John R. Mahoney

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RESEARCH INTERESTS

Dynamical systems:
Causality and representations, ϵ-machines, time asymmetry, inference algorithms

Quantum information theory:
Quantum automata, entanglement, unitary graphs

Fluids:
Chaotic transport, invariant manifolds, lobe dynamics, advection-reaction-diffusion

Interacting agents and pattern formation:
Motile bacteria, two dimensional complexity measures

EDUCATION

Ph.D., Physics 2003 - June 2010
Advisor: James Crutchfield
Extensions of the Theory of Computational Mechanics
University of California, Davis, CA

B.A., Physics & Mathematics 1997 - 2001
California State University, Chico, CA

Williams College, Williamstown, MA 1995 - 1997

RESEARCH EXPERIENCE

Project Scientist 2015 - present
James Crutchfield, UC Davis, John Templeton Foundation Grant
How does quantum mechanics allow us to more efficiently represent classical stochastic processes? If "Nature computes", what kind of computer is it—classical or quantum?

Postdoctoral Scholar 2010 - 2015
Kevin Mitchell, UC Merced
Generalize theory of invariant manifolds, lobe dynamics, and FTLEs from passive fluids to "active" fluids—fluids flows augmented by front propagation dynamics.

Graduate Student Research Assistant 2006 - 2010
Quantum Dynamics, James Crutchfield, Intel Network Dynamics Program
Investigate quantum analogs of computational mechanics. Characterize topologies of low dimensional systems. Understand the relationship between quantum entanglement and measures of structure.

Causal representations and information theory
Derive analytic forms for infinite mutual information measures. Characterize stationary processes and presentations in new information-theoretic framework. Implemente algorithms as part of Computational Mechanics in Python package.

Graduate Student Research Assistant 2007 - 2010
Modeling Cyanobacterial Motility and Mat Morphology, Dawn Sumner, Agouron Foundation
Develop model of motility-based pattern formation in colonies of elongate bacteria. Implement Cython-optimized dynamics code. Develop versatile simulation

and analysis GUI.

Visiting Scholar, University of Bristol, Center for Complexity Sciences. June, 2008
Collaboration with K. Wiesner, probabilistic automata, quantum automata. Lectures for BCCS students and QIT group. Developed exercises and sample code for BCCS graduate students.

Participant, Santa Fe Institute Complex Systems Summer School. June, 2007
Attended seminars on: Nonlinear Dynamics, Agent Based Modeling, Networks, Ecology, Finance, Economics, Genetic Algorithms, Allometry, Epidemiology,

Participant, NSF Symbolic Computation for Young Scholars Program, Rennselaer Polytechnic Institute. June, 1995

REFEREED PUBLICATIONS

JRM, C. Aghamohammadi, J. P. Crutchfield, "Occams Quantum Strop: Synchronizing and Compressing Classical Cryptic Processes via a Quantum Channel", Scientific Reports **6**: 20495 (2015).
http://arxiv.org/abs/1508.02760

JRM, John Li, Carleen Boyer, Tom Solomon, Kevin A. Mitchell, "Frozen reaction fronts in steady flows: a burning-invariant-manifold perspective", PRE **92** 063005 (2015).
http://arxiv.org/abs/1503.08233

JRM, Kevin A. Mitchell, "Finite-time barriers to front propagation in two-dimensional fluid flows", Chaos **25**: 087404 (2015). (*Featured article and cover illustration)
http://arxiv.org/abs/1503.08240

R. G. James, JRM, C. J. Ellison, J. P. Crutchfield, "The Many Roads to Synchrony: Natural Time Scales and Their Algorithms", PRE **89** (2014). http://arxiv.org/abs/1010.5545

JRM, Kevin A. Mitchell, "A turnstile mechanism for fronts propagating in fluid flows", Chaos **23**: 043106 (2013).
http://arxiv.org/abs/1305.5005

Joseph T. Lizier, JRM, "Moving Frames of Reference, Relativity and Invariance in Transfer Entropy and Information Dynamics", Entropy **15** (2013).
http://www.mdpi.com/1099-4300/15/1/177

Kevin A. Mitchell, JRM, "Invariant manifolds and the geometry of front propagation in fluid flows", Chaos **22** 037104 (2012).
http://arxiv.org/abs/1205.1258

JRM, Dylan Bargteil, Mark Kingsbury, Kevin A. Mitchell, Tom Solomon, "Invariant barriers to reactive front propagation in fluid flows". EPL **98**, 44005 (2012).
http://arxiv.org/abs/1108.1142

JRM, C. J. Ellison, R. G. James, J. P. Crutchfield, "How hidden are hidden processes? A primer on crypticity and entropy convergence". Chaos **21**, 037112 (2011).
http://arxiv.org/abs/1108.1510

C. J. Ellison, JRM, R. G. James, J. P. Crutchfield, "Information symmetries in irreversible processes", Chaos, **21**, 037107 (2011).
http://arxiv.org/abs/1107.2168

J. P. Crutchfield, C. J. Ellison, R. G. James, JRM, "Synchronization and Control in Intrinsic and Designed Computation: An Information-Theoretic Analysis of Competing Models of Stochastic Computation". Chaos **20**, 037105 (2010).
http://arxiv.org/abs/1007.5354

JRM, C. J. Ellison, J. P. Crutchfield, "Information Accessibility and Cryptic Processes", Journal of Physics A: Math. Theo. **42**, 362002 (2009).
http://arxiv.org/abs/0905.4787

C. J. Ellison, JRM, J. P. Crutchfield, "Prediction, Retrodiction, and The Amount of Information Stored in the Present", Journal of Statistical Physics **136**:6 (2009) 1005-1034.
http://arxiv.org/abs/0905.3587

J. P. Crutchfield, C. J. Ellison, JRM, "Time's Barbed Arrow: Irreversibility, Crypticity, and Stored Information", Physical Review Letters **103**:9 (2009) 094101.
http://arxiv.org/abs/0902.1209

PAPERS

C. Aghamohammadi, JRM, J. P. Crutchfield, "The Ambiguity of Simplicity", *in submission to PRX*.
http://arxiv.org/abs/1602.08646

Paul M. Riechers, JRM, C. Aghamohammadi, J. P. Crutchfield, "A Closed-Form Shave from Occam's Quantum Razor: Exact Results for Quantum Compression", *in submission to PRA*.
http://arxiv.org/abs/0902.1209

J. Li, JRM, K. Mitchell, "Basins of attraction in pinned front systems", *in preparation*

JRM, C. J. Ellison, J. P. Crutchfield, "Information Accessibility and Cryptic Processes: Linear Combinations of Causal States", (2009).
http://arxiv.org/abs/0906.5099

O. Bochmann, J. Lizier, JRM, G. Obernosterer, J. Pahle. "Computational mechanics and information measures in food webs". Proceedings of the Santa Fe Institute Complex Systems Summer School. Santa Fe Institute. August 2007.
http://www.santafe.edu/events/workshops/images/9/99/FoodWeb.pdf

JRM and K. Spiekermann. "Interacting Brains: The Dynamics of Belief among Reasoning Agents". Proceedings of the Santa Fe Institute Complex Systems Summer School. Santa Fe Institute. August 2007.
http://192.12.12.16/events/workshops/images/1/16/Belief_dynamics_working_paper_1808.pdf

TEACHING AND MENTORSHIP

Teaching Fellow, - COSMOS Summer program — Summer 2014
Prof. Rajiv Singh
University of California, Davis
Work with advanced high school students, teaching them programming through the context of biophysics.

Teacher, - DARPA High School Apprenticeship Program — Summer 2010
Prof. Richard Scalettar
University of California, Davis

Design and deliver a series of lectures small group of high school seniors.
Main teaching content: programming in C, write and explore a simple model of deterministic chaos.

Teaching Assistant, Phys 256 - (graduate) Winter 2009, 2010
University of California, Davis
Lecture on special topics. Grade homework.

Lecturer, Physics 7C Summer 2008
University of California, Davis
Lectured on electricity and magnetism, waves, fields, quantum mechanics. Developed demonstrations to engage students and highlight principles. Designed exam materials.

Teaching Assistant
Physics 7B Winter and Spring 2008
– Summer 2006
– Winter 2005
Physics 7C Summer 2007
– Spring 2006
– Summer 2004
– Spring and Summer 2004
– Fall 2003
Physics 7A Fall 2005
University of California, Davis
Lead discussion/lab emphasizing critical thinking and spiral learning. Involved with students as a class, in small group and one-on-one. Utilized Socratic teaching method. The 'Physics 7 Series' at UCD gives TAs a large responsibility and correspondingly increased flexibility in teaching.

Discussion Leader, Physics 9A Spring 2005
University of California, Davis
Lectured on missing material. Modeled physics problem solving through examples.

Math, English and SAT Prep Instructor 2002
Sylvan Learning Center, Oakland, CA
Engaged in learning activities with students of diverse abilities (K-12). Expanded my ability to teach to different learning types.

Instructor, - COSMOS Summer program Summer 2014
Prof. Rajiv Singh
University of California, Davis
Work with advanced high school students, teaching them programming through the context of biophysics.

Mentoring
David Gier
David and I worked together during the Summer of 2015 at UC Davis for his Research Experience as Undergraduate experience. After a rapid introduction to computational mechanics, we began a Summer project building upon my previous work on q-machines—quantum representations of classical stochastic processes. These were of particular interest because they displayed a compressibility not found classically. David and I investigated: a quantum analog of the classical

"block-state entropy", the reversibility of this quantum compression (for classically irreversible processes), and entanglement in these representations. We met nearly every day to discuss quantum mechanics, computational mechanics, and Python code. While I followed his progress closely and interacted frequently, David was also capable of being very independent. I worked with him in preparing his talk both for the Crutchfield group meeting and the REU end of program meeting.

John Li

John began work in this area for his undergraduate thesis in physics at UC Merced. In it, he provides a detailed analysis of those flowing front systems that have stationary asymptotic solutions—a subject motivated by advection-reaction-diffusion experiments [Schwartz, Solomon 2008]. He developed an interesting way to distill down many important features of such a system into a directed graph—a purely topological representation. John was extremely self-motivated. My role was to provide focus, to force him to think things through to the end, and to help him develop the ideas into a narrative. He subsequently moved on to USC on an NSF graduate fellowship. His work has generated material for more than one high quality research article, the first of which, "Frozen reaction fronts in steady flows: a burning-invariant-manifold perspective", will be appearing in PRE. Also, John has presented these ideas at multiple conferences including two meetings of the APS Division of Fluid Dynamics.

Rory Locke

Rory is a graduate student in physics at UC Merced. We are currently working together to reproduce and clarify some previous work of mine. It shows how when the fluid flow is periodic within some channel, the front can enter a mode-locked state—it forms regular spatial patterns as it progresses down the channel. In our work together, I have also introduced him to scientific computing in Matlab. There are several subtle numerical challenges we have faced. The foremost issue is that the system we simulate (a front in a chaotic fluid flow) is exponential in time-complexity. We have developed several algorithms that attempt to whittle this down to a linear-time problem. We expect this work to result in a research article, "Mode-locking reaction fronts and burning invariant manifolds", early this year.

Dylan Bargteil

Dylan was an REU student with Tom Solomon at Bucknell University where he performed experiments on Belousov-Zhabotinsky reaction fronts in vortex flows. Dylan was also very motivated and self-sufficient. We discussed things ranging from numerical implementation of invariant manifold theory, to image processing algorithms, to experiment design. His work clearly corroborates several features of BIM theory in the context of a two-dimensional disordered vortex array. Dylan is currently a graduate student at NYU. His research resulted in two research articles published in Europhysics Letters and Chaos.

David Brantley

I worked with David on his undergraduate thesis in physics at UC Merced. His work attempted to adapt our recent results on burning invariant manifolds to systems with swimming entities (such as bacteria). Our goal was to numerically explore the relation between the two versions of invariant manifold and the ensemble of swimmers' behavior. My role involved working with him on Matlab scripting, basic dynamical systems theory, and the organization of a research project. David is currently a graduate student at William & Mary.

Brenden Roberts

Gorm Gruner

TALKS AND POSTERS

"Structure in quantum representations of processes", Quantum Information Workshop, Telluride Science Center, Telluride, CO, Invited talk, July 17, 2015.

"Finite-time barriers to front propagation", CHAOS 15, Henri Poincare Institute, Paris, France, Invited talk, May 27, 2015.

"Front pinning in vortex flows", SIAM Dynamical Systems, Snowbird, UT, Minisymposium organizer and contributed talk, May 17, 2015.

"Front pinning in single vortex flows", DFD, San Francisco, CA, Contributed talk, November 23, 2014.

"Pinned Reaction Fronts", AIMS Conference on Dynamical Systems, Differential Equations and Applications, Madrid, Spain, Contributed talk, July 7, 2014.

"Front-pinning and invariant manifolds", ETH Zurich, Haller group, April 10, 2014.

"Reacting Flows and Turnstiles", Workshop: Mixing, Transport and Coherent Structures, Mathematisches Forschungsinstitut Oberwolfach, Poster - **best poster award**, January 26, 2014.

"Coherent Structures in Reacting Flows", Dynamics Days, Georgia Tech, Atlanta, GA, Contributed talk, January 2, 2014.

"Coherent Structures in Reacting Flows", APS Division of Fluid Dynamics, Pittsburgh, PA, Contributed talk, November 25, 2013.

"Causal Irreversibility in Stochastic Processes", Information in Dynamical Systems and Complex Systems Workshop, Burlington, VT, Invited talk, July 18, 2013.

"Front Pinning and Invariant Manifolds", Physics Colloquium, CSUC, March 3, 2013.

"An FTLE Analysis of Active Fluids", Dynamics Days, Denver, CO, Poster, January 3, 2013.

"Three Applications of Burning Invariant Manifolds", International Conference on Flow Dynamics, Sendai Japan, Contributed talk, September 21, 2012.

"Lobe Dynamics and Front Propagation in Advection-Reaction-Diffusion Systems", Nonlinear Science and Complexity, Budapest, Hungary, Contributed talk, August 8, 2012.

"Burning Invariant Manifolds in Advection-Reaction-Diffusion", Experimental Chaos and Complexity Conference, Ann Arbor, MI, Contributed talk, May 18, 2012.

"Lobe Dynamics in Advection-Reaction-Diffusion Systems", APS Division of Fluid Dynamics, Baltimore, MD, Contributed talk, November 21, 2011.

"Burning Chaos: Invariant Manifolds in Chaotic-Advection-Reaction-Diffusion Systems", SIAM DS 11, Snowbird, UT, Contributed talk, May 24, 2011.

"Burning Chaos: Invariant Manifolds in Chaotic-Advection-Reaction-Diffusion Systems", Physics Seminar, University of California Merced, Merced CA, April 25, 2011.

"Crypticity and Cryptic Order: A New Measure and Length Scale for Stochastic Processes", 'Randomness, Structure and Causality': Workshop, Santa Fe Institute, Santa Fe NM, Invited talk, January 12, 2011.

"Mode Locking in Chaotic-Advection-Reaction-Diffusion Dynamics: An Invariant Manifold Perspective", Dynamics Days, Chapel Hill, NC, Poster, January 6, 2011.

"Information Accessibility and Cryptic Processes", APS March Meeting, Portland OR, Contributed talk, March 19, 2010.

"Information Accessibility and Cryptic Processes", Dynamics Days, Northwestern University, Poster, January 05, 2010.

"Pattern Formation in Cyanobacteria", Processes in Biofilms Conference, UC Davis, Contributed talk, September 14, 2009.

"Linebugs: A Model of Pattern Formation in Cyanobacteria", Complexity Sciences Center, UC Davis, February 12, 2009.

"Computational Mechanics and Quantum Extensions", University of Bristol Quantum Information Group, June 18, 2008.

"Primer on Computational Mechanics", Bristol Centre for Complexity Sciences Graduate Program, Invited talk, June 12, 2008.

"Negative Conditional Entropy in Quantum Systems", Complexity Sciences Center, UC Davis, Invited talk, April 16, 2008.

"Quantum Type Classes", Complexity Sciences Center, UC Davis, March 12, 2008.

"Quantum Finite State Machines: Redux", Complexity Sciences Center, UC Davis, September 19, 2007.

"Quantum Finite State Machines", Complexity Sciences Center, UC Davis, May 24, 2007.

AWARDS

Coauthor of John Templeton Foundation grant for "Structural Complexity of Quantum Processes" ($440k).

Contributor to NSF grant for "Burning Invariant Manifolds" ($350k).

UC Davis Graduate Block Grant Fellowship	Winter 2006
UC Davis Graduate Block Grant Fellowship	Winter 2007
UC Davis Graduate Block Grant Fellowship	Spring 2007

Research and Creativity Award, California State University, Chico, "Exploring Sonoluminescence" 2000

COMPUTER SKILLS

Proficient in scientific modeling, analysis and GUI development in Python.

MATLAB, UNIX, MacOS X.

PROFESSIONAL ACTIVITIES

SIAM - DS11 - Session Chair Invitation - CP28

AFFILIATIONS American Physical Society (APS)
Topical Groups: Quantum Information, Statistical and Nonlinear Physics
Forums: Education, Industrial and Applied Physics

Society for Industrial and Applied Mathematics (SIAM)

OTHER Featured on PhysOrg.com – 'How to Measure What We Don't Know', by Lisa Zyga

REFERENCES

James P. Crutchfield, Professor, Complexity Sciences Center, UC Davis, crutchfield@ucdavis.edu

Kevin A. Mitchell, Associate Professor, Natural Sciences, UC Merced, kmitchell@ucmerced.edu

Dawn Y. Sumner, Professor, Department of Geology, UC Davis, dysumner@ucdavis.edu

Karoline Wiesner, Assistant Professor, Bristol Center for Complexity Sciences, Bristol University, k.wiesner@bristol.ac.uk

Raissa D' Souza, Associate Professor, Complexity Sciences Center, UC Davis, raissa@cse.ucdavis.edu