2010 NSF Summer Research Experiences for Undergraduates
in
Applied Mathematics and Biostatistics

Introduction

The Center for Computational Sciences and the Department of Mathematics and Statistics at Mississippi State University is hosting a summer REU (Research Experiences for Undergraduates) program in Applied Mathematics and Biostatistics sponsored by the National Science Foundation.

Dr. Hyeona Lim is the Principal Investigator of this project. Dr. Ratnasingham Shivaji is the Co-Principal Investigator and both Dr. Xingzhou Yang and Dr. Haimeng Zhang serve as senior personnel. The REU site project for the summers of 2010 and 2011 is aimed at involving undergraduate students each year in active research under the supervision of these four applied mathematicians and statisticians who are dedicated researchers and mentors. The major area of concentration will be applied mathematics and biostatistics. The cross-cutting themes of the project are image processing, population dynamics, computational mathematical biology, and highly stratified modeling in biostatistics.

Of the **seventy-one** applications received for the 2010 REU Program, 7 students were selected from the pool of very strong applicants.

REU Program - Summer 2010 Participants:
(L to R) Helene Duke, Providence College; Justin Hansen, University of Vermont; Yicong Yong, University of Florida; Brittany Stephenson, Mississippi State University; Emily Pool, University of Arkansas; John Corring, University of Southern Mississippi; Bonnie Roberson, Mississippi State University

Final Project Presentation
Thursday, August 5, 2010
HPCC Room 30

Agenda

8:45 am – 9:00 am	Remarks by Dr. Gary Myers, Dean of College of Arts and Sciences Dr. Mohsen Razzaghi, Department Head, Math & Stat
9:00 am – 9:45 am	Presentation by Population Dynamics group "***Weak Allee Effect, Grazing, and S-Shaped Bifurcation Curves***", **Emily Poole, Bonnie Roberson, Brittany Stephenson**
9:45 am – 10:00 am	Break
10:00 am – 10:45 am	Presentation by Image Processing group "***Edge Enhancing Speckle Denoising for Ultrasound Images***", **John Corring, Helene Duke**
10:45 am – 11:00 am	Break
11:00 am – 11:45 am	Presentation by Computational Mathematical Biology group "***Modeling Particle Dynamics around Choanoflagellates by the Regularized Stokeslets***", **Yicong Yong**
11:45 am – 12:00 pm	Break
12:00 pm – 12:45 pm	Presentation by Biostatistics group "***Efficiency of the Maximum Partial Likelihood Estimator for Nested Case Control Sampling***", **Justin Hansen**
12:45 pm – 2:00 pm	Box Lunch

Abstracts

Weak Allee Effect, Grazing, and S-Shaped Bifurcation Curves

Emily Poole, Bonnie Roberson & Brittany Stephenson
Mentor: Dr. Ratnasingham Shivaji
Graduate Student Mentors: Jerome Goddard II, Dagny Grillis

We study a one-dimensional reaction-diffusion model arising in population dynamics where the growth rate is a weak Allee type. In particular, we consider the effects of grazing on the steady states and discuss the complete evolution of the bifurcation curve of positive solutions as the grazing parameter varies. We obtain our results via the quadrature method and Mathematica computations. In particular, we establish that the bifurcation curve is S-shaped for certain ranges of the grazing parameter. We also prove this occurrence of an S-shaped bifurcation curve analytically.

Edge Enhancing Speckle Denoising for Ultrasound Images

John Corring & Helene Duke
Mentor: Dr. Hyeona Lim
Graduate Student Mentors: Arundhati Bagchi Misra

Ultrasound images contain granularity which can be modeled as speckle noise caused by sampling of nonlinearly propagating sound waves. Removing speckle noise from ultrasound images is essential for further automated processing techniques and can help the clinicians in better diagnosis and therapy. Partial differential equation (PDE)-based models for image denoising have been developed and studied in the last two decades. However, when existing models are applied to ultrasound images, they are either computationally inefficient or not effective in removing granularity. We propose a new speckle noise equation for ultrasound images, motivated by the necessity for computational efficiency and taking into account local scale discrepancies in ultrasound images. We derive an edge enhancing PDE-based model from the Euler-Lagrange equation resulting from minimizing a functional constrained by our new noise equation. We discuss stability, parameterization techniques, and computational results of the new model. Our computational results compare favorably to existing ultrasound denoising methods.

Modeling Particle Dynamics around Choanoflagellates by the Regularized Stokeslets

Yicong Yong
Mentor: Dr. Xingzhou Yang
Graduate Student Mentor: Vidhya Krishnasamysaraswathy

Choanoflagellates are unicellular microorganisms with a single flagellum surrounded by microvilli, slender fingerlike, very thin projections. Recent study shows that choanoflagellates are most relative to animals and they may reveal the origin of life. In this complex biological system, the helical beat of the flagellum is responsible for the motility of choanoflagellates. The microvilli can filter and take in the

food particles or nutrient substances. We present a computational model to understand the particle dynamics around the choanoflagellates. The nutrient substances suspended within the fluid are modeled as neutral buoyant particles. The flagellum and the microvilli are treated as elastic structures in the model. In our computer simulations, we show the flow patterns by visualizing how the flagellum, microvilli, suspended particles interact with the surrounding fluid. Since the Reynolds number is very low, the fluid flow is modeled by Stokes equations. We use the regularized Stokeslets method, a grid free method, to solve the governing equations. The Runge-Kutta method is employed to solve the related ODE system. The numerical results are compared with the data in the published biological experiments. This research may be also useful in designing future nano-robots.

Efficiency of the Maximum Partial Likelihood Estimator for Nested Case Control Sampling

Justin Hansen
Mentor. Dr. Haimeng Zhang

In making inference on the relation between failure and covariates in Cox regression models, the maximum partial likelihood estimator (MPLE) is put forward. It is always interesting to assess if the proposed estimator used the available information in the efficient manner. In a regular parametric model, the Cramer-Rao variance lower bound provides the smallest possible variance for estimating an unknown parameter. Under regularity, it is well known that the maximum likelihood estimator (MLE) achieves this lower bound and so it is asymptotically efficient. In this project, we consider the efficiency of the MPLE for nested case-control sampling under the highly stratified situation, where the covariate values are increasingly less dependent upon the past and there is no censoring. In particular, through numerical study under the parametric distribution for the failure time, the efficiency of the MPLE is investigate and its performance is compared with the MLE when the sample size is finite.