# 7th Annual Davis Math Conference

# Schedule and Abstracts

January 12th 2017

## 1 Schedule

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|---|---|---|
| Breakfast | 9:00 AM | |
| Opening Comments | 9:25 AM | Jordan Snyder |
| Geometry & Topology | 9:30 AM<br>10:00 AM | John Sullivan<br>Eric Samperton |
| Analysis & Math Physics | 10:30 AM<br>11:00 AM | Blake Temple<br>Adam Rupe |
| Statistics & Optimization | 11:30 AM<br>12:00 PM | Luis Rademacher<br>Yuan Zhou |
| Lunch | 12:30 PM | |
| Mathematical Biology | 1:15 PM<br>1:45 PM | Sam Walcott<br>Calina Copos |
| Algebra & Discrete Math | 2:15 PM<br>2:45 PM | Anne Schilling<br>Lily Silverstein |
| Department Tea | 3:15 PM | |

## 2 Abstracts

### 2.1 Geometry and Topology

**John Sullivan**

Title: TBA

Abstract: TBA

**Eric Samperton**

Title: Computational complexity in low-dimensional topology

Abstract:

I'll give an overview of 3-dimensional topology from the perspective of computational complexity theory. Roughly speaking, dimension 3 is the sweet spot for asking complexity theoretic questions: dimensions 2 and lower are too boring, and dimensions 4 and higher are hopelessly complex. One motivation for these questions is to push known structure theorems about 3-manifolds further, by making them as tractable as possible. Another motivation is to better understand the intersection of 3-manifold topology and quantum computation.

## 2.2 Analysis and Mathematical Physics

**Blake Temple**

Title: Shock Waves and General Relativity

Abstract:

General Relativity is the modern theory of gravity, introduced by Albert Einstein in 1915. In this theory, gravity is spacetime curvature, and the Einstein equations describe the evolution of the gravitational metric, and this determines the evolution of spacetime curvature. In Einsteins theory, mass converts into energy through the universal law $E = mc^2$, and the great elegance of his theory is that energy and the flow of energy alone create the dynamics of spacetime curvature through the Einstein equations. The Einstein equations impose conservation laws, and in the case of perfect fluids, the conservation of mass and momentum translate into the compressible Euler equations, the equations of shock wave theory. Thus the theory of shock waves enters General Relativity at the very start, simply because Einsteins equations impose conservation of energythe source of spacetime curvature. In this talk we will review authors research into the subject of shock waves and general relativity, a beautiful mathematical theory with many open problems.

**Adam Rupe**

Title: TBA

Abstract:

The use of computer simulation and numerical solutions have become common for handling increasingly complex mathematical models of physical phenomena. This has been most successful in nonlinear systems where analytic solutions are scarce, as exemplified by the discovery of deterministic chaos. As attention moves to higher dimensional systems, gaining insight from numerical solutions is no longer trivial. Consistent identification of structures from data is currently an open problem in climate science, for instance. In particular, systems in which simple interactions propagate in a complicated manner to produce complex emergent behavior present serious difficulties for traditional mathematical analysis. Such difficulties are similar to those faced in the theory of computation. Thus a new approach to complex systems, computational mechanics, has been developed that employs the mathematical structures of computation theory to build intrinsic representations of temporal behavior, rather than relying solely on the equations of motion.

A brief review of computational mechanics is given, as well as its generalization to spatiotemporal systems. Spatiotemporal computational mechanics is then used to develop a rigorous theory of coherent structures in fully discrete classical field theories with local dynamics. The method is demonstrated on the simplest such systems that support emergent structures, namely elementary cellular automata. Results are compared with a similar, but distinct, dynamical systems approach using temporally invariant sets of spatially homogeneous configurations.

## 2.3 Statistics and Optimization

**Luis Rademacher**

Title: TBA

Abstract: TBA

**Yuan Zhou**

Title: Computer-assisted discovery and automated proofs of cutting plane theorems

Abstract:

Inspired by the breakthroughs of the polyhedral method for combinatorial optimization in the 1980s, generations of researchers have studied the facet structure of convex hulls to develop strong cutting planes. We ask how much of this process can be automated: In particular, can we use algorithms to discover and prove theorems about cutting planes? We focus on general integer and mixed integer programming, and use the framework of cut-generating functions.

Using a metaprogramming technique followed by practical computations with semialgebraic cell complexes, we provide computer-based proofs for old and new cutting-plane theorems in Gomory–Johnson's model of cut generating functions. (Joint with Matthias Koeppe)

## 2.4 Mathematical Biology

**Sam Walcott**

Title: TBA

Abstract: TBA

**Calina Copos**

Title: Understanding cell locomotion: a mechanical approach

Abstract:

Cell movement is required in many physiological and pathological processes such as the immune system response and cancer metastasis. One of a broad spectrum of migratory mechanisms is amoeboid migration, characterized by repetitive cycles of rapid morphological expansion and contraction and highly coordinated traction forces applied on the environment by crawling cells. Despite recent intense studies, the exact mechanism of rapid shape changes and how they drive movement remains an open question. Here, we develop a simple model to mechanistically explain how key sub-cellular processes work in concert to robustly produce the experimentally reported features of amoeboid cell locomotion. Such models, provide mechanistic explanations for biological functions that have been only considered from a biochemical standpoint.

## 2.5 Algebra and Discrete Mathematics

**Anne Schilling**

Title: TBA

Abstract: TBA

**Lily Silverstein**

Title: TBA

Abstract: TBA