including bioinformatics, surgical planning, face and gait recognition, and airport surveillance.

2. Future challenges facing the PR community

Despite impressive advances in several applications areas, there remain many challenges which need to be addressed in order to enable the next leap forward in pattern recognition theory and practice. While it was pointed out by one of the workshop participants that innovations are intrinsically unpredictable, difficult challenges are easier to identify. Three of the principal challenges are:

a) to understand the relative advantages and disadvantages of the principal approaches to pattern recognition: model-based, learning-based, and heuristic-based methods. Particular questions are: what are the failure modes of each of these methods? What is the role of invariance in each of these approaches? What kinds of data sets should be used to perform fair comparisons? What performance metrics should be used for these

comparisons? Are there ways in which the three methods could be combined to collectively exploit each of their best attributes?

b) to come up with new approaches to pattern recognition which are capable of handling very large dimensional data with feasible computation (real time), which can rapidly adapt to and learn changing patterns and contexts, and which can be implemented in a distributed framework, such as a large sensor network, with limited bandwidth.

c) to create new opportunities for interdisciplinary collaboration. Benefits of such collaboration would be both in new applications areas and in new paradigms for developing pattern recognition strategies. Among the potentially fruitful areas of collaboration we identified the following: mathematics (topology; computational geometry; graph theory); the sciences (psychology and behavior modeling; genetics; neuroscience; astronomy; archeology); medicine (medical imaging and diagnostics; multi-modality image registration; searching patient databases); and security (networking; remote sensing; forensics; document recognition, steganography and watermarking).

All workshop participants agreed that a program or initiative at the National Science Foundation on pattern recognition would be a good instrument for addressing these challenges. It was also pointed out that NSF could have impact by sponsoring some new workshops. Specific suggestions were: a workshop on performance validation, including some sort of algorithm competition accompanied by a post-mortem analysis; and a series of workshops bringing together disparate disciplines to foster new collaborations.

Pattern Recognition Workshop

March 15-17, 2002

Participants

Abdali, S. Kamal
National Science Foundation

Amit, Yali
University of Chicago

Chellappa, Rama
University of Maryland

Cochran, Doug
DARPA

Cozzens, John H.
National Science Foundation

Geiger, Davi
New York University, Courant Inst.

Hero, Alfred O.
University of Michigan

Jain, Anil K.
Michigan State University

Krim, Hamid
North Carolina State University

Mardia, Kanti V.
University of Leeds

Moulin, Pierre
University of Illinois, at Urbana-Champaign

Mumford, David
Brown University

Nagy, George
Rensselaer Polytechnic Institute

Nobel, Andrew
University of North Carolina

Nowak, Robert
Rice University

Srivastava, Anuj
Florida State University

Strong, Gary
DOD

Vapnik, Vladimir
AT&T Research Labs

Yezzi, Anthony J.
Georgia Institute of Technology

APPENDIX A

- **Workshop Web Page -- may also be viewed at http://www.eecs.umich.edu/systems/NSFPatternWkshp.html**

- **Workshop Agenda**

National Science Foundation

PATTERN RECOGNITION WORKSHOP

Hosted by the University of Michigan
March 15-17, 2002
Ann Arbor, MI

Workshop Description -- The goals of this NSF workshop are broad: to bring together a multi-disciplinary group of researchers to shed light on the important challenges, the open problems, the promising approaches, and to get a general picture of the state of the art in areas related to pattern recognition. Each of the eminent researchers listed below will present a 20 minute talk. They come from diverse communities including: computer science, applied math, information theory, signal processing, and statistics. There will also be representatives from NSF-CISE, NSF-DMS, NSF-BioMed, and possibly other federal agencies (CIA, NSA, DoD), who will be attending. ***Participation in this workshop is by invitation only.***

Agenda -- The Workshop will begin at 7:00 PM, Friday, March 15, with a Reception and Greetings. Presentations will commence on Saturday morning and continue through the afternoon, followed by a banquet in the evening. Presentations will begin again on Sunday morning and conclude by around 3:00 PM. All meals through lunch on Sunday, March 17, will be provided.

Workshop Presenters

Yali Amit University of Chicago	Common themes in object detection and recognition in visual and acoustic scenes	**David Mumford** Brown University	Major Challenges Facing Pattern Recognition
Rama Chellappa University of Maryland	Recognition of Moving Patterns from Moving Observers	**George Nagy** Rensselaer Polytechnic Inst.	Interactive Pattern Recognition
Davi Geiger New York University	A test case for pattern recognition systems: Recognizing Characters and Cursive Words	**Andrew Nobel** University of North Carolina	The role of cluster analysis in the study of gene expression arrays
Alfred O. Hero University of Michigan	Emerging problems in pattern recognition: Lessons and challenges	**Rob Nowak** Rice University	Dyadic Thinking about Density Estimation and Tree Classifiers
Anil K. Jain Michigan State University	Unsupervised Learning	**Anuj Srivastava** Florida State University	Successive Refinement Strategies for Complex Pattern Recognition
Hamid Krim North Carolina State University	Energy-Driven Polygonal Approximation for Shape Classification	**Vladimir Vapnik** AT&T Research Labs	Problem of Statistical Inference in High Dimensional Spaces
Kanti V. Mardia University of Leeds	Shape Challenges in Medical Imaging and Bioinformatics	**Anthony J. Yezzi** Georgia Institute of Technology	Segmentation, Registration, and Shape Models
Pierre Moulin University of Illinois	Signal Compression for Joint Classification and Reconstruction		

Invited Participants: Hotel and Airline Reservation Instructions

Directions from Detroit Metro Airport to Hotel -- From the airport take highway I-94 West to US-23 (exit 180), then take Highway US-23 North 5.8 miles to Plymouth Road (exit 41), then turn West from the exit ramp onto Plymouth Road, cross over US-23, and you will see the Holiday Inn on your left (on the Southwest corner of US-23 and Plymouth Road). **Maps of Ann Arbor area and route from airport** and map of the NEW **Detroit Metropolitan Airport**

Updated 3/14/02 by Susan Yale -- skyale@umich.edu

National Science Foundation

PATTERN RECOGNITION WORKSHOP

The University of Michigan
at
Holiday Inn - North Campus
Ann Arbor, MI

Agenda

Friday, March 15		
7:00 PM - 10:00 PM	Reception & Welcome	*Connoisseur Room*
Saturday, March 16		
7:00 AM – 8:00 AM	**Breakfast Buffet**	*Camelot/Cornwall Rooms*
8:00 AM – NOON	**SESSIONS**	*Camelot/Cornwall Rooms*
10:15 AM	Coffee Break	
12:30 – 1:30 PM	Lunch Buffet	*Connoisseur Room*
1:00 PM – 6:00 PM	**SESSIONS**	*Camelot/Cornwall Rooms*
3:00 PM	**Coffee Break**	
7:00 PM – 10:00 PM	Reception & Banquet	*Connoisseur Room*
Sunday, March 17		
7:00 AM – 8:00 AM	Breakfast Buffet	*Camelot/Cornwall Rooms*
8:00 AM – NOON	**SESSIONS**	*Camelot/Cornwall Rooms*
10:00 AM	**Coffee Break**	
NOON – 1:00 PM	Lunch Buffet	*Connoisseur Room*
1:00 PM – 3:00 PM	**SESSIONS**	*Camelot/Cornwall Rooms*

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PATTERN RECOGNITION WORKSHOP

Saturday, March 16, 2002

8:00 AM	**Welcome**	
8:15 AM	**Rama Chellappa**	*Recognition of Moving Patterns from Moving Observers*
8:45 AM	**Pierre Moulin**	*Signal Compression for Joint Classification and Reconstruction*
9:15 AM	**David Mumford**	*Major Challenges Facing Pattern Recognition*
9:45 AM	Discussion	
10:15 Am	*Coffee Break*	
10:30 AM	Discussion Continues	
11:00 AM	**Andrew Nobel**	*The role of cluster analysis in the study of gene expression arrays*
11:30 AM	**Anil K. Jain**	*Unsupervised Learning*
12:00 PM	**Hamid Krim**	*Energy-Driven Polygonal Approximation for Shape Classification*
12:30 PM	*Lunch*	
1:30 PM	Discussion	
3:00 PM	*Coffee Break*	
3:15 PM	**Yali Amit**	*Common themes in object detection and recognition in visual and acoustic scenes*
3:45 PM	**Anuj Srivastava**	*Successive Refinement Strategies for Complex Pattern Recognition*
4:15PM	**Rob Nowak**	*Dyadic Thinking about Density Estimation and Tree Classifiers*
4:45 PM	Discussion	
6:00 PM	Session Concludes	

National Science Foundation

PATTERN RECOGNITION WORKSHOP

Sunday, March 17, 2002

8:00 AM	**Davi Geiger**	*A test case for pattern recognition systems: Recognizing Characters and Cursive Words*
8:30 AM	**Kanti V. Mardia**	*Shape Challenges in Medical Imaging and Bioinformatics*
9:00 AM	**Vladimir Vapnik**	*Problem of Statistical Inference in High Dimensional Spaces*
9:30AM	Discussion	
10:00 Am	*Coffee Break*	
10:15 AM	Discussion Continues	
11:00 AM	**Anthony J. Yezzi**	*Segmentation, Registration, and Shape Models*
11:30 AM	**George Nagy**	*Interactive Pattern Recognition*
12:00 PM	*Lunch*	
1:00 PM	**Alfred O. Hero**	*Emerging problems in pattern recognition: Lessons and challenges*
1:30 PM	Discussion	
2:45 PM	Wrap-up	
3:00 PM	Workshop Concludes	

APPENDIX B

Discussion Topics

by A. Hero

Applications

What are the longstanding problems?

What are emerging areas?

New Security-related applications?

Pattern hiding vs. pattern recognition?

What has blunted the impact of PR on society?

Problem Formulation

Modeling vs. Learning approaches?

Are asymptotic approximations and bounds useful?

What kind of role does optimization theory have in PR?

What kind of role does game theory have in PR?

What kind of role does information theory have in PR?

What kind of role does communications have in PR?

What kind of role does distributed computation have in PR?

Performance

Relevant performance measures?

What are best validation procedures?

Standardized databases for algorithm assessment?

Simulation vs. experimentation – is there a disconnect?

Education

In what programs/depts. is PR taught?

Is there sufficient PR content in our UG/G curricula?

Should PR education be centralized like statistics?

What would be the desired components of a PR curriculum?

Can we make PR more accessible to students and the public?

Breakthroughs

What kind of new approaches are needed?

New computational models?

New hardware models?

New theory?

New mathematical/statistical models?

Multimodality fusion?

How to separate share from texture?

Collaborations

What has hindered productive collaborations and how to overcome?

What opportunities exist for interdisciplinary collaborations?

What disciplines could be tapped for innovative ideas?

APPENDIX C

Session Minutes

Session I	**by A. B. Nobel**
Sessions II & III	**by R. Nowak**
Session IV	**by A. Jain**

Notes from Morning Session 16 March 2002
NSF Pattern Recognition Workshop

Scribe: AB Nobel

These notes were taken during a lively discussion on the morning of 16 March 2002 at the NSF Pattern Recognition Workshop, Ann Arbor, Michigan. All participants were present at the discussion, which touched briefly on a number of themes. A rough summary of the discussion is given below.

Pattern recognition addresses a diverse set of applied and theoretical problems, with tools and methods drawn from several fields, including engineering, statistics, computer science, and physics. It was suggested that this diversity might profitably be viewed in a hierarchical fashion, and that both problems and measures of performance can be viewed at different levels. At one end of the hierarchy there are basic problems such as character, face, and speech recognition. Here measures of performance can range from quantitative to monetary, but usually retain some qualitative features. In particular, the end user and the intended use of a method must play an important role in the assessment of its performance.

At the other end of the hierarchy there are specific problems (practical or theoretical) that can be considered and solved in isolation. Here measures of performance are more likely to be quantitative, though there are a variety of quantitative measures to choose from, and which quantitative measure one chooses can have an impact on the success of one's analysis. In real world problems, strict adherence to quantitative performance measures can be problematic. In real data the "truth" is often unknown, and the available data rarely constitute a random sample from a fixed distribution.

It was noted that researchers sometimes lose sight of the larger questions in their (necessary) pursuit of more specialized problems. There was also some concern that an over-reliance on quantitative performance measures might hinder the development of successful methods for real-world problems.

It is axiomatic that no method can claim superior performance on every problem. A working definition of a good method might be one that does as well as, or better than, other methods on several problems of practical interest. This leads to the following.

1. The need for research that aims to distinguish, at a theoretical and empirical level, between different pattern recognition methods and tools. One goal is to provide greater insight into which methods are best suited to which problems.

2. The need for continuing development of new models to address new applications, and to provide better methods for existing problems.

In either case, it is important to have access to a diverse variety of data from existing and emerging applications to which pattern recognition methods might be applied.

Workshop Discussions: Challenges in Pattern Recognition (Mar 15-17).

Minutes of Discussion Sessions II and III
taken by Rob Nowak

High Level Ideas:

Two approaches to Pattern Recognition

1. Model based
   Bayesian and likelihood based approaches
2. Learning/Data based
   Neural networks, SVMs

Another perspective

1. Automatic pattern recognition for problems humans are good at solving e.g., computer vision, image processing
2. Automatic pattern recognition for problems where humans cannot find/see patterns e.g., DNA microarrays, sensor networks

Key Challenges

1. Pattern recognition systems need to be more robust
2. In well developed key areas (e.g., face recognition) we should get people to sit down and discuss what is working and why?
3. Can model based paradigms and learning base paradigms be integrated together?
4. Interactive pattern recognition systems (partially supervised) using human interaction (semi-automatic instead of fully-automatic) are needed.
5. Dimensionality reduction
6. Performance and model assessment
7. Design/Deployment of pattern recognition systems 8. Sequential pattern recognition systems

Hinderances to Collaboration with Other Fields

1. Different cultures
2. Sensitive/proprietary data
3. Steep learning curves on both sides
4. Pattern recognition has a low profile in other sciences (credibility?)

Key Application Areas:

remote sensing
medical imaging
bioinformatics
neuroscience
network security and sensor nets
biometrics
steganography
security
brain/machine interface
data mining

Needs of Pattern Recognition Researchers

1. Better, standardized databases
2. Organized meetings for critical assessment of what is working and what is not working in specific application domains (e.g., face recognition)

NSF workshop on Challenges in Pattern Recognition
March 15-17, Ann Arbor, MI

Minutes of Discussion Session IV: 3/17/02;
(notes taken by Anil Jain)

QUESTIONS POSED

1. What kind of new approaches are needed?
2. New computational models?
3. New hardware models?
4. New theory?
5. New mathematical/statistical models?
6. Multimodal fusion?
7. Shape recovery?

RESPONSES

1. Use topological models:
   Lot of opportunities available to move from the image domain to the domain of geometry; e.g., "meshless" representation of protein folding structures and terrain structures. Determine invariant topological (e.g., no. of holes) and geometric properties of objects. There is an opportunity for pattern recognition researchers to collaborate with computational geometry and computational topology people. This will result in better tools to analyze/interpret patterns.
2. Suppose we have the following four different pattern recognition problems, each with 10 classes: (i) handwritten digits, (ii) printed digits, (iii) spoken digits, and (iv) types of aircrafts. Suppose each pattern is represented by 100 features and there are 100 training samples from each class. Will these patterns in the 100-dim space "look" different? These problems are different because they have different models for data/pattern generation. To do more "intelligent" processing of the data (e.g., feature selection), you should utilize the data generation process.
3. Need to develop a systematic methodology for feature selection; understand the geometry of high-dimensional spaces. Investigate the use of stochastic geometry, e.g., surface analysis can be useful for protein structures.
4. How should we foster collaboration with people working in algebraic geometry and topology? One way is to organize some interdisciplinary workshops!
5. How do we identify different research groups working on pattern recognition? Some are working on theory, while others are focusing on some applications. It would be good if we focused on some theme/application that will push the state-of-the-art in pattern recognition. Duke University had organized a workshop that focused on a specific dataset (provided by NCI); everyone who attended the workshop had analyzed this dataset (provided one month in advance).

6. Why should NSF care about the performance of pattern recognition systems? NSF supports basic research with some “novelty” and the proposals are peer reviewed.
7. One NSF program director (Cozzens) made the following statement. This NSF workshop was organized in response to the concern that P.R. field is “stagnant” and there is not much money available from NSF for Pattern recognition research. What would be some compelling reasons for NSF to issue a BAA for research in pattern recognition and what should be the topics listed in BAA?
8. Following is a list of topics that could be included in the BAA.

    (i) Model-based approach vs. learning-based approach; need a synthesis of these two approaches. Where does one approach work and the other fails; a case study on this issue will be helpful
    (ii) Performance and model assessment; one could conduct a competition on some large database and a specific problem (e.g., classification of Corel image database into 7 classes)
    (iii) Dimensionality reduction/feature selection
    (iv) Unsupervised learning/cluster analysis
    (v) Prediction without constructing an explicit decision boundary, e.g., as in the case of NN (nearest neighbor) decision rule. This area was called “transductive” inference.
    (vi) Intelligent data collection/acquisition; e.g. placement of sensors
    (vii) Pattern recognition systems that adapt, improve with practice, and learn in an unsupervised manner.

    Following two topics are my own (Anil Jain’s) additions

    (i) Pattern recovery from noisy environment
    (ii) Learning object models from examples