Inverse problems in earth observation and cartography


# Associated Team Shapes: Three Year Evaluation

http://www-sop.inria.fr/ariana/Projets/Shapes/

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# Overview



- People
- Visits
- Joint publications and further output
- Science:
  - Tree crown classification.
  - Marked point processes for arbitrarily-shaped objects and multiple birth and death dynamics.
  - Shape analysis of curves in Euclidean spaces.
  - Looking for shapes in two-dimensional, cluttered point clouds.

# People



- INRIA
  - Senior
    - X. Descombes, I. H. Jermyn, J. Zerubia.
  - Junior
    - M. S. Kulikova, A. El Ghoul, C. Benedek.
- FSU
  - Senior
    - A .Srivastava, E. Klassen, V. Patragenaru, A. Barbu.
  - Junior
    - S. Joshi, J. Su. S. Kurtek, W. Liu.

# Visits



- 2007:
  - April: Visit to FSU. Participants: X. Descombes, I. Jermyn, **M.S. Kulikova**.
    - "Shape Day" Workshop, Statistics Department, FSU. Plenary speaker: Prof. Kanti Mardia, Univ of Leeds. Participants: X. Descombes, I.Jermyn, **S. Joshi**, **M. S. Kulikova**, A. Srivastava.
  - June: Visit to INRIA. Participant: **S. Joshi**.
  - September: Visit to INRIA. Participants: V. Patrangenaru, A Srivastava.
- 2008:
  - April: Visit to FSU. Participants: X. Descombes, I. Jermyn.
  - June: Visit to INRIA. Participant: A. Srivastava.
  - July: Visit to INRIA. Participants: E. Klassen, A. Barbu.
  - December: Visit to FSU. Participants: **A. El Ghoul**, **C. Benedek** (+ seminars).
  - December: Visit INRIA. Participant: **J. Su**.
- 2009:
  - February: Visit to FSU. Participant: **M. S. Kulikova** (+ seminar).
  - March: Visit to FSU. Participant: I. Jermyn.
  - June: Visit to INRIA. Participants: A. Srivastava**, S. Kurtek**, **W. Liu**.

# Joint publications

- Conference papers
  - "Tree classification using radiometry, texture and shape based features", **M. S. Kulikova**, M. Mani, A. Srivastava, X. Descombes, J. Zerubia. Proc. EUSIPCO, 2007.
  - "An efficient representation for computing geodesics between n-dimensional elastic shapes", **S. Joshi**, E. Klassen, A. Srivastava, I. H. Jermyn. Proc. CVPR, 2007.
  - "Riemannian analysis of probability density functions with applications in vision" , A. Srivastava, I. H. Jermyn, **S. Joshi**. Proc. CVPR, 2007.
  - "Removing shape-preserving transformations in square-root elastic (SRE) framework for shape analysis of curves", **S. Joshi**, E. Klassen, A. Srivastava, I. H. Jermyn. Proc. EMMCVPR, 2007.
  - "Bayesian classification of shapes hidden in point cloud data", A. Srivastava, I. H. Jermyn, Proc. IEEE DSP Workshop, 2009.
- Journal papers
  - "Looking for shapes in two-dimensional cluttered point clouds", A. Srivastava, I. H. Jermyn. IEEE Trans. Pattern Analysis and Machine Intelligence, 2009.
  - "Shape analysis of elastic curves in Euclidean spaces", **S. Joshi**, E. Klassen, **W. Liu**, I. H. Jermyn, A. Srivastava. IEEE Trans. Pattern Analysis and Machine Intelligence (under review).

# Further output

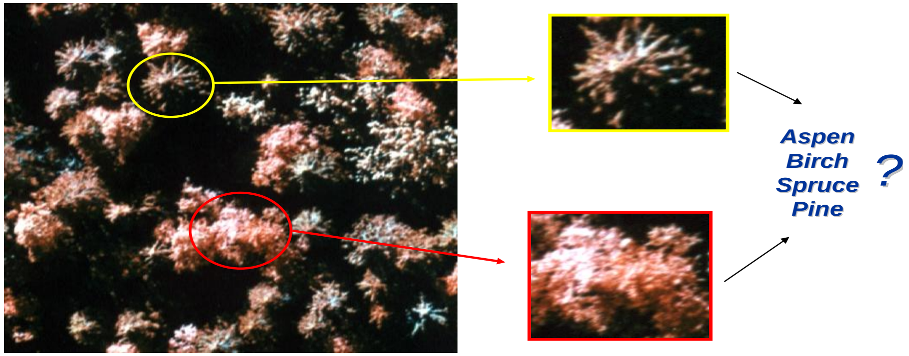


- Conference papers
  - "A marked point process model with strong prior shape information for extraction of multiple, arbitrarily-shaped objects", **M. S. Kulikova**, I. H. Jermyn, X. Descombes, E. Zhizhina, J. Zerubia. Proc. IEEE SITIS, 2009.
  - "Extraction of arbitrarily shaped objects using stochastic multiple birth-and-death dynamics and active contours", **M. S. Kulikova**, I. H. Jermyn, X. Descombes, E. Zhizhina, J. Zerubia. Proc. IS&T/SPIE Electronic Imaging Conference, 2010.
- PhD defences
  - **S. Joshi**: July, 2007. "Inference in shape spaces with applications to computer vision".
  - **M. S. Kulikova**: December, 2009. "Shape recognition for image scene analysis". (A. Srivastava is a member of PhD committee.)
- Training
  - **M. S. Kulikova**, **A. El Ghoul**, **C. Benedek** all gave seminars during their visits to FSU.
  - **M. S. Kulikova** benefited greatly from in-depth discussions on theory and code with A. Srivastava and **S. Joshi**.

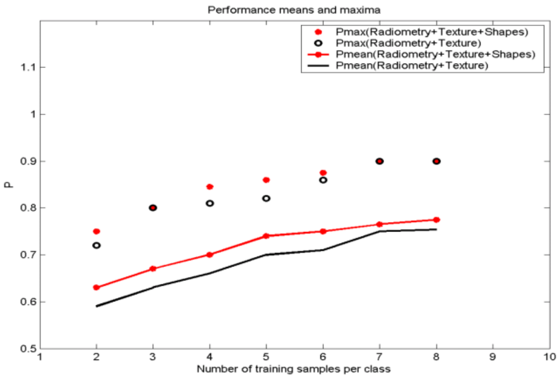
- Motivation: facilitate the task of forest inventory and assessment.
- Obtain information about:
  - Density of planting;
  - Age of trees;
  - Stem volume;
  - Tree species composition;
  - Biotopes and habitats.

# Improving tree species classifiers based on radiometry and texture using shape descriptors

- Classical radiometric and textural descriptors:
  - Histogram; Haralick features.
- Shape descriptors:
  - Distance to a circle; total curvature; number of convexities; size of irregularities.
- SVM with Gaussian kernel.



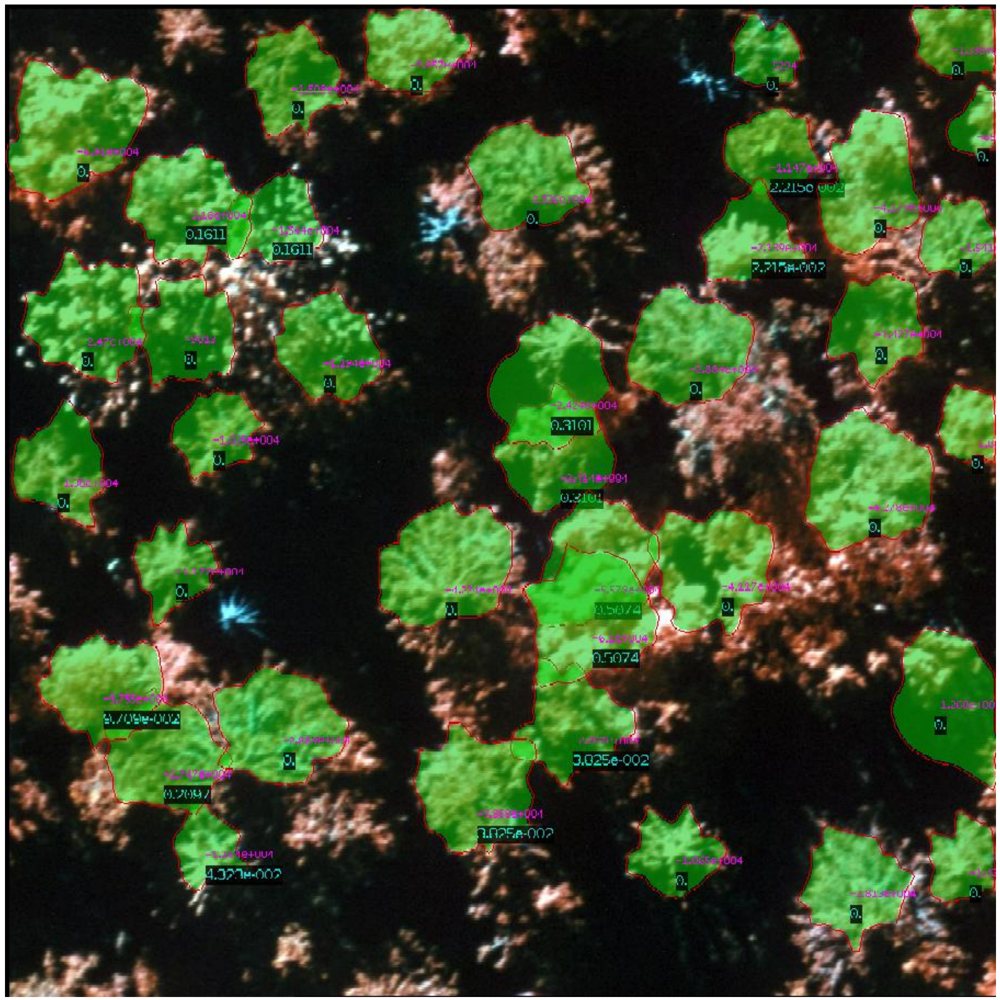

Resolution 3 cm, ©Swedish University of Agricultural Sciences



# Multi-object detection using point process models of arbitrary shapes

- Goal: improve the geometric accuracy of marked point process models.
- Objects are no longer parametric (circle, rectangle,...) but are arbitrary closed curves.
  - But objects are chosen to be local minima of single-object energy (active contour):
    - The possible objects are adapted to the data;
    - Keeps computational complexity under control.
    - Shape models can be included as a prior.
- Optimization is performed using a multiple birth and death algorithm (*cf*. EA Odessa).

# Result of tree crown delineation



# Shape analysis in $\mathbb{R}^n$

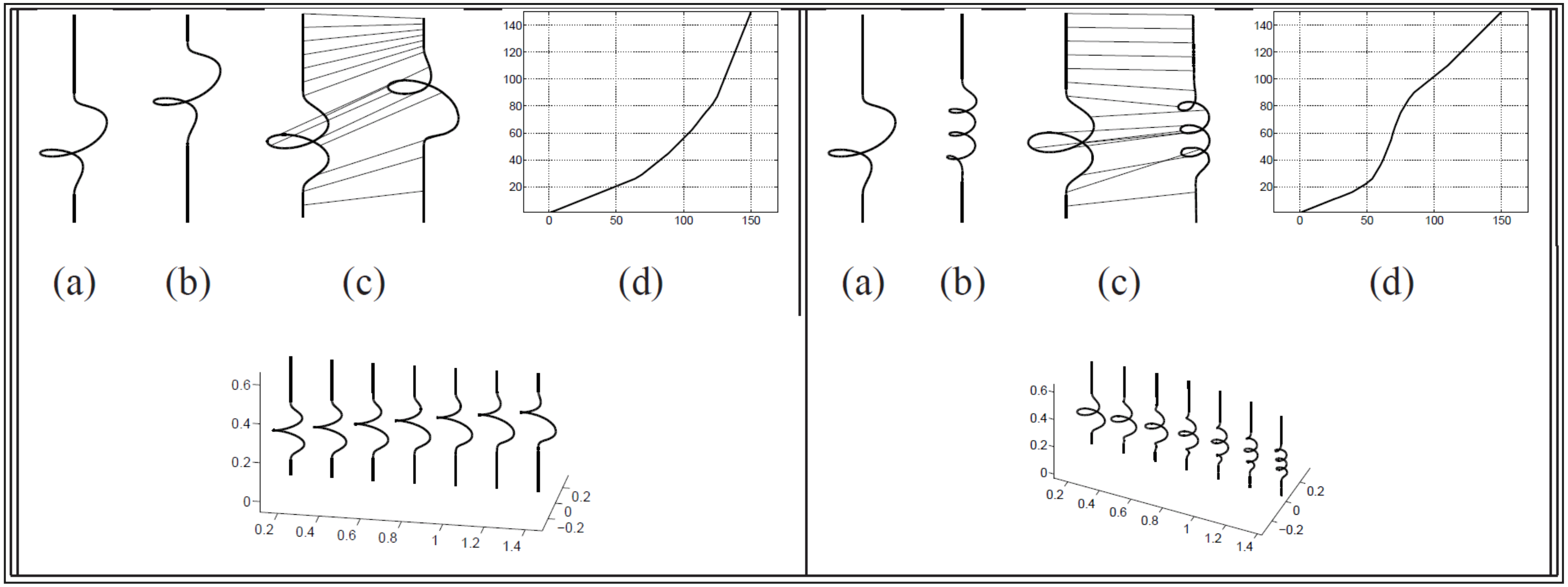
- Space $\Gamma$ of curves $\gamma$: I $\to \mathbb{R}^n$.
- Place Diff(I) $\times$ Sim($\mathbb{R}^n$) equivariant metric *G* on $\Gamma$ to measure shape similarity.
- Popular choice: elastic metric.
  - Measures changes in orientation *and* stretching.
  - Preserves corners and other 'shape' features.
- One-parameter family $G_c$, c $\in \mathbb{R}^+$.
  - Problem: how to choose?

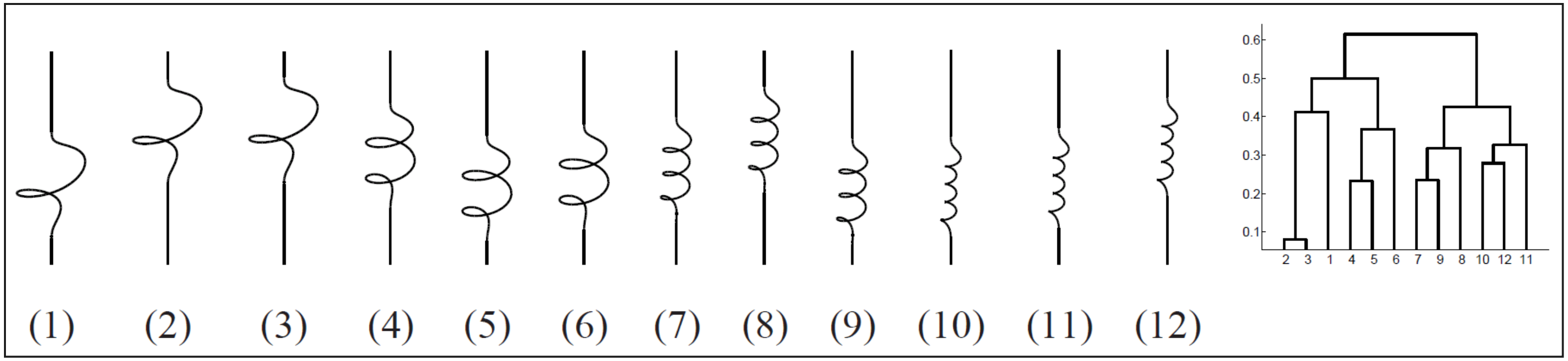
# Shape analysis in $\mathbb{R}^n$



- For n = 2, Younes et al. (2008) used c = ½.
  - Analytically tractable, but does not extend to n > 2.
- We showed:
  - n = 2: $\Gamma$ is flat for all c except for singularity at origin. Singularity disappears for c = 1.
  - n > 2: $\Gamma$ is curved for all $c \neq 1$, with singularity at origin. Only for c = 1 is $\Gamma$ flat, and this for all n.
- Thus c = 1 and its Euclidean 'coordinates' are uniquely selected as a shape representation
  - Leads to greatly simplified algorithms.

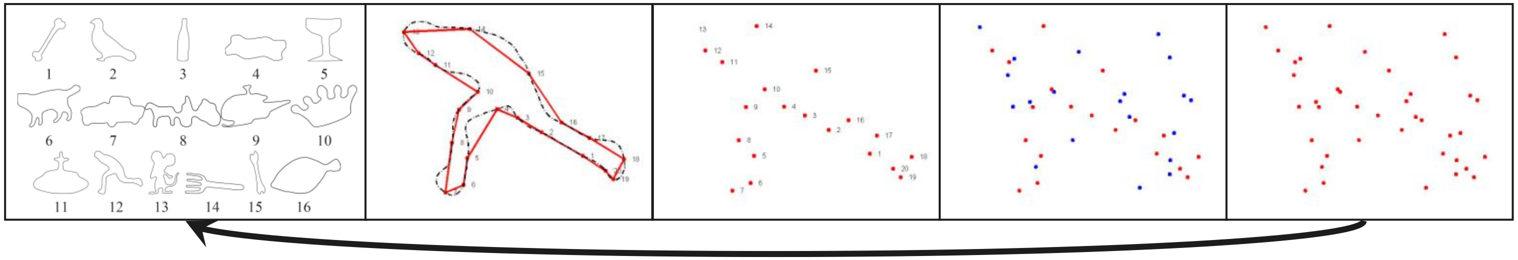
# Synthetic result



# Looking for shapes in 2d cluttered point clouds

- Image formation:
  - An object has a bounding contour in the image.
  - Sensor produces noisy, sub-sampled contour.
  - The background and interior also produce ‘clutter’.
- Problem: given the cluttered, noisy, sampled points, recognize the object from a given set of object classes.



# Looking for shapes in 2d cluttered point clouds

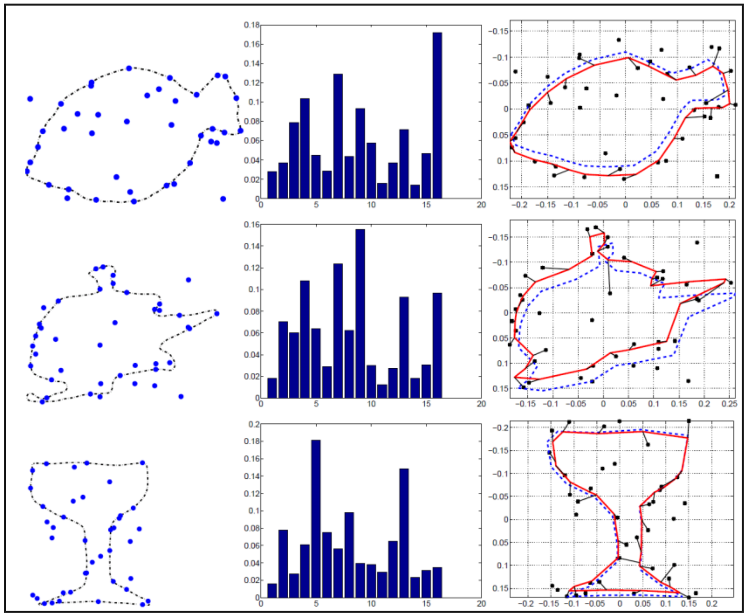


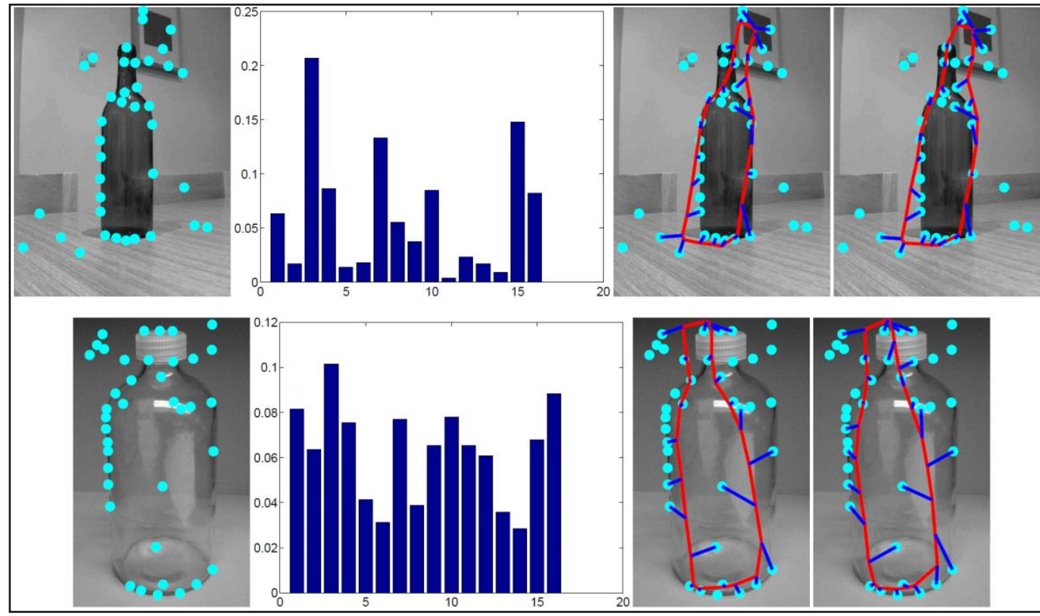
- MAP estimation: $C^* = \arg\max_C P(C \mid y)$ .
- Under some (removable) assumptions:

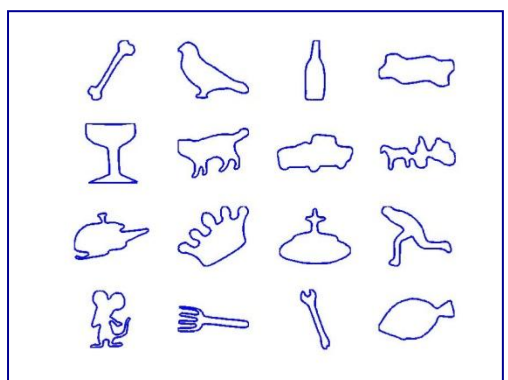
$$\mathrm{P}(C|\mathbf{y}) \propto \mathrm{P}(C)\,\mathrm{P}(\mathbf{y}|C) \propto \sum_i \iiint dq\, d\sigma\, dg\, \mathrm{P}(\mathbf{y}|i,\sigma,g,q)\,\mathrm{P}(\sigma|C)\,\mathrm{P}(q|C)$$

- Where:
  - $q \in \Gamma / (\mathrm{Diff}(I) \times \mathrm{Sim}(\mathbb{R}^2))$; $g \in \mathrm{Sim}(\mathbb{R}^2)$; $\sigma$ is a sampling of the curve (random number n of random points on the curve); *i* is an injection of these n points into the m data points.
- Compute integrals by sampling *q* and $\sigma$ and maximizing over *g* and *i*.

# Results





# Future



- Work on shape will continue with FSU, on:
  - Making precise the mathematical framework of shape space.
  - Extending the approach to surfaces $\Sigma: S^2 \to \mathbb{R}^n$.
- Work of **M. S. Kulikova** will lead to further work in Ariana combining marked point processes with higher-order active contours.
- Ariana will participate, along with several other EPIs, in a new Shapes WG at INRIA SAM.
- EADS Foundation grant 2010–2012 will fund a PhD on modelling complex shapes with HOACs.