Preface

The theory and practice of Multiple Classifier Systems (MCS) and related methods address the issues surrounding the optimality of decision-making in a multiple classifier framework. What contributes to the fascination of this field is that solutions have been developed by many diverse research communities, including machine learning, neural networks, pattern recognition, and statistics. The aim of the series of workshops on MCS is to create a common international forum for researchers of the diverse communities working in the field. The common thread running through the different approaches is the exploitation of methods involving several classifiers to obtain a better estimate of the optimal decision rule than can be obtained by trying to optimize the design of a single classifier.


This volume presents 40 papers selected by the scientific committee and organized into seven thematic sessions dealing with boosting, combination rules, multi-class methods, fusion schemes and architectures, neural network ensembles, ensemble strategies, and applications. The workshop program was enriched by invited talks from Jerry Friedman (Stanford University, USA) and Mohamed Kamel (University of Waterloo, Canada), the latter’s paper appearing as the first in this volume.

The workshop was sponsored by the University of Surrey, UK and the University of Cagliari, Italy and was cosponsored by the International Association for Pattern Recognition through its Technical Committee TC1: Statistical Pattern Recognition Techniques. We also wish to express our gratitude to all those who helped to organize MCS 2003. First of all our thanks are due to the members of the Scientific Committee who selected the best papers from a large number of submissions to create excellent technical content. Special thanks are due to the members of the Organizing Committee, Josef Kittler, Rachel Gartshore, Giorgio Fumera and Giorgio Giacinto, for their indispensable contributions to local organization and Web site management.

June 2003

Terry Windeatt

Fabio Roli
Workshop Chairs
Terry Windeatt (Univ. of Surrey, UK)
Fabio Roli (Univ. of Cagliari, Italy)

Scientific Committee
J.A. Benediktsson (Iceland)
H. Bunke (Switzerland)
L.P. Cordella (Italy)
B.V. Dasarathy (USA)
R.P.W. Duin (The Netherlands)
C. Furlanello (Italy)
J. Ghosh (USA)
T.K. Ho (USA)
S. Impedovo (Italy)
N. Intrator (Israel)
A.K. Jain (USA)
M. Kamel (Canada)
J. Kittler (UK)
L.I. Kuncheva (UK)
L. Lam (Hong Kong)
D. Landgrebe (USA)
D.-S. Lee (USA)
D. Partridge (UK)
A.J.C. Sharkey (UK)
K. Tumer (USA)
G. Vernazza (Italy)

Local Committee
G. Fumera (Univ. of Cagliari, Italy)
R. Gartshore (Univ. of Surrey, UK)
G. Giacinto (Univ. of Cagliari, Italy)
J. Kittler (Univ. of Surrey, UK)

Sponsored By
University of Surrey, University of Cagliari
International Association for Pattern Recognition

Supported By
University of Surrey, University of Cagliari
Dept. of Electrical and Electronic Eng. of University of Cagliari
# Table of Contents

## Invited Paper

Data Dependence in Combining Classifiers ........................................... 1  
*Mohamed S. Kamel and Nayer M. Wanas*

## Boosting

Boosting with Averaged Weight Vectors ............................................. 15  
*Nikunj C. Oza*

Error Bounds for Aggressive and Conservative AdaBoost ...................... 25  
*Ludmila I. Kuncheva*

An Empirical Comparison of Three Boosting Algorithms  
on Real Data Sets with Artificial Class Noise ..................................... 35  
*Ross A. McDonald, David J. Hand, and Idris A. Eckley*

The Beneficial Effects of Using Multi-net Systems That Focus  
on Hard Patterns ................................................................. 45  
*J. Arenas-García, A.R. Figueiras-Vidal, and A.J.C. Sharkey*

## Combination Rules

The Behavior Knowledge Space Fusion Method: Analysis of Generalization  
Error and Strategies for Performance Improvement .................................. 55  
*Sarunas Raudys and Fabio Roli*

Reducing the Overconfidence of Base Classifiers  
when Combining Their Decisions ......................................................... 65  
*Sarunas Raudys, Ray Somorjai, and Richard Baumgartner*

Linear Combiners for Classifier Fusion:  
Some Theoretical and Experimental Results ........................................ 74  
*Giorgio Fumera and Fabio Roli*

Comparison of Classifier Selection Methods  
for Improving Committee Performance ............................................. 84  
*Matti Aksela*

Towards Automated Classifier Combination for Pattern Recognition ...... 94  
*Alper Baykut and Ayşil Erçil*
# Multi-class Methods

Serial Multiple Classifier Systems Exploiting a Coarse to Fine Output Coding .................................................. 106
   Josef Kittler, Ali Ahmadyfard, and David Windridge

Polychotomous Classification with Pairwise Classifiers: A New Voting Principle ............................................ 115
   Florin Cutzu

Multi-category Classification by Soft-Max Combination of Binary Classifiers ..................................................... 125
   Kaibo Duan, S. Sathiya Keerthi, Wei Chu, Shirish Krishnaj Shevade, and Aun Neow Poo

A Sequential Scheduling Approach to Combining Multiple Object Classifiers Using Cross-Entropy .............. 135
   Derek Magee

Binary Classifier Fusion Based on the Basic Decomposition Methods ........... 146
   Jaepil Ko and Hyeran Byun

# Fusion Schemes Architectures

Good Error Correcting Output Codes for Adaptive Multiclass Learning . . 156
   Elizabeth Tapia, José Carlos González, and Javier García-Villalba

Finding Natural Clusters Using Multi-clusterer Combiner Based on Shared Nearest Neighbors ................................. 166
   Hanan Ayad and Mohamed Kamel

An Ensemble Approach for Data Fusion with Learn++ ......................... 176
   Michael Lewitt and Robi Polikar

The Practical Performance Characteristics of Tomographically Filtered Multiple Classifier Fusion ..................... 186
   David Windridge and Josef Kittler

Accumulated-Recognition-Rate Normalization for Combining Multiple On/Off-Line Japanese Character Classifiers Tested on a Large Database ............................................................... 196
   Ondrej Velek, Stefan Jaeger, and Masaki Nakagawa

Beam Search Extraction and Forgetting Strategies on Shared Ensembles . . 206
   V. Estruch, C. Ferré, J. Hernández-Orallo, and M.J. Ramírez-Quintana

A Markov Chain Approach to Multiple Classifier Fusion ................. 217
   S.P. Luttrell
Neural Network Ensembles

A Study of Ensemble of Hybrid Networks with Strong Regularization . . . . . 227
Shimon Cohen and Nathan Intrator

Combining Multiple Modes of Information
Using Unsupervised Neural Classifiers .............................................. 236
Khurshid Ahmad, Matthew Casey, Bogdan Vrusias, and Panagiotis Saragiotis

Neural Net Ensembles for Lithology Recognition ................................. 246

Improving Performance of a Multiple Classifier System
Using Self-generating Neural Networks .............................................. 256
Hirotaka Inoue and Hiroyuki Narihisa

Ensemble Strategies

Negative Correlation Learning and the Ambiguity Family
of Ensemble Methods ........................................................................ 266
Gavin Brown and Jeremy Wyatt

Spectral Coefficients and Classifier Correlation ................................. 276
Terry Windeatt, R. Ghaderi, and G. Ardeshir

Ensemble Construction via Designed Output Distortion ...................... 286
Stefan W. Christensen

Simulating Classifier Outputs
for Evaluating Parallel Combination Methods ................................... 296
H. Zouari, L. Heutte, Y. Lecourtier, and A. Alimi

A New Ensemble Diversity Measure Applied to Thinning Ensembles ...... 306
Robert E. Banfield, Lawrence O. Hall, Kevin W. Bowyer, and W. Philip Kegelmeyer

Ensemble Methods for Noise Elimination in Classification Problems ...... 317
Sofie Verbaeten and Anneleen Van Assche

Applications

New Boosting Algorithms for Classification Problems with Large Number
of Classes Applied to a Handwritten Word Recognition Task ............... 326
Simon Günter and Horst Bunke

Automatic Target Recognition Using Multiple Description Coding Models
for Multiple Classifier Systems ......................................................... 336
Widhyakorn Asdornwised and Somchai Jitapunkul
Table of Contents

A Modular Multiple Classifier System for the Detection of Intrusions in Computer Networks .............................................. 346
   Giorgio Giacinto, Fabio Roli, and Luca Didaci

Input Space Transformations for Multi-classifier Systems Based on n-tuple Classifiers with Application to Handwriting Recognition .... 356
   K. Sirlantzis, S. Hoque, and M.C. Fairhurst

Building Classifier Ensembles for Automatic Sports Classification .... 366
   Edward Jaser, Josef Kittler, and William Christmas

Classification of Aircraft Maneuvers for Fault Detection ............... 375
   Nikunj C. Oza, Kagan Tumer, Irem Y. Tumer, and Edward M. Huff

Solving Problems Two at a Time: Classification of Web Pages Using a Generic Pair-Wise Multiple Classifier System .................. 385
   Hassan Alam, Fuad Rahman, and Yuliya Tarnikova

Design and Evaluation of an Adaptive Combination Framework for OCR Result Strings ............................................. 395
   Elke Wilczok and Wolfgang Lellmann

Author Index ........................................................................... 405