Guest Editors' Introduction to the Special Section on Shape Analysis and Its Applications in Image Understanding

Anuj Srivastava, James N. Damon, Ian L. Dryden, and Ian H. Jermyn

WE present the special section on Shape Analysis and Its Applications in Image Understanding to the *IEEE Transactions on Pattern Analysis and Machine Intelligence*. This special section attracted 21 papers, of which seven high-quality papers were recommended for publication. Each paper was reviewed by at least three reviewers and more than 50 reviewers participated in this review process. We are very grateful to these outstanding reviewers for their help and their contribution to the success of this effort. The editors are also thankful to Professor Laurent Younes of the Johns Hopkins University, Baltimore, Maryland, and Professor Alain Trouvé of the École Normale Supérieure Cachan, France, for their participation in this special section.

This section is dedicated to investigating and advancing the role of shape in computer vision and image understanding. Shape is a fundamental characteristic of objects and, thus, has an important role to play in their detection and recognition in image data. Although shape has been used in a variety of ways in the past, there has been a resurgence of ideas and methods for studying shape in recent years. In particular, studies of shape spaces, driven by tools from functional analysis, differential geometry, and statistics, have increased remarkably. Since shape is defined as a geometric quantity that is invariant to certain transformations, the techniques from standard Euclidean calculus and statistics do not apply directly. Shapes are most naturally studied as quotient spaces of certain manifolds under the actions of groups of shape-preserving transformations. Within this framework, several representations have been explored.

One of the earliest ideas in this regard was landmark-based shape analysis, pioneered by David Kendall. This approach is based on selecting a finite number of salient points, or landmarks, on a shape and restricting the analysis to the manifold formed by these points modulo shape-preserving transformations. This representation is perhaps the most advanced in terms of the tools for statistical analysis and stochastic inference that have been developed for it. The first two papers in this section are devoted to modeling and analysis using landmark representations for shapes. The first paper, titled "Nonstationary Shape Activities: Dynamic Models for Landmark Shape Change and Applications," by Samarjit Das and Namrata Vaswani, develops a model for the evolution of 2D silhouettes and 3D human body shapes in video data. The second paper, titled "Intrinsic MANOVA for Riemannian Manifolds with an Application to Kendall's Space of Planar Shapes," by Stephan Huckemann, Thomas Hotz, and Axel Munk, takes a general view and develops tools for performing multivariate analysis of variance on 2D shape data, with applications to the analysis of leaf shapes in forest biometry.

The development of shape analysis for use in specific contexts in computer vision is also growing. One example is the detection of parts or pieces of objects in images and their joint use under shape-based considerations. The paper "Shape-Based Human Detection and Segmentation via Hierarchical Part-Template Matching," by Zhe Lin and Larry S. Davis, describes a tree representation of parts that is used for organizing and matching segmented parts in images, under the learnt models. These ideas are illustrated by detecting human shapes in images. The next paper, titled "Rigid Shape Matching by Segmentation Averaging," by Hongzhi Wang and John Oliensis, studies matching using a representation of shapes obtained from image segmentations. It uses the "structure entropy" of a combination of two segmentations to measure shape similarity, and creates robustness by averaging over all possible segmentations of each image.

Due to advances in imaging technology and computational power, there is a growing interest in shape analysis of 3D objects. The shape analysis of their boundaries as surfaces naturally brings up both new challenges and benefits. One important challenge is to establish correspondences (registration) between different surfaces in an automated fashion. The paper "Automatic Construction of Correspondences for Tubular Surfaces," by Toon Huysmans, Jan Sijbers, and Brigitte Verdonk, addresses this problem for tubular surfaces using a cylindrical coordinate system. While the statistical shape analysis of a single object is a difficult problem, this task is even more difficult for multiple objects, where one wants joint statistical measures for the shapes of these objects. The paper titled "Multi-Object Analysis of Volume, Pose, and Shape Using

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Statistical Discrimination," by Kevin Gorczowski, Martin Styner, Jan Yeon Jeong, J.S. Marron, Josephy Piven, Heather Cody Hazlett, Stephen M. Pizer, and Guido Gerig, addresses this problem using the medial axis representation which replaces landmarks on the boundaries of objects by internal medial structures; these medial representations are then statistically analyzed for a population of objects and collections of multiple objects. The last paper, "Ricci Flow for 3D Shape Analysis," by Wei Zheng, Dimitris Samaras, and Xianfeng David Gu, uses Ricci Flow, which is a form of heat flow, but for curvature. It provides a natural representation of the boundary surface of an object using a conformal mapping, independent of the topology. This method has been exploited to include feature points and curves. This representation reduces 3D surface matching to the better understood 2D image matching for conformal mappings.

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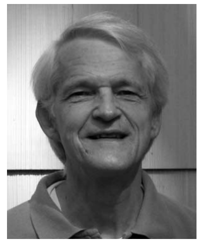
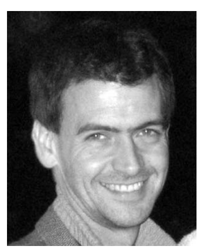
Guest Editors

Anuj Srivastava received the MS and PhD degrees in electrical engineering from Washington University in St. Louis, Missouri, in 1993 and 1996, respectively. He is a professor of statistics at Florida State University (FSU) in Tallahassee, which he joined in 1997 as an assistant professor after spending the year 1996-1997 at Brown University as a visiting researcher. He has received the Developing Scholar and the Graduate Faculty Mentor Awards at FSU. His research is focused on pattern theoretic approaches to problems in image analysis, computer vision, and signal processing. He has developed computational tools for performing statistical inferences on certain nonlinear manifolds, in particular the shape spaces of curves and surfaces. He has published more than 100 journal and conference articles in these areas. His research has been supported by grants from the NSF, the ARO, the AFOSR, and the Northrop-Grumman Company.



James N. Damon received the BA degree in mathematics from Dartmouth College in 1967, the Diploma in advanced mathematics from Oxford University, United Kingdom, in 1969, and the PhD degree in mathematics from Harvard University in 1972. He has been a professor of mathematics at the University of North Carolina, Chapel Hill, since 1983. He has been a Fulbright Lecturer at the Universidad Tecnica del Estado in Santiago Chile, an SERC Senior Visiting Fellow at the University of Liverpool, a Fulbright Scholar at the Mathematical Institute of the University of Warwick, a visiting CNRS "Professeur Associé" at the University of Nice, and an invited semester visiting member of both the Issac Newton Institute at Cambridge and the Institute for Mathematics and Its Applications in Minneapolis. In addition, he has held invited short term visiting positions at the Tokyo Institute of Technology, Instituto Matematica Pura et Applicada in Rio de Janeiro, Brazil, University of Copenhagen IT, Université de Provence, and Instituto Matematica Interdisciplinar in Madrid. He has served on the editorial board of the *Houston Journal of Mathematics* and as an editor for the *Proceedings of the ICTP Summer Institute* in Trieste on singularity theory. His areas of interest include singularity theory and its applications to bifurcation theory and computer imaging, especially medical imaging.

Ian L. Dryden received the PhD degree in statistics from the University of Leeds, United Kingdom, in 1989 for work on statistical shape analysis. He is a professor in the School of Mathematical Sciences, University of Nottingham, United Kingdom, and the Department of Statistics, University of South Carolina. His career began at the University of Leeds in 1989 as a Lecturer then Senior Lecturer in statistics. He was visiting assistant professor in statistics at the University of Chicago from 1996-1997, and then he moved to the University of Nottingham in 2000 as a professor of statistics. His research interests include shape analysis, statistical image analysis, medical image analysis, spatial statistics, high-dimensional data analysis, and applications of statistics in biology, medicine and computer science. He was recently chair of the Research Section of the Royal Statistical Society.



Ian H. Jermyn received the BA Honours degree (First Class) in physics from Oxford University in 1986, and the PhD degree in theoretical physics from the University of Manchester, United Kingdom, in 1991. After working for a total of three years at the International Centre for Theoretical Physics in Trieste, Italy, he began study for the PhD degree in computer vision in the Computer Science Department of the Courant Institute of Mathematical Sciences at New York University, receiving the PhD in July 2000. He joined the Ariana research group at INRIA Sophia-Antipolis as a postdoctoral researcher in August 2000. Since September 2001, he has been a senior research scientist in the Ariana group. His main research interests concern the modeling of shape and texture, and information geometry as applied to inference.