RESEARCH STATEMENT

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I specialize in the study of high-dimensional spatiotemporal data using *persistent homology,* a tool from the relatively new field of topological data analysis (TDA). For the past three years, as part of my Ph.D. studies under the supervision of Prof. K. Mischaikow in the Department of Mathematics at Rutgers University, I have used TDA to study experimental and numerical data associated with fluid flows (Rayleigh-Bénard convection, combustion, and fully-developed turbulence), and have used the challenges posed by these applications to develop new theoretical results in TDA. Persistent homology is a multi-faceted tool; it provides dimensionality reduction while retaining important geometric features of the original data, and it provides a well-defined procedure for encoding data in terms of geometric features. Persistent homology is expressed through persistence diagrams and has the fundamental property that small changes in data lead to small changes in the persistence diagram.

Current research

Theory: I developed a way to measure local changes in persistence diagrams. This is an important improvement over classical methods that only provided measurements of global changes. As an example, in the context of almost-periodic dynamics in Rayleigh-Bénard convection, my techniques allow us to down sample the time series data set and still extract the geometric features that represent the periodicity from the computational noise.

I am currently exploring algebraic techniques to identify the evolution of individual patterns in time series data. While the immediate application in mind relates to temperature fields in convection-driven fluid flow (a fundamental model for weather), if successful, these methods will be applicable to the study of any time-dependent scalar field.

Applications: I am actively working on numerous applications of TDA. The following are the projects most directly related to my Ph.D. thesis.

- In collaboration with the Prof. M. Schatz, Physics, Georgia Tech and Prof. M. Paul, Engineering, Virginia Tech, we are attempting to classify pattern defects in spiral defect chaos.
- In collaboration with Prof. T. Ishihara, Engineering, Nagoya University, Japan, we are studying the vorticity fields of fully-developed turbulence and the low-temperature oxidation regime of a large-scale simulation of 33 chemical species undergoing homogeneous charge compression ignition.
- Development of an interactive tool for studying persistence diagrams generated by image data or any scalar field on a 2D domain.

Future work

My future goal is to combine TDA with statistical methods and machine learning algorithms to find complex patterns in large datasets. To jump-start the next phase of my research, I am studying advanced techniques in Bayesian inference for latent variable models. I am currently working on developing a statistical model for classifying topological trajectories in the space of persistence diagrams for Rayleigh-Bénard convection. I hope to continue to combine techniques in TDA with machine learning approaches to build more general predictive models for large, high-dimensional datasets. While I have focused primarily on applications to fluid flows, on the mathematical level, most of the theory I have developed or worked on is immediately transferrable to other settings.