Statistical Inferences on Shape Manifolds
Version V.6 (05/02/05)

Goals: To identify and discuss outstanding issues in algorithmic shape analysis, statistical inferences on shape manifolds, and applications to areas such as medical imaging, homeland security and military target recognition.

More specific goals during the workshop:

1. Introduce, discuss, and analyze state-of-the-art techniques in shape analysis.
2. Prepare minutes of the discussions and enumerate important challenges.
3. Motivate and steer younger participants to the area of statistical shape analysis.
4. Allow for plenty of interactions between participants, especially between mathematicians and more applied researchers.

Participants: Greg Arnold, Yan Cao, Jamylle Carter, Damiel Cremers, Xavier Descombes, Matt Feiszli, Peter Giblin, Polina Golland, Ulf Grenander, David Groisser, Weihong Guo, Shantanu Joshi, Jonathan Kaplan, David Kaziska, John Kent, Nkem-Amin Khumbah, Kathryn Leonard, Kanti Mardia, Andrea Mennucci, Mario Micheli, Peter Michor, Michael Miller, Washington Mio, David Mumford, Kenneth Nordstrom, Vic Patrangenaru, Eitan Sharon, Stefano Soatto, Anuj Srivastava, Kenneth Stephenson, Namrata Vaswani, Anthony Yezzi.

A Common Theme for Discussion at the Workshop

Across different subtopics, a common theme will be discussions on the choices of representations, algorithms for efficient computations, and ideas for imposition of statistical models. In each context, we would like to start from an introductory short talk, followed by other talks and/or discussions that focus on fundamental issues, both from a mathematical perspective and from (application-driven) requirements perspective. Additionally, we would like to unify/simplify terminology across subtopics and communities to improve communication and understanding. Finally, we would like to enumerate and report open issues in this area and publish it on a website.

Date: Thursday, May 5th, 2005

6:30pm We are planning an informal **get-together over dinner** at Cibo restaurant in the hotel. In case you are interested, you are welcome to join us. Let's plan on meeting in the hotel lobby at around 6:30pm

Date: Friday, May 6th, 2005

9:00 – 9:10am **Welcome Remarks**
Brian Conrey, Director, ARCC

9:10 – 9:45am **Workshop Overview**
Organizers (David Mumford, Washington Mio, Anuj Srivastava)

Participant Introductions

1. **Group of Diffeomorphisms and Its Actions:** A variety of "background deformation" techniques have been used to capture and analyze shape variations, especially in medical image analysis. We expect to review the general approach, present new ideas in this area, and discuss outstanding issues in analysis of shapes using diffeomorphisms.

9:45am – **Topic Introduction -- General framework, Notation**
Laurent Younes, Johns Hopkins University

Break (30 minutes)

Biological Growth Models
Ulf Grenander, Brown University

noon - 2:00pm: Lunch

Results/challenges in 3D Medical Shape Analysis
Michael Miller, Johns Hopkins University

Break (15 minutes)

Multiscale Diffeomorphisms
Jonathan Kaplan, Harvard University

Break (15 minutes)

3:30pm -- **Discussion** on topics including strengths and limitations of template-based methods, limitations of tangent representations, curvature of shape spaces, stability of geodesic equations, dynamic models for shape variations, growth models, statistics on group of diffeomorphisms.

Happy Hour

Date: Saturday, May 7th, 2005

2. **Shapes of Planar Curves**: Shapes of curves in images has become an active area of research. Several different representations (coordinate functions, angle function, curvature function), constraints (similarity transform invariance, closure constraint), and metrics (L^p, Sobolev, conformal, etc) have been proposed. We expect to discuss these different choices, their merits and limitations, and their applications in statistical analyses.

9:00am –

Topic Introduction
Washington Mio, Florida State University

Break (45 minutes)

Representations/Metrics for Shapes of Planar Curves
David Mumford, Brown University

noon - 2:00pm: Lunch

Metrics and Geodesics in Spaces of Curves
Tony Yezzi, Georgia Tech University

Break (15 minutes)

Conformal Geometry and Circle Packing
Ken Stephensen, University of Tennessee

Break (15 minutes)

Curvature of Shape Spaces
Peter Michor, University of Vienna

4:00pm –

Discussion on topics including (Task-dependent metrics, Computational costs, Geodesic computations, Shooting methods, Curve-straightening flows, Non unit-speed parameterizations, Implicit representations)

Banquet

Date: Sunday, May 8th, 2005

3. **Shapes Defined by Landmarks in 2D and 3D:** Since Kendall's work on representation and analysis of shapes using landmarks, there has been tremendous activity in development and application of this methodology. We would like to discuss newer ideas and unsolved issues in this approach.

9:00am -- **Topic Introduction**
John Kent, University of Leeds

Advances/Challenges
Kanti Mardia, University of Leeds

Break (15 minutes)

Discussion on topics including matching problem, strengths and limitations of landmark solutions -- (time-varying number of landmarks, stochastic processes, particle filtering, intrinsic statistics, limitations of tangent representations, useful shape coordinate systems, Veronese-Whitney embeddings)

noon - 2:00pm: Lunch

2:00pm – Presentations on databases, softwares

Break

3:30pm – **Poster Session**
See last page for poster presenters

Happy Hour

Date: Monday, May 9th, 2005

Statistics on Shapes of Planar Curves:

9:00am – **Statistics of Planar Shapes, Probability Models**
Anuj Srivastava, Florida State University

Break (15 minutes)

Statistics of Planar Shapes
Vic Patrangenaru, Texas Tech University

Break (15 minutes)

11:00am – noon **Discussion** on topics including (Bayesian inferences, shape extraction, stochastic processes on shape spaces, global motion versus local deformation, nonparametric models)

noon - 2:00pm: Lunch

4. **3D Shape Analysis and Challenges:** Of course, an important challenge is to analyze shapes of objects and surfaces using 3D data. With the advent of 3D scanners and range cameras, 3D shape data is readily available for use in object classification and recognition. Analysis of 3D shapes lags behind its counterpart in 2D shape analysis.

2:00pm – **Representations and Analysis of surfaces in 3D**
Peter Giblin, University of Liverpool

Break (15 minutes)

3D Medical Shape Analysis
TBA

Break (30 minutes)

4:00pm – **Discussion** on topics including: ideas for registration of surfaces, surface mappings, explicit (e.g. deformation) versus implicit (level set) representations, interesting applications, available datasets, range image analysis.

Happy Hour

Poster Session

In addition to a standard poster board presentations, laptop/PC based demos are encouraged.

Possible presenters:

1. Shantanu Joshi, FSU on *Shape Clustering, Learning and Testing*
2. David Kaziska, FSU on *Human Recognition using Gait ShapeAnalysis*
3. Greg Arnold, AFRL on *Object-Image Metric*
4. Yan Cao, JHU maybe on *Generalized Cylinders*
5. Kanti Mardia, Leeds, on (i) *Matching Active sites*, and (ii) *Protein Matching*
6. Vic Patrangenaru, Texas Tech, on *3D and 2D Analysis for Electrophoretic Gels*
7. Namrata Vaswani, Georgia Tech, on *Tracking Continuous Curves and Landmark Configurations*
8. Anuj Srivastava, FSU, on *A Pattern Theoretic Model for Biological Growth*.
9. Kathryn Leonard, Cal. Tech, on *Measuring Shape Space: Epsilon-Entropy, Adaptive Coding and Two-Dimensional Shape.*
10. David Groisser, UF, on (i) *Finding Non-Rigid Correspondences Between Implicitly Defined Plane Curves*, or (ii) *Existence and Local Uniqueness of Certain Optimal Correspondences Between Plane Curves*.
11. Daniel Cremers, Siemens Corporate Research, on *Nonparametric Statistical Shape Models for Bayesian Inference*
12. Polina Golland, MIT, on *Discriminative Analysis and Interpretation in Shape Space.*
13. Xavier Descombes, INRIA, on *Object Recognition from Aerial Images*
14. Eitan Sharon, on *2D-shape analysis using conformal mapping: computational aspects*