# SIAM Great Lakes Spring Meeting 2016

**University of Michigan - Dearborn**

**April 30, 2016**

# PROGRAM

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|---|---|---|
| 8:00 - 8:45am | Registration, Coffee and Continental Breakfast | 2nd Floor CB |
| 8:45-9:00am | Welcome | 1030 CB |
| 9:00-9:50am | Invited Talk, Gang George Yin | 1030 CB |
| 10:10-11:00am | Invited Talk, Victoria Booth | 1030 CB |
| 11:10-12:10pm | Parallel Sessions 1-3 | 1019 -1021 CB |
| 12:10-1:10pm | Lunch | 4th floor CB |
| 1:10-2:00pm | Invited Talk, Mark Iwen | 1030 CB |
| 2:20-3:10pm | Invited Talk, Fadil Santosa | 1030 CB |
| 3:10-3:40pm | Coffee and Poster Session | 2nd Floor CB |
| 3:40-5:00pm | Parallel Sessions 4-6 | 1019-1021 CB |

# PARALLEL SESSIONS

| **Session 1**, 11:10 am -12:10 am | 1019 CB |
|---|---|
| Dang Nguyen, Wayne State University | Classification of Asymptotic Behavior in a Stochastic SIR Model |
| Kevin Hannay, University of Michigan | Uncovering the Nature of Circadian Coupling in Mammals |
| Brian Yurk, Hope College | Homogenization of a directed dispersal model for animal movement |

| **Session 2**, 11:10 am -12:10 am | 1020 CB |
|---|---|
| Fatih Celiker,Wayne State University | Incorporating Local Boundary Conditions into Nonlocal Theories |
| Aycil Cesmelioglu, Oakland University | Interaction of a fluid and a poroelastic structure |
| Yingwei Wang, Purdue University | Fast structured spectral methods |

| **Session 3**, 11:10 am -12:10 am | 1021 CB |
|---|---|
| Bin Pei, Wayne State University | Averaging principles for SPDEs with delay driven by fBm with fast-slow Markovian switching processes |
| Trang Bui, Wayne State University | Stochastic systems arising from Markov modulated empirical measures |
| Tuan Hoang, Wayne State University | On the Milstein Method for Stochastic Differential Equations with Markov Switching. |

| **Session 4**, 3:40 pm -5:00 pm | 1019 CB |
|---|---|
| Oleg Zikanov, University of Michigan - Dearborn | Convection instabilities as a major factor of design of nuclear fusion reactors |
| Ling Xu, University of Michigan | An efficient particle vortex method for vorticity dynamics in free space |
| Pawel Marcinek, Oakland University | Analysis and Simulations of Debonding of Bonded Rods Caused by Humidity and Thermal Effects |
| Pilhwa Lee, University of Michigan | They are not third-parties: solutes and polymers in the fluid-structure interaction |

| **Session 5**, 3:40 pm -5:00 pm | 1020 CB |
|---|---|
| Tan Cao, Wayne State University | Optimality conditions for a controlled sweeping process with applications to the crowd motion model |
| Hongwei Mei, Wayne State University | Numerical Algorithms for Approximating Ergodic Means of Switching Diffusions |
| Xiaofeng Zong, Wayne State University | Stochastic consensus of continuous-time multi-agent systems with additive measurement noises |
| Aditya Viswanathan, Michigan State University | Phase Retrieval from Local Correlation Measurements |

| **Session 6**, 3:40 pm -5:00 pm | 1021 CB |
|---|---|
| Vani Cheruvu,The University of Toledo | Numerical solution of Laplace equation in an arbitrary shaped domain using wavelet regularization |
| Huda Nassar, Purdue University | Multimodal Network Alignment |
| Hang Nguyen, Wayne State University | Sufficient Conditions for Error Bounds of Difference Functions and Applications |
| Weiqun Zhang, Wright State University | Fitted Numerical Operator for Quasilinear Singularly Perturbed Problems |

# KEYNOTE PRESENTATIONS

**Gang George Yin**, Wayne State University

### ***Hybrid Uncertain Systems with Switching and Applications***

Many problems arising in applications involve uncertainty as well as interactions of continuous and discrete events. In this talk, we study a class of such problems. The underlying system consists of a continuous component and a discrete component, so it is termed a hybrid system. The continuous component can be described as a solution of a (random) differential equation, whereas the discrete component represents discrete dynamics taking values in a finite set. We present a survey of some recent progress on the study of such systems. In our setup, the discrete event is formulated as a random switching process, and the continuous component is represented by a (random) differential equation. Such two-component processes possess a number of salient features distinctly different from the one-component processes with only continuous state. We present a number of examples arising in wireless communications, identification, finance, singular perturbed Markovian chains, manufacturing, and consensus controls. Then we study necessary and sufficient conditions for the existence of unique invariant measure, stability, stabilization, and numerical solutions of control and game problems.

**Victoria Booth**, University of Michigan

***Dynamics of sleep-wake regulation***

The timing and duration of sleep and wake states are primarily influenced by the 24 h circadian rhythm and the homeostatic sleep drive. An early mathematical model for predicting sleep and wake behavior, the Two-Process model, accounts for the interaction of these two processes on determining sleep timing in a generalized, phenomenological manner and the dynamics of the model is a slowly modulated hysteresis loop. Recent experimental studies have identified numerous neuronal populations in the brainstem and hypothalamus, as well as the neurotransmitters they express, whose interactions directly govern sleep and wake states and their transitions. Motivated by these experimental findings, more recent mathematical models for sleep-wake regulation have been developed to investigate hypotheses for this sleep-wake regulatory network. Interestingly, the core dynamics of these network models can be reduced to a slowly modulated hysteresis loop. We will discuss the relationships between the Two-Process model and these recent sleep-wake regulatory network models, their related dynamics and their applications to understanding sleep-wake behavior.

**Mark Iwen**, Michigan State University

***Sparse Fourier Transforms: A General Framework with Extensions***

Compressive sensing in its most practical form aims to recover a function that exhibits sparsity in a given basis from as few function samples as possible. One of the fundamental results of compressive sensing tells us that $O(s \log^4 N)$ samples suffice in order to robustly and efficiently recover any function that is a linear combination of $s$ arbitrary elements from a given bounded orthonormal set of size $N > s$. Furthermore, the associated recovery algorithms (e.g., Basis Pursuit via convex optimization methods) are efficient in practice, running in just polynomial-in-$N$ time. However, when $N$ is very large (e.g., if the domain of the given function is high-dimensional), even these runtimes may become infeasible.

If the orthonormal basis above is Fourier, then the sparse recovery problem above can also be solved using Sparse Fourier Transform (SFT) techniques. Though these methods aim to solve the same problem, they have a different focus. Principally, they aim to reduce the runtime of the recovery algorithm as much as absolutely possible, and are willing to sample the function a bit more often than a compressive sensing method might in order to achieve that objective. By doing so, one can indeed achieve similar recovery guarantees to Basis Pursuit, but with radically reduced runtimes that depend only logarithmically on $N$. However, SFTs are highly adapted to the special properties of the Fourier basis, making their extension to other orthonormal bases difficult.

In this talk we will present a general framework that can be used in order to construct a highly efficient SFT algorithm. The framework abstracts many of the components required for SFT design in an attempt to simplify the application of SFT ideas to other basis choices. Extension of arbitrary SFTs to the Chebyshev and Legendre polynomial bases will also be discussed.

**Fadil Santosa**, IMA, University of Minnesota

***Magneto-Acoustic Tomography – Analysis and Algorithms***

Magneto-acoustic tomography with magnetic induction (MAT-MI) is a coupled-physics medical imaging modality for determining conductivity distribution in biological tissue. The capability of MAT-MI to provide high resolution images has been demonstrated experimentally. The presentation will go over the science behind the imaging method, followed by an analysis of the well-posedness of the partial differential equations that model the system. A numerical approach for recovering the conductivity is proposed and results from computational experiments are presented.

# PARALLEL SESSIONS

**Dang Nguyen**, Wayne State University (PS1)

### ***Classification of Asymptotic Behavior in A Stochastic SIR Model***

We investigate asymptotic behavior of a stochastic SIR epidemic model, which is a system with degenerate diffusion. Sufficient conditions that are very close to the necessary conditions for the permanence are given. In addition, this paper develops ergodicity of the underlying system. It is proved that the transition probabilities converge in total variation norm to the invariant measure. Rates of convergence are also ascertained.

**Kevin Hannay**, University of Michigan (PS1)

### ***Uncovering the Nature of Circadian Coupling in Mammals***

We apply the Ott-Antonsen dimension reduction technique to study coupling mediated by the two predominant neurotransmitters in the mammalian circadian clock. This powerful technique allows for the reduction of a high-dimensional phase oscillator model to a three variable system for macroscopic variables. Remarkably, we find analysis of the reduced model in combination with experimentally derived constraints is sufficient to resolve the nature of coupling in the circadian clock.

**Brian Yurk**, Hope College (PS1)

### ***Homogenization of a directed dispersal model for animal movement***

Animal dispersal in heterogeneous environments has important ecological implications. In this talk, I will discuss a model for directed movement with small scale heterogeneity. Intuitively, the model is connected to a simple random walk, suggesting diffusive behavior at large spatial scales. The method of homogenization is used to confirm this and to determine the diffusion coefficient from fast scale movement parameters. Applications include predicting speeds of biological invasions.

## **Fatih Celiker**, Wayne State University (PS2)

### ***Incorporating Local Boundary Conditions into Nonlocal Theories***

In this talk, we study nonlocal wave equations on bounded domains related to peridynamics. We display a methodology for enforcing boundary conditions (periodic, Dirichlet, or Neumann) through an integral convolution. We present a numerical study of the approximate solution, study convergence order with respect to the polynomial order of approximation, and observe optimal convergence. We depict solutions for each boundary condition to ascertain the behavior of waves under the nonlocal theory.

## **Aycil Cesmelioglu**, Oakland University (PS2)

### ***Interaction of a fluid and a poroelastic structure***

The interaction of a fluid and a poroelastic structure, as in the blood vessel interaction, can be stated mathematically by a coupling of the incompressible Navier Stokes equations and the Biot equations. Mathematical analysis for a weak formulation will be presented and a numerical method based on a decoupling strategy for a simplified version of the problem will be discussed.

## **Yingwei Wang**, Purdue University (PS2)

### ***Fast structured spectral methods***

In this talk, I will present the Fast Structured Spectral Methods, including fast structured Jacobi transforms, fast structured spectral Gelerkin methods for differential equations with variable coefficients and fast structured spectral collocation methods.

## **Bin Pei**, Wayne State University (PS3)

### ***Averaging principles for SPDEs with delay driven by fBm with fast-slow Markovian switching processes***

Motivated by applications of hybrid systems, this work considers SPDEs with fBm modulated by a two-time-scale Markovian switching process with a finite state space. It is proved that there is a limit process in which the fast changing noise is averaged out and the limit is an average with respect to the stationary measure of the fast varying processes. The limit process being substantially simpler than that of the original system, can be used to reduce the computational complexity.

## **Trang Bui**, Wayne State University (PS3)

### ***Stochastic systems arising from Markov modulated empirical measures***

This work concerns about stochastic system arising form empirical measures of random sequences that are modulated by a discrete-time Markov chain with a finite state space. The Markov chain is used to model random discrete events that are not represented in the primary sequence. One novel feature is that in lieu of the usual scaling in empirical measure sequences, we consider scaling in both space and time, which leads to a new limit results. Under broad conditions, it is shown that a scaled sequence of the empirical measure converges weakly to a number of Brownian bridges modulated by a continuous-time Markov chain. Ramifications and special cases are also considered.

## **Tuan Hoang**, Wayne State University (PS3)

### ***On the Milstein Method for Stochastic Differential Equations with Markov Switching***

This work is concerned with numerical methods for approximating the solution of stochastic differential equations that involve Markovian switching. Inspired by the Milstein scheme for the purely diffusion processes, using stochastic Taylor expansion, we devise a numerical scheme with strong rate of convergence one. We establish the strong convergence of the proposed scheme by studying carefully the terms in the expansion. Finally, Numerical experiments are provided for demonstration.

**Oleg Zikanov**, University of Michigan - Dearborn (PS4)

***Convection instabilities as a major factor of design of nuclear fusion reactors***

The thermal convection caused by neutron absorption is a major factor affecting the operation of liquid metal blankets for fusion reactors. In the presence of a strong magnetic field, the convection manifests itself in new, often unexpected forms and may lead to strong unsteady fluctuations of velocity and temperature of liquid metal. In the presentation, we will discuss the results of the recent computational and theoretical analysis of convection flows.

**Ling Xu**, University of Michigan (PS4)

***An efficient particle vortex method for vorticity dynamics in free space***

We present an efficient particle vortex method for directly simulating the fluid flow motion in free space. The method employs techniques to accelerate the computation (adaptive mesh refinement and MPI parallelism) and maintain the accuracy and stability of the solutions (vorticity remeshing, high order interpolation). For the case of inviscid flow, a comparison to the inviscid elliptic dipole computation is made. For the viscous case, some preliminary results will be presented.

**Pawel Marcinek**, Oakland University (PS4)

***Analysis and Simulations of Debonding of Bonded Rods Caused by Humidity and Thermal Effects***

There is a considerable industrial interest in developing light-materials, such as metals with low density in new parts and components to make them stronger and more fuel economic. It is observed that the bonding strength decreases in time due to mechanical stresses, thermal and humidity effects. In this lecture we present the model for the process of debonding of two rods that are glued together. We discuss the physical and mathematical details of the model and present numerical simulations.

**Pilhwa Lee**, University of Michigan (PS4)

***They are not third-parties: solutes and polymers in the fluid-structure interaction***

The immersed boundary method is considered in two contexts: I) With chemical potential barriers, membrane electrophysiology and osmotic swelling are well realized while interface condition are removed. II) polymeric complex fluids in the fluid-structure interaction are represented by non-Newtonian two-phase medium. In the C. elegans swimming, generation of hyperbolic points and swimming speed retardation is elucidated by extensional flows and stretching/compression of polymers.

**Tan Cao**, Wayne State University (PS5)

***Optimality conditions for a controlled sweeping process with applications to the crowd motion model***

The paper concerns the study and application of a new class of optimal control problems governed by a perturbed sweeping process. We develop the method of discrete approximations to derive necessary optimality conditions to the optimal control problems under consideration and apply these results to an optimal control problem associated with the crowd motion model of traffic flow in a corridor.

**Hongwei Mei**, Wayne State University (PS5)

***Numerical Algorithms for Approximating Ergodic Means of Switching Diffusions***

This work focuses on numerical algorithms for approximating the ergodic means for suitable functions of solutions to stochastic differential equations with Markov regime switching. Our main effort is devoted to obtaining the convergence and rates of convergence of the approximation algorithms. The study is carried out by obtaining laws of large numbers and laws of iterated logarithms for numerical approximation to long-run averages of suitable functions of solutions to switching diffusions.

## **Xiaofeng Zong**, Wayne State University (PS5)

***Stochastic consensus of continuous-time multi-agent systems with additive measurement noises***

This work is concerned with stochastic consensus of multi-agent systems with additive measurement noises. By combing the algebraic graph theory, matrix theory and stochastic analysis, the mean square and almost sure weak and strong consensus are examined. It is shown that mean square strong consensus and almost sure strong consensus are equivalent, and the almost sure weak consensus implies the mean square weak consensus.

## **Aditya Vishwanathan**, Michigan State University (PS5)

***Phase Retrieval from Local Correlation Measurements***

Certain imaging applications such as x-ray crystallography and ptychography require the recovery of a signal from phaseless (or magnitude-only) measurements - a problem commonly referred to as Phase Retrieval. This is a challenging problem since the phase encapsulates a significant amount of structure in the underlying signal. In this work, we discuss a framework for solving the discrete phase retrieval problem using (in many cases, deterministic) local correlation measurements. We develop an essentially linear-time phase retrieval algorithm and present theoretical as well as numerical results demonstrating its speed, accuracy and robustness.

## **Vani Cheruvu**, The University of Toledo (PS6)

***Numerical solution of Laplace equation in an arbitrary shaped domain using wavelet regularization***

A numerical method for the solution of interior Dirichlet problem for the two-dimensional Laplace equation in an arbitrary shaped domain is presented. The domain is embedded into a circular domain using analytic continuation. This implementation results in an inverse problem for the unknown boundary function on the circular domain. The resulting ill-conditioned system is solved using wavelet regularization. In this talk, we present the idea and conclude with couple of numerical results.

## **Huda Nassar**, Purdue University (PS6)

### ***Multimodal Network Alignment***

The pairwise network alignment problem aims at finding a matching between two networks, such that some similarity measure is maximized. The pairwise multimodal network alignment problem adds an extra piece to the basic problem. Aside from satisfying the matching constraint and maximizing the similarity measure, inter-modal matches are not allowed. In this talk I intend to define the problem of multimodal network alignment, discuss the challenges and present my current results.

## **Hang Nguyen**, Wayne State University (PS6)

### ***Sufficient Conditions for Error Bounds of Difference Functions and Applications***

This paper establishes verifiable sufficient conditions for the existence of error bounds for the sub-level set of a difference function over an abstract constraint by applying a technique used by A. D. Ioffe. As a consequence, error bounds for constraint systems defined by d.c. inequalities and their applications in studying of exactness of the associated $\ell_1$ penalty function and existence of Lagrange multipliers as necessary optimality conditions are also investigated.

## **Weiqun Zhang**, Wright State University (PS6)

### ***Fitted Numerical Operator for Quasilinear Singularly Perturbed Problems***

A new method is developed by detecting the boundary layer of the solution of a singular perturbation problem. On the non boundary layer domain, the singular perturbation problem is dominated by the reduced equation which is solved with standard techniques for initial value problems. While on the boundary layer domain, it is controlled by the singular perturbation. Its numerical solution is provided with finite difference methods, of which up to 6th order methods are developed.

# POSTER PRESENTATIONS

**Xuan Zhang**, University of Michigan-Dearborn

### ***Numerical analysis of thermal convection in liquid metal flows with strong magnetic fields***

Thermal convection in liquid metal flows with strong internal heating and strong imposed magnetic fields is analyzed. Several configurations modeling perspective designs of cooling blankets for nuclear fusion reactors are considered. In some cases, the flow is turbulent, while in the other turbulence is suppressed by magnetic field and stable stratification. A rare example of purely two-dimensional turbulence in a realistic system is found in one case.

**Richard Uber**, Air Force Institute of Technology

### ***Analysis of Transient Electromagnetic Scattering from Two Cavities Embedded in a Ground Plane***

This research presents a finite-element boundary integral (FE-BI) method to model transient scattering from two cavities embedded in a ground plane. The variational formulation is shown to be well-posed and a stable numerical implementation for rectangular cavities is presented.