AFRL Summer 07 report, 2007: Adviser: Dr Greg Arnold, Wright Patterson Airforce Base, Dayton, OH

This is my report for the 7 week AFRL summer fellowship, I held at Wright-Patterson Airforce Base during the summer of 2007. My advisor was Dr Greg Arnold. I would like to take this oppurtunity of thanking Greg for a great experience and for this unique oppurtunity and for being a great host and colleague. A few survey papers linking many of the ideas below are currently in progress with Greg and myself. Greg and I are also expected to work jointly on many of the problems detailed below. Participation with other faculty involved with AFRL who work with or under Greg particularly at Wright Patterson is hoped as well over many years to come. The remainder of this report is broken down into sections detailing my work.

The report is currently posted at:

http://math.georgiasouthern.edu/ damelin/greg/greg.html

The following papers, presentations and work in progress pertaining to this 7 week stay in Dayton are also posted at:

http://math.georgiasouthern.edu/ damelin/greg/greg.html

Contents of this webpage are as follows:

High data problems-via dimension reduction (supervised learning)

(1) Classification constraint dimensionality reduction (with J. Costa, A. Hero, R. Raich).

(2a) Ccdr and dimension estimation of mstar data (with Sung Jin Wang (joint PhD student with Al Hero) and Al Hero: Power point with results.

(5a) Classification using diffusion bases, SSP-Madison (Joint with Yossi Keller): Power point with results.

(9) Clustering of Cancer Tissues Using Diffusion Maps And Fuzzy ART with Gene Expression Data (with D. Wunsch and R. Xu).

High data problems-via clustering, unsupervised learning, non dimension reduction, graph-clustering methods

(2b) Entropic graph dimension estimator of mstar data (with Sung Jin Wang (joint PhD student with Al Hero) and Al Hero: Power point with results.

(3) Triangle Prim Inequalities (joint with Mark Kliger, P. Olvier and A. Hero).

(4a) Directed study-part 1 (Sung Jin Wang)[with Al Hero].

(4b) Directed study-part 2 (Sung Jin Wang)[with Al Hero].

Radar and Start presentations

(6) X band radar data for 6 points of a rotating octahedron-Poster at CMMSE, IIT, June 2007 (joint with M. Ferrara and undergradute students B. Beevan, T. Brooks and W. Tripplet.

(7) AFRL Start Workshop Presentation, July 2007.

Compressive Sampling

(8) This is a part of several chapters on compressive sampling written jointly with Willard Miller for our forthcoming book on signal processing.

We now provide a short summary of each of our projects. When work above relates to a particular project, we will indicate this directly.

Part 1

Large data poblems using dimension reduction methods, labelling and local/global dimension estimation. See items (1,2a,5a,9). Here our aim is to use dimension reduction on object space using for example non-linear spectral methods to do various things in image space for example clustering, labeling, feature matching, feature extraction, boundary detection, noise removal, classification in the reduced image space. The reduction is done via a fixed kernel often from a reproducing Hilbert space but more generally group invariant and postive definite. The reduction preserves certain features of the data for example local distances which allow for new metric coordinates in image space sensitive to local distances and robust to noise. Group invariant kernels relate also to different camera models of pictures from object space for example affine and orthographic. Reproducing Hilbert spaces and positive definite, group invariant kernels have been used by myself in many other problems relating to numerical integration, discretization, random matrices. See my homepage http://math.georgiasouthern.edu/damelin and my start talk linked above.

Other ongoing projects using this circle of ideas are as follows:

- Local dimension estimation using non-linear diffusion spectral methods and questions related to data representation by manifolds of local/global given dimension. [The inverse discretization problem has been studied by myself for several years in a series of well cited papers–this study is ongoing].

- Feature and boundary detection using diffusion spectral methods. This is done on radar/ladar mstar data and brachial plexus data of humans with large amounts of fatty tissue.
- Clustering of data using diffusion reduction, labelling and fuzzy ART and related fuzzy tools in image space. See for example the recent [9] on cancer data. We are interesting in developing similar approaches to mstar and other radar/ladar data.
- Out of sample extensions in ccdr labelling diffusion and interpolation and approximation on scattered data, (in relation to the manifold learning problem).
- Noise to feature problems from pictures for nonlinear spectal methods. The linear problem has been understood partially only recently. This also relates to the problem of building invariant detectors which quotient out many different sensors. More precisely, for large classes of kernels and in the limit as the number of data points goes to infinity, we know that the discrete Laplacian converges (pointwise) to a fixed operator for vary general manifolds embedded in the data. There are few results known as to what happens in the case of a finite number of points and when the convergence is taken eigenfunction wise.

Part 2

In this part, we devlop methods to deal with high dimensional data without any reduction. Here we are interested in building graphs on the data by way of kernels which are adaptive for example signature and prim like kernels. This is purely unsupervised learning and clustering. See items (2b,3,4a,4b). We are also interested in corresponding approximation tools on point clouds and quotient spaces and boundary-shape space tracking methods to track moving objects.

Other ongoing projects using this circle of ideas are as follows:

- Signature, prim, triangle inequalities.
- Entropic graphs methods, Entopy limits, shape space and vector support methods.
- Approximation on point clouds via graphs, shannon theory, approximation on quotient spaces.
- Boundary tracking using deformable contours (we have used this in medical imaging with Mumford-sha type models) together with object image, space shape methods to track moving objects in Radar/Ladar (MAJI+Human-Adversarial project).

Part 3

In this part, we apply and develop the the theory of compressive sampling to numerous problems described in parts 1-2. During the summer, I attended a 2 week intensive course on compressive sampling at the IMA, University of Minnesota. In item (8), I present, one of several chapters I am currently writing on the subject in my new book with Willard Miller (UMN) on signal and sensor processing. This chapter was completed during the summer. One particular problem of interest is to develop the theory of compressive sampling with metrics defined by way of nonlinear spectral methods such as diffusions and then apply these methods to many of the problems described above.