My research is aimed at a formal study of applied problems with selected areas of interest: Computational Topology and Topological Data Analysis, Discrete and Computational Geometry, Signal Processing, and Distributed Algorithms. My research focused on developing robust and efficient algorithms targeted at specific problem areas, while maintaining a broad scope of applicability.

During my doctoral studies, I focused on applications of localization and tracking failures in sensor networks. Algebraic topology offers meaningful formalization of topological properties such as coverage area of a sensor network in a coordinate free setting. I used the close relationship between this formalism and higher order combinatorial Laplacians to develop fast and distributed algorithms to localize the coverage holes. Given some geometric information, features such as alpha-complexes and Delauny-Čech complexes (which I developed), serve as topologically faithful network boundaries. I showed that these network boundaries can also be computed distributively and extremely fast to enable boundary tracking in dynamically changing networks.

My research goals in the near future are directed towards what is generally termed as “big data” processing which from my perspective, has two important characteristics, 1) large in quantity necessitating parallel and distributed algorithms, and 2) complex with several partially dependent sources and various modalities necessitating novel and innovative data processing techniques. I am fortunate to have obtained expertise in distributed algorithms and burgeoning field of topological data analysis (which has seen a lot of success in the recent years) through my research as a graduate student and a post doctoral researcher. I am particularly excited about one of my current projects, generalization of the notion of spectral clustering and Laplacian eigenmaps to higher order topological features. I am confident that this project has the potential to provide deep insight into existing open problems and giving rise to a new line of data processing techniques, with many applications in computer vision and signal processing. My goals reflect my philosophy of engineering research, that it is our job to find applications of new mathematical tools, to work with people from other fields, with the ultimate goal of solving real-world problems.

Perhaps the most important lesson I have learnt is the necessity of collaboration for a successful and fulfilling career. As a post-doc, my duties include collaboration with members from our lab in a supervisory position. This has given me a very good opportunity to work closely with several of my colleagues, on a broad range of applications. My work with Saba Emrani has produced a robust technique using topological methods for fast and low complexity detection of wheezes in breathing signals. This method will be implemented on wearable low power sensors, as a part of bigger project under the Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) program here at North Carolina State University. I worked with Adam Wilkerson and our colleagues from Army Research Lab (ARL) to develop distributed algorithms...
for topology preserving dimensionality reduction of social networks, with evidence to spotlight the importance of topology in network analysis.

In a collaborative effort with Dr. Rocio Gonzalez Diaz from Universidad de Sevilla, we have formulated an information theoretic criterion to quantify the optimality of persistent bar-codes, and an algorithm to produce optimal bar-codes. Persistent bar-codes are widely used as topological summaries of point clouds, and have been successfully applied in classification problems. We are currently working on a project in collaboration with Dr. Cranos Williams, on analyzing gene regulatory networks with potential applications including drug design.

In the long term, I see myself collaborating with scientists and engineering from various fields, with a symbiotic relationship of identifying and solving real world problems.