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Topological and Geometric Learning for Anomaly Detection and Forecasting

Abstract

Most recently, the tools of topological data analysis (TDA) and geometric deep learning (GDL), emerge as promising new alternatives for modeling spatio-temporal data with a complex dependence structure such as various geospatial surveillance systems. Prevailing GDL-based methods, solely based on computational approaches, for anomaly detection and forecasting tend to exhibit limited capabilities to capture multiscale spatio-temporal variability, which is ubiquitous in many applications, particularly in those related to climate science, biosurveillance, and biothreats. We postulate that anomalies in underlying graph structures are likely to also be manifested in anomalous patterns of the network shape properties. As such, we invoke the machinery of persistent homology on graphs to systematically and efficiently track evolution of the network shape and, as a result, to detect changes in the underlying network topology and geometry. We develop novel approaches to unsupervised anomaly detection and forecasting in spatio-temporal data by fusing the notion of GDL with the tools of persistent homology and topological data analysis. I present the utility of the new approaches in application to various geospatial and cyber-physical systems. Finally, I provide a brief overview of new research perspectives in data science that integrating topological signatures into statistical and machine learning models can offer, ranging from anomaly detection in blockchain transaction graphs to learning crop yield patterns in digital agriculture insurance.

Biography

Dr. Ignacio Segovia-Dominguez is a visiting scientist at NASA Jet Propulsion Laboratory, Caltech, and a research associate at the University of Texas at Dallas, developing novel methods to model and predict behaviours of time evolving objects, e.g. dynamic networks, with applications to wildfire, infectious diseases, transportation, blockchain, and other related topics. He participates in a number of collaborative research projects with universities across North America. Dr. Segovia-Dominguez received his doctoral degree from the department of Computer Science at the Center for Research in Mathematics (CIMAT) in Guanajuato, Mexico. His broader research agenda spans topological and geometric methods in statistics and machine learning, analysis of complex dynamic networks, evolutionary computation, optimization, computational statistics, and statistical foundations of data science. For more information, please see his website: www.IgnacioSD.com.