TYRUS BERRY

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EDUCATION

2013 PhD in Mathematics (expected June 2013) from George Mason University. GPA: 4.0

- **Thesis:** *Model-Free Techniques for High Dimensional Dynamics*
- **Advisor:** Timothy Sauer

2008 MS in Mathematics from Ohio State University. GPA: 3.5

- **Thesis:** *An Overview of Optimal Stopping Times for Various Discrete Time Games*

2006 BS in Applied Mathematics and
BA in Physics from the University of Virginia. GPA: 3.9

- Graduated with Highest Distinction from the School of Engineering and Applied Sciences

RESEARCH INTERESTS

Dynamical systems, data assimilation, prediction and control systems, nonlinear dimensionality reduction, geometry of data, signal processing, and image/video analysis.

PUBLICATIONS

Articles in Refereed Journals

- T. Berry, F. Hamilton, T. Sauer, N. Peixoto, *Detecting connectivity changes in neuronal networks.* Journal of Neuroscience Methods (Impact Factor: 1.98 and 5-year Impact Factor: 2.4) 209, 388-397 (2012). `http://math.gmu.edu/~tberry/JNM2012.pdf`

  We refine previous work on the Cox method for detecting connections in neuronal networks and improve the multiple hypothesis testing technique. We develop a new statistical test to allow experimental scientists to use the Cox method to determine if a connection strength has changed. We show that the technique is independent of the neuron model and robust to choice of model for the connections and apply the technique to experimental data.

- T. Berry, T. Sauer, *Convergence of periodically-forced rank-type equations.* Journal of Difference Equations and Applications 17 (2011). `http://math.gmu.edu/~tberry/forcedranktype.pdf`

  Previous results on the convergence of rank-type difference equations are elegantly subsumed in a unified theory of sup-contractive difference equations. We show that sup-contractive equations have a limiting periodic behavior with period no more than the forcing period, and independent of the 'memory' of the difference equation.

- T. Berry, S. Heilman, R. Strichartz, *Outer approximation of the spectrum of a fractal laplacian.* Experimental Mathematics 18 (2009), no.4, 449-480. Received 9 citations.

  `http://math.gmu.edu/~tberry/OuterApproximationV6.pdf`

Articles Submitted for Publication

- T. Berry, R. Cressman, Z. Greguric-Ferencek, T. Sauer, *Time-scale separation from diffusion-mapped delay coordinates.* Submitted in June 2012 to SIAM Journal on Applied Dynamical Systems (Impact Factor: 1.903, Rank: 16/175), 31 pages. `http://math.gmu.edu/~tsauer/dmdc.html`

  We extend the classical state space reconstruction of Takens in order to find the latent geometry of a dynamical system from an observed time series using a model-free, data driven approach. We give a new interpretation to the diffusion maps algorithm of Coifman and Lafon for time series, and show that this is the natural technique for achieving time-scale separation. We develop our approach into a novel algorithm called Diffusion Mapped Delay Coordinates (DMDC).

- T. Berry, T. Sauer, *Adaptive ensemble Kalman filtering of nonlinear systems.* Submitted in Dec. 2012 to Tellus A (Impact Factor: 2.062, ISI Journal Citation Reports Ranking: 14/59), 14 pages. `http://math.gmu.edu/~tberry/QR.pdf`

  We develop a novel technique for adaptively determining the covariance matrices of system and observation noise using the innovation errors of an ensemble Kalman filter. We show that our technique leads to significantly improved state estimates, and when the noise is non-autonomous our method can automatically track the changing covariance structure. Finally, we show that an adaptive filter can compensate for model error by automatically inflating the system noise covariance which reduced estimation error from 200% higher than the level of no model error to just 20%.

- T. Berry, F. Hamilton, T. Sauer, *Unscented Kalman filtering for link detection and tracking in neural networks.* To be submitted Jan. 2013 to Physical Review E (Impact Factor: 2.255), 6 pages. `http://math.gmu.edu/~tberry/UKF.pdf`

  Building on the success of the Cox method statistical test for detecting changes in connections, this paper addresses the large data requirements of the Cox method. We use the Hindmarsh-Rose model for the neurons at the nodes of the network, and connect these nodes via the variables representing the intracellular potential. We use an ensemble Kalman filter to estimate the parameters of the individual neurons as well as parameters which quantify the connection strengths. We show that multiple hypothesis testing can be used to develop statistical tests for connectivity and we examine the robustness of the test to errors in the connection models.

Research Reports

- T. Berry, T. Sauer, *Diffusion maps and the discrete exterior calculus.* Research Report, 11 pages, Dec. 16, 2011. `http://math.gmu.edu/~tberry/diffdec.pdf`

  This report demonstrates for the first time that diffusion maps can be written in the language of the discrete exterior calculus by identifying the discrete hodge star operator which is implied by the diffusion geometry. We show that with this discrete hodge star, the discrete Laplacians constructed by the two techniques coincide. This report is currently being developed into a paper which shows that the discrete exterior calculus can be used to construct higher order Laplacians. This may allow fast algorithms for estimating the cohomology groups (via the kernel of the higher order Laplacians) of large data sets using the multi-scale nature of the diffusion geometry.

- T. Berry, T. Sauer, *Diffusion wavelets for natural image analysis.* Research Report, 15 pages, Dec. 1, 2012. http://math.gmu.edu/~tberry/diffwavelets.pdf

  This report was motivated by an example in the thesis of Mauro Maggioni which indicated a novel approach to understanding the content of images using his diffusion wavelets. In this report we examine the practical implications of such an approach, including the possibility of using over-complete frames rather than bases to represent the data.

- T. Berry, *An overview of optimal stopping times for various discrete time games.* Masters Thesis, 15 pages, Ohio State University (2008). http://math.gmu.edu/~tberry/OptimalStopping.pdf

- T. Berry, *Model-free techniques for high dimensional dynamics.* Ph.D. Thesis, George Mason University (Expected May 2013).

Posters at Conferences

- T. Berry, *Dimension reduction in spatiotemporal dynamics*, SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, May 22-26, 2011.
  http://math.gmu.edu/~tberry/nldr2011.pdf

- T. Berry, F. Hamilton, *Identifying dynamics in neural networks*, Building Engineered Complex Systems Workshop, Mar. 28-29, 2011. http://math.gmu.edu/~tberry/BECS.pdf

- T. Berry, *Dimension reduction in spatiotemporal dynamics*, February Fourier Talks, University of Maryland, Feb. 17 - 18, 2011. http://math.gmu.edu/~tberry/isomap2011.pdf

Invited Talks

- T. Berry, *Convergence of periodically forced rank-type equations.* Joint Mathematics Meeting at Boston, January 4, 2012, Special Session for Difference Equations and Applications, I.
  http://jointmathematicsmeetings.org/amsmtgs/2138_abstracts/1077-39-669.pdf

- T. Berry, *Convergence of periodically forced rank-type equations.* AMS Meeting at Syracuse University, October 2, 2010, Special Session on Difference Equations and Applications.
  http://www.ams.org/meetings/sectional/1062-39-9.pdf

DATA ANALYSIS SYSTEMS DESIGNED AND DEVELOPED

- T. Berry, **Diffusion Mapped Delay Coordinates System (DMDC).**

  The DMDC system is based on the theory developed in the paper *Time-scale separation from diffusion-mapped delay coordinates* and its development was supported by the NSF Grant #DMS0811096. The DMDC system is currently in its sixth version and consists of modules to load images, preprocess them according to various spatial structure models, and then apply a practical implementation of the theoretical DMDC algorithm. The system also includes a graphical user interface module for exploring the data analysis.

  The DMDC system allows a user to analyze a video and extract the slow time scale, including variables representing the projection onto the slow time scale, and a reconstructed video using this projection. Sample videos demonstrating this analysis can be viewed at
  http://math.gmu.edu/~tsauer/dmdc.html

The source code is available upon request and the system is currently being used in the Physics Department at George Mason University to study pattern formation in the dynamics of nematic liquid crystals. The main component of the system is developed in Matlab, however the algorithm was bottlenecked by the need to compute the k-nearest neighbors for up to 2^{17} high dimensional points. To solve this problem we incorporated a state-of-the-art solution using a Graphics Processing Unit (GPU) via the MEX interface between Matlab and C.

I plan to continue to develop and extend DMDC, motivated by my ideas to fully utilize both the a priori and hidden structure of image data and I describe my ideas for such techniques in my Research Statement.

- T. Berry, F. Hamilton, **Network Reconstruction and Tracking System (NRAT).**

  The NRAT system was motivated by the readily available micro-electrode array (MEA) data used for measuring activity in neuronal network experiments. Often the goal of these experiments is to determine the effect of some electrical or chemical stimulation regime on the neuronal network. The NRAT system consists of modules which preprocess the raw data output of a MEA into either a formatted spike trains or into scaled voltage time series. The spike trains can then be used in an efficient implementation of the Cox method and the results can be analyzed by a special module for performing the statistical tests developed in our paper *Detecting connectivity changes in neuronal networks*. The voltage time series can be analyzed by an implementation of the technique of *Unscented Kalman filtering for link detection and tracking in neural networks*. These papers also detail the special numerical techniques required to make these algorithms practical for real data.

  The next goal for the NRAT system is to incorporate the technique developed in *Adaptive ensemble Kalman filtering of nonlinear systems* which will help to compensate for modeling errors. We then plan to apply the system (using the current model) to simulations produced using alternative neuronal models to see if the system can overcome the model error and find the correct connections.

  The source code is available upon request and the system is currently being used in the Bioengineering Department at George Mason University.

PROFESSIONAL EXPERIENCE

Research Experience

- *Computational methods in applied nonlinear dynamical systems*, NSF Grant #DMS0811096. Worked as a graduate research assistant developing the DMDC algorithm and associated theory for analyzing high dimensional dynamical systems (2008-2012).

- *Pattern-steering in nonlinear dynamical networks*, NSF Grant #EFRI-1024713. Worked as a graduate research assistant developing theory and algorithms for finding connections in neuronal networks including the Cox method and the adaptive ensemble Kalman filter (2010-2013).

- Awarded a *Dissertation Completion Grant* by George Mason University for Spring 2013.

Teaching Experience

- *Volunteer Teaching Assistant*, George Mason University, 2009-2012.

  Research Experience for Undergraduates (REU) and Undergraduate Research in Computational Mathematics (URCM) Summer Programs, providing lectures on:

  - Introduction to Stochastic Differential Equations and Applications to Portfolio Theory

  - Introduction to Dynamical Systems and Attractors
  - Introduction to LaTeX

- *Instructor*, Ohio State University, Summer Session 2007.

  - Pre-Calculus

- *Teaching Assistant*, Ohio State University, 2006-2008.

  - Pre-Calculus
  - Calculus I
  - Calculus II

Compute Science Experience

- Extensive experience with C/C++ including CUDA programming for Graphics Processing Units (GPUs) and MEX for integration with MATLAB.

- Extensive experience with JAVA and MATLAB programming.