Gaussian Process Classification Using Image Deformation

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ABSTRACT
An image deformation algorithm is integrated with a Gaussian process classifier for application to remote-sensing tasks in which data is in the form of imagery. To combine these disparate techniques, we introduce a novel kernel covariance function for the Gaussian process that allows us to incorporate the result of the image deformation algorithm into a rigorous Bayesian classification framework. The resulting classifier is completely non-parametric in the sense that no parameters or hyperparameters must be learned. The promise of the proposed algorithm is demonstrated on a data set of real, measured land mine data.

Summary:
• A new, novel covariance function integrates the result of an image deformation algorithm into a Gaussian process classification framework
• Method is relevant when data points are initially in the form of images
• Approach obviates feature extraction process
• Image deformation algorithm permits large-scale deformations, preserves topology of structure in original image, and requires no human assistance
• Gaussian process classifier is general and has no parameters to learn
• Paper and extensive additional details available at www.duke.edu/~dpw5

Image Deformation

Gaussian Processes

Novel Covariance Function

Classification

• Image deformation objective: Deform a template image (T) into a study image (S)
• Simplified viscous fluid model governs the non-rigid deformation process
• Model explains how “particles” (image pixels) “flow” (are displaced) in the image during deformation
• Pixel displacement (u) is driven by a set of body forces (b)
• Body forces are manifested by a difference between the template and study images
• Model PDE is solved for velocity (v) of each pixel location (x,y)
• Process is conducted iteratively until deformed template image matches study image

Example deformation result for two image chips

Template Image

Progression of Template Image during deformation process

Study Image

Final Deformation

Final Deformation Applied to a Rectangular Grid

Example deformation process:
1. Determine initial locations of each pixel in the study image
2. Compute initial body forces
3. Solve for velocity field using the simplified viscous fluid model
4. Update body forces based on velocity field
5. Re-compute body forces
6. Repeat steps 2-5 until the deformation process converges

Additional examples of deformation process:
- [1]
- [2]
- [3]

Objective: Detect land mines in a scene from an airborne sensor that collects a ground-penetrating radar image.
- 110 objects (25 mines, 85 clutter) detected, each characterized by a 20 pixel by 20 pixel image chip.
- Train GP classifier on 2 objects (1 mine and 1 clutter, randomly selected), test on remaining 108 objects.
- ROC curves are averages over 1000 trials.

Deformation: Proposed method.
Misfit: New covariance function, but with misfit minimized (without performing deformation)
Features: Extract 3 features from each chip; use standard (Gaussian) covariance function.