

# TX-LA Undergraduate Mathematics Conference

## University of Houston

November 11 – 12, 2017

### Schedule

Saturday, November 11 [Honors College]

**8:00 am** Signing in, breakfast

**8:30 am** Opening remarks

**8:45 am** Introduction of participants

**9:10 am** Guest lecture: Yan Li (Senior Research Scientist, Chevron Energy Technology Company): *Upscaling of flow and transport in subsurface formations*

**10:00 am** Karen Weber (Assistant Dean of Co-Curricular Programs, Director of Honors ePortfolio Program – Honors College)

**10:20 am** Coffee break

**10:40 am–12:40 pm** Student talks

- **10:40 am** Angelique Morvant (TAMU): *Modeling Liquid Crystal Droplets via Ericksen and Allen-Cahn equations*
- **11:10 am** Matthew Cabrera and Taylor Daigle (LSU): *Infant Metabolic Chamber Analysis*
- **11:40 am** Samad Ahmed and Shahzad Kalloo (UH): *Homological Criteria for Coverage in Sensor Networks*
- **12:10 pm** Parth Sarin (TAMU): *Tensors: From Phylogenetics to Statistical Physics*

**12:40 pm–2:00 pm** Lunch

**2:00 am–3:30 pm** Student talks

- **2:00 pm** Thomas Ayton and Zachary Bradshaw (LSU): *The Least-Time Problem With Irregular Velocity Sets*
- **2:30 pm** Noam Harari (UH): *Locating defects in spring-mass systems through Laplace domain and function limit analysis*
- **3:00 pm** Advait Parulekar (TAMU): *Locating matrices with degenerate eigenvalues*

**3:30 pm** Coffee break

**4:00 pm–5:30 pm** Student talks

- **4:00 pm** Joshua Brock and Margarite LaBorde (LSU): *Infant Suck Detection Interface*
- **4:30 pm** Thomas Settlemyre (TAMU): *Soft wall: a model of Casimir interaction between a quantum field and a conducting boundary*
- **5:00 pm** Ivan Rodriguez (UH): *Using Numerical Integration to Further Understand Dynamical Systems*

**5:30 pm** Dinner

**Sunday, November 12 [PGH, 6th floor]**

**8:30 am** Breakfast [PGH 646]

**9:45 am** Poster Session [PGH 6th floor]

- Samad Ahmed and Shahzad Kallou (UH): *Homological Criteria for Coverage in Sensor Networks*
- Thomas Ayton and Zachary Bradshaw (LSU): *Convex Optimization For Least-Time Problem With Irregular Velocity Sets*
- Joshua Brock and Margarite LaBorde (LSU): *Infant Suck Detection Interface*
- Matthew Cabrera and Taylor Daigle (LSU): *Infant Metabolic Chamber Analysis*
- Noam Harari (UH): *Locating defects in spring-mass systems through Laplace domain and function limit analysis*
- Nicholas Moorman (UH): *Determining coherent sets in 2D fluid flows by transfer operator methods*
- Angelique Morvant (TAMU): *Simulating Liquid Crystal Droplets*
- Advait Parulekar (TAMU): *Locating matrices with degenerate eigenvalues*
- Ivan Rodriguez (UH): *Using Numerical Integration to Further Understand Dynamical Systems*

**11:30 am** Panel Discussions [PGH 646]

**12:30 pm** Lunch [PGH 6th floor]

# Talk Abstracts

**9:10 am** Yan Li (Senior Research Scientist, Chevron Energy Technology Company): *Upscaling of flow and transport in subsurface formations*

Subsurface formations are characterized by strong heterogeneities occurring on multiple length scales. High-resolution formation descriptions are often generated through geostatistical simulation by integrating data from different sources and at various scales. Due to the very high resolution involved, direct numerical simulation of subsurface flow is usually not feasible. Therefore, upscaling procedures are often applied to coarsen the highly detailed models to scales that are suitable for reservoir simulation. In this talk, we will give an introduction of subsurface flow and transport problem, discuss and compare different upscaling techniques, challenges and applications.

**10:40 am** Angelique Morvant (TAMU): *Modeling Liquid Crystal Droplets via Ericksen and Allen-Cahn equations*

Liquid crystals are substances with the properties of both solids and liquids. They are most commonly used in LCD's, but more recently droplets of liquid crystal have also been used to produce devices such as spherical lasers. Since many of these new applications depend on the shapes of the droplets, mathematical models that determine these shapes under various conditions may be useful. Our model couples the Ericksen model to the Allen-Cahn equations to give the energy of liquid crystal droplets. This energy can then be discretized and minimized using a gradient flow scheme to determine the equilibrium shapes of the droplets. After describing the model in more detail, we will present the results of several simulations that demonstrate its capabilities and limitations.

**11:10 am** Matthew Cabrera and Taylor Daigle (LSU): *Infant Metabolic Chamber Analysis*

Our partners at Pennington Biomedical Research Center in Baton Rouge, LA, are studying infants at various ages and their metabolism via a device called an Infant Metabolic Chamber. We developed methods to analyze data received from the device statistically and graphically, using various techniques. We incorporated these analyses into a user-friendly and portable graphical user interface using the Matrix Laboratory (MATLAB) programming software.

**11:40 am** Samad Ahmed and Shahzad Kalloo (UH): *Homological Criteria for Coverage in Sensor Networks*

Recently the classical subject of Algebraic Topology has recently taken on a new life in Applied Mathematics. In this project we examine the problem of coverage in sensor networks via homological methods. We then generalize the initial coverage problem by weakening boundary conditions and adding dynamic behavior to the sensors, and provide a sufficient homological criterion for dynamic coverage.

**12:10 pm** Parth Sarin (TAMU): *Tensors: From Phylogenetics to Statistical Physics*

Tensors are ubiquitous in the sciences. In this talk, we will explore a diverse variety of applications of these objects. Although many applications involve more advanced geometry, this talk will only assume prior knowledge of Linear Algebra. From that, we will build the theory of multilinear algebra. Finally, we will see how that theory has allowed geometers to solve rather surprising problems across a wide range of fields.

**2:00 pm** Thomas Ayton and Zachary Bradshaw (LSU): *The Least-Time Problem With Irregular Velocity Sets*

The least-time problem consists of finding a trajectory from a point A to another point B in the least amount of time. A trajectory is a solution to a differential equation where parameters (or control variables) and specifications of the parameters determine the trajectory. In the main case, A and B are situated in separate regions and the velocity sets in each region are different but constant. We will show the least-time problem can be formulated as a convex optimization problem and how its solution can be explicitly found. If the velocity sets are balls, then the solution reduces to the familiar Law of Refraction, or Snell's Law. The methods we use are extendable to irregular convex velocity sets. However, the GUI we construct to find the set of all reachable points applies only to circular or elliptical velocity sets.

**2:30 pm** Noam Harari (UH): *Locating defects in spring-mass systems through Laplace domain and function limit analysis*

Chains of springs and masses can be used to model many real world phenomena, such as deformable objects, acoustic vibrations, soft tissue deformation, automobile suspension systems, and more. As such, it is a matter of interest to analyze the behavior of non-uniform spring-mass systems, as well as to examine how experimental data can be used to find the location of defects in a chain. We start by converting a spring-mass system in matrix form into the Laplace domain in a way that allows the length of the system to remain unspecified. This allows us to find an empirical solution for any chain length. We then expand the solution to account for an "error" mass: one location in the chain that has a higher or lower mass than the rest of the objects. We then use the resulting empirical solution of a non-uniform spring-mass system to devise a method for obtaining the location of the defect by analyzing the behavior of the first mass, and devise a proof based on function limit analysis to confirm the method's validity. We then confirm that this method works when starting from a standard time-domain description of the first mass movement. As a final step, we explore minimization methods as a solution to dealing with systems with two or more unknowns.

**3:00 pm** Advait Parulekar (TAMU): *Locating matrices with degenerate eigenvalues*

It is known that a typical two-parameter family of real symmetric matrices has degenerate eigenvalues at isolated points in the parameter space. To find those points, we propose a numerical algorithm derived from the Newton-Raphson method. We also provide a geometric interpretation of the optimal step direction, which involves a "non-rotating" condition on the corresponding eigenvectors.

**4:00 pm** Joshua Brock and Margarite LaBorde (LSU): *Infant Suck Detection Interface*

Pennington Biomedical Research Center in Baton Rouge, LA. required a GUI able to accurately identify and detect individual sucks in signals obtained from infant bottle feeding. This project focused on creating and improving the algorithms used for that purpose. Proper orthogonal decomposition was used to create a database of prototypes for suck signatures against which an arbitrary signal could be compared. Fourier analysis and convolutions were applied to the signal to reduce noise that was impeding suck detection. Our work resulted in a vastly more efficient GUI, implemented in Matlab, that allows Pennington to quickly and accurately analyze infant sucking signals.

**4:30 pm** Thomas Settlemyre (TAMU): *Soft wall: a model of Casimir interaction between a quantum field and a conducting boundary*

The presence of an electrical conductor changes the energy of the surrounding electromagnetic field. As a result, two nearby conductors attract each other in what is called the Casimir effect. In this project we study the case of only one conducting boundary. We further develop the "Soft Wall" model studied by Fulling and others, which was the subject of Whisler and Murray's undergraduate thesis of 2015 at Texas A&M University. In this model, the conductor is approximated by a potential that is a power of the distance into the wall. In the limit of large degree, the potential approaches a perfectly reflecting boundary. The soft wall model aims to solve the "pressure anomaly" problem that comes out of a hard wall model with an ultraviolet cutoff. We report preliminary results from ongoing calculations of the stress-energy-momentum tensor both outside and inside the boundary.

**5:00 pm** Ivan Rodriguez (UH): *Using Numerical Integration to Further Understand Dynamical Systems*

Chaos Theory became popular when meteorologist Edward Lorenz tried to use computer simulations to predict the weather, but instead determined that some systems cannot accurately be predicted, even if they are deterministic in behavior. In this project, we examine the effects of using different numerical integrators in analyzing chaotic systems, namely the Lorenz System and Double Pendulum. We also take a look at measuring the symbolic entropy of the Lorenz system.