World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:16, No:05, 2022

Persistent Homology of Convection Cycles in Network Flows

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Abstract : Convection is a well-studied topic in fluid dynamics, yet it is less understood in the context of networks flows. Here, we incorporate techniques from topological data analysis (namely, persistent homology) to automate the detection and characterization of convective/cyclic/chiral flows over networks, particularly those that arise for irreversible Markov chains (MCs). As two applications, we study convection cycles arising under the PageRank algorithm, and we investigate chiral edges flows for a stochastic model of a bi-monomer's configuration dynamics. Our experiments highlight how system parameters---e.g., the teleportation rate for PageRank and the transition rates of external and internal state changes for a monomer---can act as homology regularizers of convection, which we summarize with persistence barcodes and homological bifurcation diagrams. Our approach establishes a new connection between the study of convection cycles and homology, the branch of mathematics that formally studies cycles, which has diverse potential applications throughout the sciences and engineering.

Keywords : homology, persistent homolgy, markov chains, convection cycles, filtration
Conference Title : ICCTTDA 2022 : International Conference on Computational Topology and Topological Data Analysis
Conference Location : Paris, France
Conference Dates : May 16-17, 2022

Open Science Index, Mathematical and Computational Sciences Vol:16, No:05, 2022 publications.waset.org/abstracts/146580.pdf