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 complicated fluid flows, and have used the challenges posed by this application to drive the development of new theoretical results in TDA that have implications to image and video analysis. 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 this geometric data into an object called a persistence diagram. As such, features coming from persistence diagrams are meaning-enriched from a topological/structural perspective, providing not only utility for statistical models and machine learning, but also retaining a level of interpretability.

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 in terms of a single, maximum change, much like a uniform error measurement. For instance, my techniques allow us to down sample a time series data set and still extract the geometric features that represent the true dynamics with confidence.

I am currently exploring algebraic techniques to identify the evolution of individual patterns in spatiotemporal data. While the immediate application I'm working on relates to temperature fields in convection fluid flows (a fundamental model for weather), these methods will be applicable to the study of any time-dependent scalar field, such as video data.

Applications: I am actively working on numerous applications of TDA. The following are 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 the time evolution of patterns 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 35 chemical species undergoing homogeneous charge compression ignition.
- Development of an interactive visualization tool for studying persistence diagrams generated by image or video data.

Future work

My research objective is to combine TDA with statistical methods and machine learning algorithms to find complex patterns in large datasets, focusing primarily on spatiotemporal data. I am currently studying advanced techniques in Bayesian inference for latent variable models at Columbia University under Prof. David Blei, focusing on the use of graphical models for studying large, unstructured datasets such as document collections, images/video, and trajectories in Euclidean space. During my final semester as a graduate student at Rutgers University, I will attend a graduate course in image analysis taught by Prof. Ahmed Elgammal, who I am currently collaborating with on an application of persistent homology to the study of images in fine art as part of the Art & Artificial Intelligence group at Rutgers University.

I hope to continue to combine techniques in TDA with machine learning approaches to build more general predictive models for large, high-dimensional datasets. My background in theoretical mathematics will enable me to continue to push the theory of TDA and other mathematical tools when limitations are encountered, and my programming abilities enable me to develop proof of concept applications of said tools to ensure that any new theory rests on a firm and practical foundation that is also computationally feasible. I look forward to continuing to drive the development of new mathematical tools and approaches in the study of high-dimensional data. Most importantly, I'm looking forward to continuing to solve difficult problems.